Nutr Hosp. 2014;29(3):513-518
Hospitalaria

Original / *Obesidad*

Effectiveness of prediction equations in estimating energy expenditure sample of Brazilian and Spanish women with excess body weight

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Abstract

Objective: **To assess the adequacy of predictive equations for estimation of energy expenditure (EE), compared with the EE using indirect calorimetry in a sample of Brazilian and Spanish women with excess body weight**

Methods: **It is a cross-sectional study with 92 obese adult women [26 Brazilian —G1— and 66 Spanish —G2— (aged 20-50)]. Weight and height were evaluated during fasting for the calculation of body mass index and predictive equations. EE was evaluated using the open-circuit indirect calorimetry with respiratory hood.**

Results: **In G1 and G2, it was found that the estimates obtained by Harris-Benedict, Shofield, FAO/WHO/ONU and Henry & Rees did not differ from EE using indirect calorimetry, which presented higher values than the equations proposed by Owen, Mifflin-St Jeor and Oxford. For G1 and G2 the predictive equation closest to the value obtained by the indirect calorimetry was the FAO/WHO/ONU (7.9% and 0.46% underestimation, respectively), followed by Harris-Benedict (8.6% and 1.5% underestimation, respectively).**

Conclusion: **The equations proposed by FAO/WHO/ONU, Harris-Benedict, Shofield and Henry & Rees were adequate to estimate the EE in a sample of Brazilian and Spanish women with excess body weight. The other equations underestimated the EE.**

(*Nutr Hosp.* 2014;29:513-518)

DOI:10.3305/NH.2014.29.3.7170

Keywords: *Energy expenditure. Prediction equations. Indirect calorimetry. Obesity.*

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Recibido: 5-IX-2013.
1.ª Revisión: 25-XI-2013.
Aceptado: 1-XII-2013.

EFICACIA DE LAS ECUACIONES DE PREDICCIÓN PARA LA ESTIMACIÓN DEL GASTO ENERGÉTICO EN UNA MUESTRA DE MUJERES BRASILEÑAS Y ESPAÑOLAS CON EXCESO DE PESO CORPORAL

Resumen

Objetivo: **Evaluar la adecuación de las ecuaciones de predicción para la estimación del gasto energético (GE), en comparación con el GE medido por calorimetría indirecta en una muestra de mujeres brasileñas y españolas con exceso de peso corporal.**

Métodos: **Se trata de un estudio transversal con 92 mujeres adultas obesas [26 brasileñas —G1— y 66 españolas —G2— (20-50 años)]. Se evaluó el peso y la talla durante el ayuno para el cálculo del índice de masa corporal y las ecuaciones de predicción. Se evaluó el GE usando la calorimetría indirecta de circuito abierto con campana respiratoria.**

Resultados: **En G1 y G2, se encontró que las estimaciones obtenidas por Harris-Benedict, Shofield, FAO/OMS/ONU y Henry y Rees no difieren del GE estimado por calorimetría indirecta, la cual presentó valores más altos que las ecuaciones propuestas por Owen Mifflin -St Jeor y Oxford. Para G1 y G2 la ecuación predictiva que presentó valores más cercanos al valor obtenido por la calorimetría indirecta fue la FAO/OMS/ONU (7,9% y 0,46% subestimación, respectivamente), seguido por Harris-Benedict (8,6% y 1,5% subestimación, respectivamente).**

Conclusión: **Las ecuaciones propuestas por la FAO/OMS/ONU, Harris-Benedict, Shofield y Henry & Rees fueron adecuadas para estimar el GE en una muestra de mujeres brasileñas y españolas con exceso de peso corporal. Las otras ecuaciones subestimaron el GE.**

(*Nutr Hosp.* 2014;29:513-518)

DOI:10.3305/NH.2014.29.3.7170

Palabras clave: *Gasto energético. Ecuaciones de predicción. Calorimetría indirecta. Obesidad.*

Introduction

Obesity is a multifactorial disease characterized by excessive deposition of fat in adipose tissue, which may be due to excessive energy intake, and or changes in body energy expenditure, resulting in positive energy balance.[1]

Ahmadi et al.[2] demonstrated that obese people had higher total energy expenditure (TEE), compared with normal weight. However, this increase may be due to increased basal metabolic rate (BMR) due to higher fat-free mass (FFM) and energy demand during physical activity. Mela and Rogers,[3] found higher TEE in obese compared with normal weight, but the BMR that corresponds to the energy expenditure per kilogram of body weight at a given time, is lower in obese individuals.

The low metabolic rate (MR), expressed relative to FFM seems to be a risk factor for weight gain.[4] In a prospective study in Pima Indians, Ravussin et al.[5] showed that both the low resting metabolic rate (RMR) and low TEE increased risk of weight gain. The basal energy expenditure (BEE) and resting (REE) can be obtained through BMR and RMR, respectively, multiplied by 24 hours (1,440 minutes).

