



Original/*Obesidad*

Validating an energy expenditure prediction equation in overweight and obese Mexican patients

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Abstract

Background: The prevalence of overweight and obesity in Mexico is approximately 70%; thus, obtaining a reliable measurement of the resting energy expenditure (REE) in these patients is of extreme importance. The aim of the study was to obtain a prediction equation of REE in overweight or obese outpatients in the Mexican population.

Methods: The study was conducted at The National Institute for Medical Sciences and Nutrition Salvador Zubirán (Mexico, D.F.). Consecutive outpatients (18-70 years old) at the Clinical Nutrition were evaluated between March 2010 and August 2012 after being diagnosed with overweight or obesity (body mass index [BMI] ≥ 25 kg/m²). Patients with any disease that could affect the measurement of gas exchange were excluded. Participants were evaluated by indirect calorimetry (IC), bioelectrical impedance analysis (BIA) and anthropometric measurements to design the REE prediction equation. Two groups were evaluated: one group for derivation and another group for validation. The REE was also estimated using the equations of Harris-Benedict, Mifflin St-Jeor, Ireton-Jones, Carrasco, Kleiber and Owen, assessing current weight, ideal weight and adjusted weight. A REE equation was obtained by multiple linear regression based on the evaluated variables, and those that gave the best precision to the model were selected. The real REE and the estimated REE were then compared using Student's t-test. To highlight differences, pairs of measurements were further analyzed using the Bland & Altman plot. Pearson correlation coefficients and coefficients of determination between REE values measured by IC and REE values estimated using various formulas were calculated.

Results: A total of 77 patients were included in the derivation group: 38 men (49.4%) and 39 women (50.6%).

VALIDACIÓN DE UNA FÓRMULA DE PREDICCIÓN DEL GASTO ENERGÉTICO EN PACIENTES CON SOBREPESO Y OBESIDAD EN MÉXICO

Resumen

Antecedentes: La prevalencia de sobrepeso y obesidad en México se sitúa aproximadamente en el 70%; así, la obtención de una medición fiable del gasto energético en reposo (GER) en estos pacientes tiene una importancia crucial. El objetivo del estudio consistió en obtener una ecuación de predicción de GER en pacientes ambulatorios con sobrepeso u obesidad en la población mexicana.

Métodos: El estudio fue realizado en el Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán (México, D.F.). Se evaluó a pacientes ambulatorios consecutivos (18-70 años) en el servicio de Nutriología Clínica entre marzo de 2010 y agosto 2012 tras un diagnóstico de sobrepeso u obesidad (índice de masa corporal [IMC] ≥ 25 kg/m²). Los pacientes con cualquier enfermedad que pudiera afectar la medición de intercambio de gases fueron excluidos. Los participantes fueron evaluados mediante calorimetría indirecta (CI), análisis de impedancia bioeléctrica (AIB) y mediciones antropométricas para diseñar la ecuación de predicción de GER. Fueron evaluados dos grupos: un grupo para diseño y otro para validación. El GER también fue calculado empleando las ecuaciones de Harris-Benedict, Mifflin St-Jeor, Ireton-Jones, Carrasco, Kleiber y Owen, calculando el peso actual, el peso ideal y un peso ajustado. Se obtuvo una ecuación GER mediante regresión lineal múltiple basada en las variables evaluadas, y fueron seleccionadas aquellas que aportaron la mayor precisión al modelo. Luego se compararon el GER real y el GER estimado, utilizando la prueba de t de student. Para destacar las diferencias entre pares de mediciones se utilizó el método de Bland & Altman. Se calcularon los coeficientes de correlación de Pearson y los coeficientes de determinación entre valores GER medidos mediante valores de CI y GER con diversas fórmulas.

Resultados: Un total de 77 pacientes fueron incluidos en el grupo de diseño: 38 hombres (49.4%) y 39 mujeres (50.6%). La edad media fue 48.5 ± 13.9 años, y el IMC medio fue 34.7 ± 5.7 kg/m². Un total de 50 participantes fueron incluidos en el grupo de validación: 16 hombres (32%) y 34 mujeres (68%). La edad media fue 48.5 ± 15.5 años, y el IMC medio fue 34.2 ± 5.2 kg/m². Las ca-

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The mean age was 48.5 ± 13.9 years, and the mean BMI was 34.7 ± 5.7 kg/m². A total of 50 participants were included in the validation group: 16 men (32%) and 34 women (68%). The mean age was 48.5 ± 15.5 years, and the mean BMI was 34.2 ± 5.2 kg/m². The baseline characteristics of both groups were homogeneous. IC reported an average of 2001 ± 552 kcal, with a respiratory quotient (RQ) of 0.75 ± 0.04 . The new REE equation that resulted from the statistical model had an $R^2 = 0.52$ and a bias of ± 3.39 kcal. When the REE obtained from IC was compared with the REE estimated by the new formula, there was no significant difference between the results, and the correlation for all participants was 0.71 ($p < 0.0001$). When the equations were analyzed using the Bland-Altman method, the difference between the new formula and the REE measurement by IC was a bias of 3.39 ± 384 kcal. Furthermore, a correlation was obtained between the real and estimated REE values using different equations; the most accurate correlation with the new formula was Owen's formula ($r = 0.712$).

Conclusion: The new formula had an acceptable correlation with IC REE measurement in overweight and obese patients in the Mexican population. This equation may represent a useful tool for health care professionals who do not have access to IC equipment for the estimation of REE.

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Key words: *Indirect calorimetry, resting energy expenditure, prediction equation, obesity, overweight.*

Background

Obesity is a major health issue, and its prevalence and related complications are increasing worldwide. Mexico is among the top locations in terms of incidence, with prevalence rates of approximately 70% for obesity and overweight in both sexes¹. To prevent associated diseases and to control this condition, a multidisciplinary approach is required with these patients. Nutrition therapy is fundamental and should include achievable short-, medium- and long-term goals, which are necessary for establishing various strategies based on estimated consumption and energy expenditure, as imbalance (greater consumption than expenditure) is a key point in the multifactorial etiology of obesity.

Assessment of this balance should include estimations of energy consumption from diet (using, for example, 24 hour recall) and of total energy expenditure for each individual. The main component of energy expenditure is resting energy expenditure (REE). To measure this variable, indirect calorimetry (IC) is considered the gold standard². However, IC is not feasible in most institutions or clinics due to costs and the protocol required for its determination³. Given this situation, in clinical practice, it is common to use formulas for estimating REE.

These formulas are easy to use, are free and are available at any time; they are obtained from a regression model that usually includes sex, age, anthropometric

measurements (weight, height, body type), body composition (lean and fat mass) or other independent variables that have proven to be predictive⁴⁻⁶. Some of the most popular formulas are⁷ Harris-Benedict⁸, FAO/WHO/UNU⁹, Owen¹⁰, Mifflin-St Jeor¹¹, Ireton-Jones¹²⁻¹³, Kleiber¹⁴ and Carrasco^{15, 16}. However, the formulas may not be accurate because they are generated in different populations (age, ethnicity, body mass index [BMI], etc.)¹⁷, and it is possible to find large errors in the estimated values compared to REE values measured by IC in obese patients¹⁸⁻²¹. Considering that weight gain and obesity are associated with a disproportionate increase in fat mass (FM) and that FM is metabolically less active than fat-free mass (FFM), it can be assumed that most of the established REE prediction equations will fail in the obese population²¹. Moreover, thus far, it is not even clear whether the accuracy of REE prediction equations can be improved by including body composition variables²². Our goal was to obtain a REE prediction equation for use in overweight or obese Mexican outpatients.

Conclusion: La nueva fórmula tuvo una correlación aceptable con medición CI de GER en pacientes con sobrepeso y obesidad en la población mexicana. Esta ecuación podría suponer una útil herramienta para los profesionales de la salud que no tienen acceso a equipos de CI para el cálculo del GER.