There are several methods for the assessment of EE with different levels of precision, including indirect calorimetry, which measures the MR by the determination of oxygen consumption (O2) (with a spirometer), the production of carbon dioxide (CO2) and excretion of urinary nitrogen, for a given period of time.[6] This technique relies on the fact that all the O2 consumed and CO2 produced is due to the oxidation of the three major energy substrates, which are lipids, carbohydrates and proteins.[7] In practice, an estimated value is used for the production of CO2, measuring only the entrance of O2.[8,9]

Recognizing the need to estimate energy expenditure in institutions that have no indirect calorimetry, researchers have proposed the use of specific equations, developed from calorimetry studies in groups of individuals with similar clinical characteristics.[10] Although the estimate of EE is the most common method, the predictive equations might generate errors.[11] Shetty[12] considers that the equations used to estimate the BEE in normal weight adults have reasonable precision (coefficient of variation 8%). By using predictive equation is important to know whether it predicts the spending baseline, resting or total, the population from which the equation was obtained and the factors that affect the predictive capability.[13]

In clinical practice it is impracticable to measure the calorimetric methods for EE, so the international use of the equations was recommended, modified from a compilation of data carried out by Schofield.[14] Studies conducted in different ethnic groups found that these equations provide high BEE estimates, particularly for residents in the tropics.[15,16,17] Wahrlich and Angels[17] confer these differences to the fact that equations have been developed mostly from population samples of North America and Europe which show differences in body composition, and live in different environmental conditions.

It is known that in populations with severe obesity is actually more difficult to fit the equations, because there is the difficulty in choosing the weight to be applied in the equation, which may influence a lot the results.[18] The use of current weight leads to the overestimation of the results independent of the equation to be applied, and the use of ideal or adjusted weight can result in the underestimation of energy needs.[19]

This present study proposes to assess the adequacy of predictive equations for estimation of EE, using actual weight, based on the estimate of EE using indirect calorimetry in a sample of Brazilian and Spanish women with excess body weight.

It is expected that the equations obtained in tropical populations[20,21] are more appropriate to estimate the EE of Brazilian women, and the equations proposed by FAO/WHO/ONU[22] and Schofield[14] are more appropriate for the estimation of EE in Spanish women. It is suggested that the prediction equations overestimate the EE, in a greater proportion among the women with overweight, compared with normal weight women.

Methods

Methodological course

All utilized data (indirect calorimetry and anthropometry) were obtained from two studies entitled: "Study of body composition and energy metabolism in normal weight, overweight and obese post-stable women" and "Effect of the association of diet with the polymorphism of genes PPARγ2 and beta2-adrenergic receptor in energy metabolism and body composition in obese women." These studies were approved by the Ethics Committee on human research at the Federal University of Viçosa (UFV) (No 059/2008) and University of Navarra (Nº 24 (2)/2004), respectively.

All women signed a formal informed consent. The data were supplemented by estimates of the EE calculations based on the equations of Harris Benedict,[23] Schofield,[14] FAO/WHO/ONU,[22] Henry and Rees,[20] Mifflin-St Jeor,[24] Owen[25] and Oxford.[21]

It is a cross-sectional study with 92 obese adult (aged between 20 and 50 years) women, counting 26 Brazilian (G1) and 66 Spanish (G2).

Casuistic

The data presented are derived from two studies. In the first study, 26 overweight women were selecting [body mass index (BMI) > 25 kg/m^2)], at the Health Division of the Federal University of Viçosa (UFV). In the second study, 66 overweight women were selecting (BMI > 25 kg/m^2) in the Physiology and Nutrition

Department of the Faculty of Pharmacy and in the University Clinic of Navarra's University, Spain.

In both studies, the eligibility criteria were: absence of weight loss over 3 kg in the last 3 months, absence of chronic diseases (diabetes mellitus type 2, cardiovascular disease, kidney disease, thyroid disorders or cancer), nonsmoking, without using prescription drugs and not menopausal. Women who did not meet the above criteria or who did not meet the protocol provided were excluded.

In the selection, to prove the healthiness of the volunteers laboratory evaluations were held (blood count, fasting glucose, urinary nitrogen balance, urea, creatinine, total proteins and fractions, total cholesterol and its fractions and triglycerides) and urine (creatinine, albumin and total proteins) in specialized laboratories.

Anthropometric evaluation

Weight and height were the parameters evaluated, during fasting, for the calculation of BMI.[26] The women were weighed using electronic microdigital scale (Seca®) with the capacity of 150 kg and 100 g precision, wearing a lightweight fabric aprons. Height was determined using milimetric vertical anthropometer graph attached to scale, with 0.5 cm range.[27] The women remained upright, firm, with arms relaxed and head in the horizontal plane.

Evaluation of energy expenditure by indirect calorimetry

The women presented themselves at the metabolic unit by 07:00 o'clock, after fasting for 12 hours without performing strenuous physical activity in the last 24 hours and with minimal effort. The evaluation was performed using the open-circuit indirect calorimetry with respiratory hood (Metabolic Monitor Deltatrac-R3D).[6]

For the calculation of EE, it was used the values of the following volumes; inspired O2 (VO2), expired CO2 (VCO2) (ml/min) and urinary nitrogen.[6,28] obtained by the calorimeter.

Evaluation of energy expenditure using prediction equations

The equations for predicting EE (kcal/24 hours) used in the study were the following:

- Harris & Benedict (1919): BEE = 655.0955 + (9.5634 x BM, kg) + (1.8496 x H, cm) - (4.6756 x age, years).
- Schofield (1985): BEE = [(0.062 x BM, kg) + 2.036] x 239 (18-30 years) [(0.034 x BM, kg) + 3.538] x 239 (30-60 years).
- FAO/WHO/ONU (1985): BEE = (14.7 x BM, kg) + 496 (18-30 years) (8.7 x BM, kg) + 829 (30-60 years).
- Owen (1986): BEE = 795 + (7.18 x BM, kg).
- Mifflin-St Jeor (1990): BEE = (9.99 x BM, kg) + (6.25 x H, cm) - (4.92 x age, years) – 161.
- Henry & Rees (1991): BEE = [(0.048 x BM, kg) + 2.562] x 239 (18-30), RMR = [(0.048 x BM, kg) + 2.448] x 239 (30-60 years).
- Oxford (Henry, 2005): BEE = (10.4 x BM, kg) + (615 x H, m) - 282 (18-30 years) BEE = (8.18 x BM, kg) + (502 x H, m) - 11.6 (30-60 years).

Note: BEE: Basal energy expenditure, BM: body mass (kg), H: height (m).

Statistical analysis

The data were evaluated as an average and standard deviation. To check the distribution of continuous variables was conducted adherence test of Kolmogorov-Smirnov.

For parametric variables, it was used the ANOVA test and Tukey test for comparison of the measured metabolic data with those obtained by each prediction equation. The unpaired test was used to compare metabolic and anthropometric data between groups.

It was used the computer program SPSS version 16.0, considering $p < 0.05$.

Results

The women's age in G1 and G2 was 36.62 ± 7.76 and 34.59 ± 7.56 years, respectively. These women's BMI was 31.16 ± 3.18 and 37.66 ± 6.24 kg/m², respectively. The age and BMI of the two groups G1 and G2 did not differ ($p > 0.05$). Of the total of 92 women with excess body weight, 17% were overweight, 39% grade 1 obesity, 25% were grade 2 obese and 19% grade 3 obesity. G1 were composed predominantly of overweight and obesity grade 1, while G2 were composed predominantly of obesities grade 1 and 2.

The REE obtained by indirect calorimetry (REE_{cal}) was higher in G2. Differences were found between the groups as proposed by the equations: Harris-Benedict, Shofield, FAO/WHO/ONU, Owen, Mifflin-St Jeor and Henry & Rees, being all the higher EE values in G2 (table I).

In G1, it was found that the estimates obtained by Harris-Benedict, Shofield, FAO/WHO/ONU and Henry & Rees did not differ from REEcal, which presented higher values than the equations proposed by Owen, Mifflin-St Jeor and Oxford (table II).

In G2, only the equations proposed by Owen, Mifflin-St Jeor and Oxford presented EE lower than the indirect calorimetry, while the other equations did not differ from the indirect calorimetry (table II).

Table I
Comparison of energy expenditure by indirect calorimetry and prediction equations between groups

Variables	*G1 (n = 26)*		*G2 (n = 66)*		*p-value*
	Mean	*SD*	*Mean*	*SD*	
GER_{cal} (kcal.)	1680	139	1730	253	< 0,01
Harris-Benedict (kcal.)	1535	103	1705	161	< 0,01
Schofield (kcal.)	1524	113	1687	195	< 0,01
FAO/WHO/ONU (kcal.)	1547	108	1722	199	< 0,01
Owen (kcal.)	1363	61	1483	116	< 0,01
Mifflin-St Jeor (kcal.)	1445	131	1626	181	< 0,01
Henry & Rees (kcal.)	1498	99	1691	186	< 0,01
Oxford (kcal.)	1392	301	1606	166	< 0,01

G1: Brazilian obese; G2: Spanish obese.
SD: Standard deviation.

For G1 the prediction equation that was closest to the value obtained by the indirect calorimetry was the FAO/WHO/ONU (7.9% underestimation), followed by Harris-Benedict (8.6% underestimation), Shofield (9.2% underestimation) and Henry & Rees (10,8% underestimation), respectively.