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Palabras clave: *Calorimetría indirecta, gasto energético en reposo, ecuación de predicción, obesidad, sobrepeso.*

measurements (weight, height, body type), body composition (lean and fat mass) or other independent variables that have proven to be predictive⁴⁻⁶. Some of the most popular formulas are⁷ Harris-Benedict⁸, FAO/WHO/UNU⁹, Owen¹⁰, Mifflin-St Jeor¹¹, Ireton-Jones¹²⁻¹³, Kleiber¹⁴ and Carrasco^{15, 16}. However, the formulas may not be accurate because they are generated in different populations (age, ethnicity, body mass index [BMI], etc.)¹⁷, and it is possible to find large errors in the estimated values compared to REE values measured by IC in obese patients¹⁸⁻²¹. Considering that weight gain and obesity are associated with a disproportionate increase in fat mass (FM) and that FM is metabolically less active than fat-free mass (FFM), it can be assumed that most of the established REE prediction equations will fail in the obese population²¹. Moreover, thus far, it is not even clear whether the accuracy of REE prediction equations can be improved by including body composition variables²². Our goal was to obtain a REE prediction equation for use in overweight or obese Mexican outpatients.

Methods

The study was conducted at The National Institute for Medical Sciences and Nutrition Salvador Zubirán. Consecutive outpatients (18-70 years old) at the Clinical Nutrition were evaluated between March 2010 and

August 2012 after being diagnosed as overweight or obese (BMI ≥ 25 kg/m²). Patients with any disease that could affect the measurement of gas exchange were excluded.

Participants were evaluated by IC, bioelectrical impedance analysis (BIA) and anthropometric measurements to design the REE prediction equation. Two groups were evaluated: one group for derivation and another group for validation. The REE was also estimated by using the equations of Harris-Benedict, Mifflin St-Jeor, Ireton-Jones, Carrasco, Kleiber and Owen, assessing current weight, ideal weight and adjusted weight.

Anthropometry: A trained and certified nutritionist conducted the anthropometric measurements. Stature was measured while the subject stood with feet together, arms at sides, legs straight, shoulders relaxed and head in the Frankfort horizontal plane, with the heels, buttocks, shoulder blades and back of the head resting against a vertical wall. These measurements were taken in centimeters using a Seca Model 206 wall stadiometer. Weight was evaluated using a Gambro scale with gradations of 0.1 kg. The subject was weighed while seated without shoes and with his or her back reclining on the chair and feet elevated.

Knee height: This value was measured using a measuring tape while the subject was seated in a chair. The right leg was measured with the knee positioned at a 90-degree angle. The measurement was taken from the lateral epicondyle of the femur to the lower outer edge of the foot.

Calf circumference: The maximum perimeter of the calf was located on the internal leg above the gastrocnemius muscles on a plane perpendicular to the longitudinal axis of the leg.

Wrist circumference: With the patient's arm extended at an angle of approximately 45° relative to the body axis and the hand in an anthropometric position, we measured the perimeter of the area between the distal end of the forearm (immediately below the ulnar styloid process and the radius) and the proximal end of the carpus.

Waist circumference: Because all of the subjects were overweight and obese, and given the probable variability of points of measurement, we decided to measure waist circumference at the level of the umbilical scar for all patients.

Hip circumference: With the subject standing and facing the right side, the hip circumference measurement was taken at the level of the greatest posterior protuberance of the buttocks, a position that in most cases coincides with the pubic symphysis.

Arm average circumference: The circumference was taken at the middle point between the acromion and the olecranon with the subject standing and relaxed with his/her arms at the sides.

Halfspan: This value is half the distance between the ends of the middle finger of the right hand and the left hand, expressed in centimeters. All circumferences were taken with a Seca measuring tape, Model 201.

Bioelectric Impedance Analysis: The percentages of fat mass and fat-free mass were obtained using an RJL systems Quantum II Desktop BIA Analyzer. At the time of study, the patient was required to fast, not drink large amounts of fluids prior to analysis, not drink coffee or energy drinks for 4 hours or alcohol for 24 hours prior to analysis; not play sports, do strenuous exercise or sauna within 12 hours before the test; and urinate before the test (at least in the last 30 min). In women, the best days for analysis are the first days of the cycle, during which water retention is lower.

Measurement of REE: To determine REE, IC was performed on all patients using the Cosmed metabolic monitor. The space was maintained at a temperature of 20-25°C, ensuring that each individual was physically comfortable and in the proper positions for measurements. All participants were asked to fast for 12 hours and to abstain from alcohol, nicotine, caffeine and physical activity for 24 hours (minimum abstinence from moderate or anaerobic exercise and vigorous resistance exercise for 24 hours before the test). Before the test, there was a rest period of 10 to 20 minutes. Energy expenditure was estimated for each patient, which took 20 minutes.

Estimation of REE: REE was also estimated using the equations of Harris-Benedict, Mifflin St-Jeor, Ireton-Jones, Carrasco, Owen, and Kleiber, assessing current weight, ideal weight and adjusted weight.

This study was approved by the hospital's ethics committee, and all of the participants signed a letter of informed consent.

Statistical analysis: Continuous variables were expressed as means and standard deviations, and dichotomous variables were expressed as frequencies and percentages. Continuous variables were assessed using the Kolmogorov-Smirnov Z test to analyze distribution type. Comparisons between changes in REE and demographic and clinical characteristics between the design and validation groups were performed using Student's t test for independent samples.

A REE equation was obtained by multiple linear regression based on the variables that were evaluated, and those that gave the best precision to the model were selected. The real REE and the estimated REE were then compared using Student's t-test. To highlight differences, pairs of measurements were further analyzed using the Bland & Altman plot. The Pearson correlation coefficients and the coefficients of determination (R²) between REE values measured by IC and REE values estimated by various formulas were calculated. The significant two-tailed p value was set at <0.05. Data were analyzed using SPSS software (version 12.00, SPSS Inc., Chicago, IL).

Results

Seventy-seven patients were included in the derivation group: 38 men (49.4%) and 39 women (50.6%).

Table I
Clinical and demographic characteristics of study participants

Variable	Derivation (n= 77)	Validation (n= 50)	p**
Age, years	48.5 ± 13.9*	48.5 ± 15.5	0.992
Height, m	1.61 ± 9.0	1.60 ± 10	0.351
Actual weight, kg	91.2 ± 20.5	87.7 ± 17.2	0.323
Ideal weight, kg	58.3 ± 8.0	56.7 ± 8.7	0.244
Adjusted weight, kg	66.6 ± 10	64.4 ± 9.9	0.231
Waist circumference, cm	111 ± 14	110 ± 13.8	0.668
Hip circumference, cm	114 ± 12.3	114 ± 11.6	0.972
Mid-arm, cm	36.7 ± 4.6	36.3 ± 4.0	0.520
Halfspan, cm	84.2 ± 5.3	83.2 ± 5.8	0.283
Calf circumference, cm	40.8 ± 4.5	40.0 ± 3.9	0.280
Wrist circumference, cm	17.4 ± 1.5	16.9 ± 1.4	0.06
Body mass index, kg/m ²	34.7 ± 5.7	34.2 ± 5.2	0.605
Percentage of fat mass	38.2 ± 7.5	39.0 ± 7.6	0.526
Percentage of fat-free mass	61.8 ± 7.5	60.9 ± 7.6	0.508

*The values show the means ± SD; **The data were analyzed using Student's t test.

The mean age was 48.5 ± 13.9 years, and the mean BMI was 34.7 ± 5.7 kg/m². Fifty participants were included in the validation group: 16 men (32%) and 34 women (68%). The mean age was 48.5 ± 15.5 years, and the mean BMI was 34.2 ± 5.2 kg/m². The baseline characteristics of both groups were homogeneous (table I).