For G2, the equation of the FAO/WHO/ONU (0.46% underestimation) also showed the most similar values to the calorimetry, then by order of approximation Harris-Benedict (1.5% underestimation), Henry & Rees (2.3% underestimation) and Schofield (2.5%underestimation).

For both G1 and G2 for the best equations were FAO/WHO/ONU, Harris-Benedict, Shofield and Henry & Rees.

Table II
Comparison of the energy expenditure prediction equations in relation to indirect calorimetry, for group

Variables	*G1 (n = 26)*		*G2 (n = 66)*	
	Mean	*SD*	*Mean*	*SD*
REE_{cal}	1680	139	1730	253
Harris-Benedict	1535	103	1705	161
Schofield	1524	113	1687	195
FAO/WHO/ONU	1547	108	1722	199
Owen	1363[a]	61	1483[a]	116
Mifflin-St Jeor	1445[a]	131	1626[a]	181
Henry & Rees	1498	99	1691	186
Oxford	1392[a]	301	1606[a]	166

G1: Brazilian obese; G2: Spanish obese; REE_{cal}: resting energy expenditure for calorimetry indirect; SD: Standard deviation.
[a]p < 0,005 *vs* calorimetry.

Discussion

Indirect calorimetry is considered a standard method, after validation by comparison with the direct calorimetry,[29] however, its use is restricted to research due to the demanding cost and time for its conclusion,[17] requiring the use of prediction equations in clinical practice.

The present study has shown that some equations were able to estimate the EE from a sample of overweight women in Brazil and Spain. In obese individuals, the accuracy of all prediction equations was reduced compared with non-obese individuals and the range of individual errors increases.[11]

G2 showed greater REEcal compared with G1, which is expected, since Spanish women had higher total body mass and fat-free mass. The standardization of REE, as suggested by Cercato et al.,[30] divides the population according to quintiles of weight, demonstrating that the higher the body weight, the higher is the REE.

Weg et al.[19] state that the degree of overweight is a major factor influencing the result of the predictive equations, however, most of the equations used was applied to normal weight individuals, which makes it very difficult to choose the most appropriate equation to determine the BEE of these individuals.

According to Rodrigues et al.,[18] the Harris-Benedict equation tends to overestimate the values of BEE (around 7%) in obese Brazilian women. This overestimation may result in 20% less of the body weight loss than estimated value per month. Studies report that this equation when used in obese patients for evaluation of the BEE has mixed results, reaching 33% of variation.[31,32] Wahrlich & Angels,[33] studying 60 women (20 to 40 years old) in Porto Alegre-Brasil, with a BMI of 21.7 ± 2.7 kg/m^2, observed that the equations of Harris & Benedict, FAO/WHO/ONU (only weight), Schofield and Henry & Rees, were not adequate to estimate the BEE, overestimating the results obtained by measurement in calorimetry.

However, the results of this study do not confirm these findings, as the Harris-Benedict equation did not differ from the calorimetry, both in the Brazilian (Viçosa-MG), and in the Spanish samples (Pamplona-Navarra). Both in G1 and G2 the equation with the highest percentage of adequacy was the FAO/WHO/ONU with underestimation related to the EE measured of 7.9% and 0.46% respectively.

Our results were similar to the study of Fett et al.,[34] which examined 28 sedentary women, from the state of São Paulo, with a BMI ranging between normality and obesity. There was an underestimation of up to 16% of the EE from these ones when compared with the measured by indirect calorimetry. The equations more appropriate were also FAO/WHO/ONU and Harris-Benedict, presenting, respectively, 4% and 3% of underestimation.

The main difference between REE and BEE is that REE is measured after the individual dislocation to the exam site. However, it is needed a prior resting period of 30 minutes to neutralize the effects of the physical activity performed.[35] Thus the result of the EE obtained by indirect calorimetry (REE) can be effectively compared with those estimated by the prediction equations in this study, which evaluated the BEE.

However, studies claim that REE is 10-15% higher than the BEE, which might explain the lower values of EE in some predictive equations when compared with indirect calorimetry.[36]

This study presented limitations as specific sample of women from two regions, and small numbers of participants. The comparative evaluation between studies was also limited by the deficiency in the methodological description of them and the fact sides consider the BEE and REE as being equal.

Conclusion

Regardless the women nationality the equations proposed by FAO/WHO/ONU, Harris-Benedict, Shofield and Henry & Rees were adequate to estimate the EE in a sample of Brazilian and Spanish women with excess body weight. The equations of Owen, Mifflin-St Jeor and Oxford underestimated the EE of obese Brazilian and Spanish women.

Acknowledgements

This work was supported by Conselho Nacional de Pesquisa (CNPq) and Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG).

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