IC reported an average of 2001 ± 552 kcal, with a respiratory quotient (RQ) of 0.75 ± 0.04. The new equation (table II) that resulted from the statistical model had an R² = 0.52 and a bias of ± 3.39 kcal. When the REE obtained from IC was compared with the REE estimated using the new formula, there was no significant difference between the results, and the correlation for all participants was 0.71 (p < 0.0001).

The difference between the new formula and the REE measurement by IC when analyzed using the Bland-Altman method was a bias of 3.39 ± 384 kcal (fig. 1). Furthermore, a correlation was obtained between the real and estimated REE values using different equations. Taking into account current weight, we observed a major correlation with our new formula (r = 0.714) (table II), followed by Owen's formula (r = 0.712) (table 3).

However, considering ideal and adjusted weights, the formula that correlated most was Carrasco (0.712), followed by Kleiber (r = 0.709) (table III).

Discussion

It has been proposed that an estimation of REE can be conducted using both BIA and IC; thus, both tools were used. However, when using BIA, proper execution of the protocol should be considered, as non-compliance can create more discrepant estimates than IC, possibly compromising the application of BIA in clinical practice²³. Utilizing anthropometric data provides a useful alternative methodology to improve the predictability of REE⁶.

Most of the variation resided between subjects, with relatively little variance due to within-subject and analytic error effects. Of the between-subject variance, most (63%) was explained by FFM⁵. In all prediction models, there was an inverse relationship between age and REE; the age-related decline could be mainly attributed to a reduction in FFM quantity⁴. Thus, predic-

Table II
Equation for estimating the resting energy expenditure of overweight and obese Mexican patients

Equation	R	R ²	Bias	SD of bias	IC 95%
12.204(AW) -244.892(1) +83.954 (WC) -402.204	0.714	0.52	-3.39	384.4	-756 to 750

AW: Actual weight, kg; WC: Wrist circumference, cm; 1: if female and 0 if male. The multiple regression analysis steps to derive the new formula and the subsequent residual analysis were performed using the Bland-Altman method.

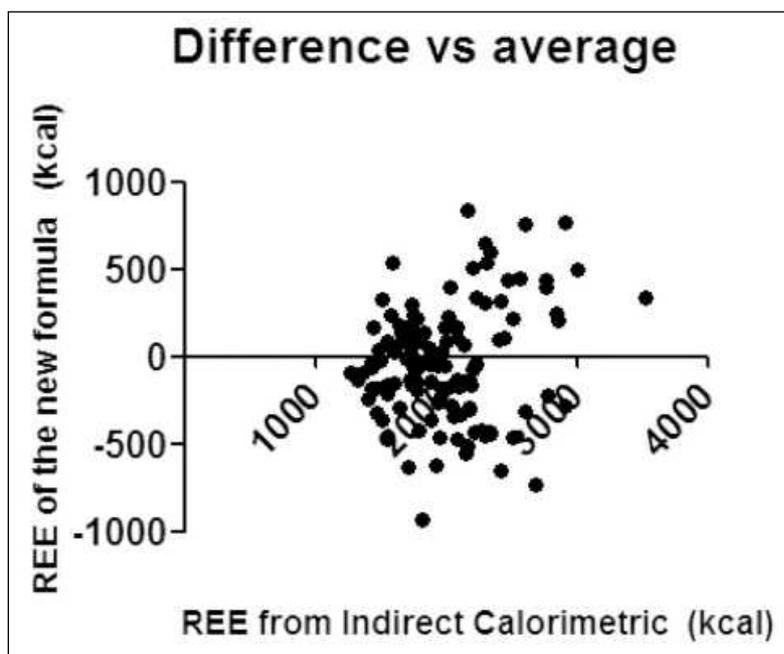


Fig. 1.—Comparison of the resting energy expenditure (REE) measured by indirect calorimetry vs difference the REE estimated using the new formula in overweight and obese subjects.

Table III
Equations for estimating the resting energy expenditure calculated with the current weight, ideal weight and adjusted weight

Equation	R	R ²	Bias	SD of bias	IC 95%
Actual weight					
Harris-Benedict	0.698	0.49	308.61	396.51	-468 a 1085
Mifflin-St Jeor	0.700	0.49	428.63	400.35	-356 a 1213
Ireton-Jones	0.615	0.38	233.11	470.67	-689 a 1155
Carrasco	0.705	0.50	513.60	394.177	-258 a 1286
Owen	0.712	0.51	399.56	400.193	-384 a 1183
Kleiber	0.682	0.47	-30.08	405.964	-825 a 765
Ideal weight					
Harris-Benedict	0.564	0.32	675.79	469.36	-244 a 1595
Mifflin-St Jeor	0.579	0.34	749.68	457.07	-146 a 1645
Ireton-Jones	0.355	0.13	1036.54	531.84	-5.87 a 2078
Carrasco	0.621	0.39	1045.65	471.37	121 a 1969
Owen	0.567	0.35	673.460	466.105	-240 a 1587
Kleiber	0.614	0.38	539.94	472.56	-386 a 1466
Adjusted weight					
Harris-Benedict	0.633	0.40	584.0	444.04	-286 a 1454
Mifflin-St Jeor	0.632	0.40	669.4	438.62	-190 a 1529
Ireton-Jones	0.481	0.24	835.7	490.0	-124 a 1796
Carrasco	0.712	0.51	912.63	439.6	50 a 1774
Owen	0.644	0.42	604.9	446.0	-269 a 1479
Kleiber	0.709	0.51	390.0	441.5	-475 a 1255

The Pearson correlation coefficients and the coefficients of determination (R²) between REE values measured by IC and REE values estimated by various formulas were calculated. To highlight differences, pairs of measurements were further analyzed using the Bland-Altman method.

ting REE from body composition data as derived from BIA is not feasible in obese populations²¹.

In clinical practice, if IC or BIA equipment is not available, prediction formulas are used to estimate REE. Out of the formulas evaluated in this study, when current weight was taken into account, we found that our formula and Owen's formula can be used. However, when ideal and adjusted weights are taken into account, the Carrasco formula can be used, followed by the Kleiber formula. These formulas have greater significant correlations with REE measured by IC; thus, they can be used in the overweight and obese Mexican population. This finding is supported by the fact that there is a metabolic size proportionate to the metabolic rate that is constant for all mammals. The Mifflin St. Jeor formula has been used in different populations and has shown good correlations when it has included samples of obese patients in critical condition and healthy populations with or without obesity, giving errors of 10% with respect to that measured by IC.⁷ Weijs et al.¹⁹ compared 27 equations in US and Dutch obese populations and reported good accuracy in the US population, although no equation was accurate for the Dutch population. Therefore, formulas have been proposed for specific populations²¹.

There are some considerations that should be taken into account when analyzing a new REE prediction formula, which we highlight in the proposal resulting from this study:

- a) Sample size (a minimum of 50 subjects or 8 to 10 individuals for each independent variable).
- b) Description of the predictive variables and the significance level: three variables were obtained that had good correlations with regard to REE: sex, current weight and wrist circumference. The last anthropometric parameter is easy to evaluate. Although not routinely measured, wrist circumference provides information regarding the individual's body type. As Kleiber postulates in his theory, body type is closely related to an individual's body size.
- c) Restrictions and limitations: the formula was obtained in adults with some degree of overweight and obesity; it must still be validated in the normal-weight population, among other age groups and among people with specific diseases for which we did not perform stratification analysis.
- d) Correlation value (r^2 result): for a correlation to be considered good, it must be at least 0.4. The proposed equation obtained a value of $r^2 = 0.52$.
- e) Significance level (" p "): must be below 0.05 to be considered statistically significant; variables included in the new equation are significant. Additionally, compared to IC, there is no significant difference when calculating REE.
- f) Prediction error: our formula has an error of 3.39 and a bias of 384 kcal, unlike the other equations that underestimate or overestimate REE kcals.

The new formula had an acceptable correlation with REE measurement by IC in overweight and obese patients in the Mexican population. This equation may represent a useful tool for health care professionals who do not have access to IC equipment for REE estimations.

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