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Research Article

Healthy Adults' Basal Metabolic Rate Comparison Measured with Indirect Calorimetry Versus Predictive Formulas

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Abstract

Introduction: The total daily energy expenditure is composed of the basal metabolic rate (BMR), the thermic effect of food (TEF) and the energy expenditure during physical activity, the latter being subdivided into the energy used specifically in exercise training and energy in activities not associated with exercise. BMR is understood as the "cost of living", that is, the energy cost of keeping all physiological processes active, cognitive alertness and sets the stage for all life activities. It comprises the caloric expenditure at rest and occupies approximately 2/3 of the total daily caloric expenditure. BMR varies between subjects and is proportional to weight, particularly muscle mass, body composition and energy imbalance.

Objective: To compare the basal metabolic rate of healthy adults, recreational athletes by indirect calorimetry and predictive formulas.

Methods: Non-experimental design study, with a quantitative approach, correlational scope with the objective of group comparison. 76 people with normal weight and overweight according to BMI were evaluated with indirect calorimetry.

Results: Significant differences were found when comparing the basal metabolic rate of recreational athletes by indirect calorimetry and predictive formulas proposed by Owen, Mifflin and Schofield, whereas no significant differences were found when comparing with the Harris-Benedict predictive formula.

Keywords: Metabolism; Calorimetry; Energy; Cost; Formula

Abbreviations

BMR: Basal Metabolic Rate; TEF: Thermic Effect of Food; BMI: Body Mass Index; IC: Indirect Calorimetry; FAO: Food and Agriculture Organization; WHO: World Health Organization; UNU: United Nations University; HB: Harris-Benedict; O_2: Oxygen; VO_2: Oxygen Volume; CO_2: Carbon Dioxide; VCO_2: Carbon Dioxide Volume; SD: Standard Deviation; Kg: Kilograms; cm: Centimeters; IOM: Institute of Medicine; RMR: Resting Metabolic Rate

Introduction

Basic components in energy balance include energy intake, energy expenditure, and energy storage. Total daily energy expenditure is composed of basal metabolic rate (BMR), thermic effect of food (TEF) and energy expenditure through physical activity, the latter being subdivided into the energy used specifically in exercise training and energy in activities not associated with exercise [1]. BMR is considered 'cost of living', which means it is the energy cost of maintaining all physiological processes, cognitive alert and setting the stage for life endeavors [2].

Basal metabolic rate refers to the amount of energy expended while resting or under idle conditions [2,3]. It is comprised of resting energy expenditure and corresponds to 2/3 of total daily energy expenditure. BMR varies from one individual to another and it is proportional to weight- particularly to muscle mass- body composition and energy imbalance [4].

Interest towards BMR was first manifested a long time ago out of the need to understand the biology and etiology of obesity and, secondly, following a publication by FAO/WHO/UNU in 1985 in which, for the first time, the use of energy expenditure –specifically BMR- was proposed as a predictor of daily energy expenditure instead of the amount of energy expended [5]. From this moment, predictive equations were developed to calculate BMR. These were widely accepted due to their usability, zero cost, and permanent availability. Among the main equations for BMR estimations are the ones by FAO/WHO (Joint FAO/WHO/UNU Expert Consultation, 1981), Harris and Benedict (HB) [6] and Mifflin-St Jeor (MSJ) [7].

Setting predictive formulae aside, there is a practical method of greater reliability to determine BMR, which consists of measuring the resting energy expenditure through indirect calorimetry (IC). This procedure estimates BMR indirectly by subtracting CO_2 production (VCO_2) from O_2 consumption (VO_2), based on the fact that energy metabolism, ultimately, depends on the use of O_2 [8]. This is a non-invasive, replicable, reliable, technique which demands a strict methodology. However, it is expensive and only available in a few clinical centers.

Purpose of the Study

The purpose of this study was to compare results from four predictive formulae for BMR estimations (Harris-Benedict, Mifflin-St Jeor, Owen y Schofield) with indirect calorimetry, used as method of reference in men and women between 18 and 44 years of age, in different weight classifications (normal and overweight by BMI), who went to Clinica Ciencia y Deporte, thus determining which predictive formula is mostly associated to the Paraguayan population.

Materials and Methods

The study is non-experimental in design, with a quantitative approach, correlational scope with an objective of group comparison.

76 individuals took part in the study (ages from 17 to 44 years), all healthy, recreational athletes (4 to 6 hours of exercise a week) with no underlying pathologies nor having taken any medication that might affect their basal metabolic rate; all from Asuncion, Paraguay. All subjects were informed of the procedure and signed a consent form previous to the evaluation.

Subjects were present at the clinic early in the morning, between 7 and 9 am, to take the test. Previous to said procedure, they were weighed on a SECA 813 digital scale and measured with a height measuring rod installed on a wall. For BMR quantification, the equipment of choice was the PNOE 1517-05. All measurements were carried out in a comfortable environment at a room temperature between 20 to 25ºC. Subjects were required to fast for a minimum of 8 hours previous to the test, not to exercise for 12 hours and to avoid caffeine, tobacco, mate nor tereré (herbal infusions) for the same 12 hours. The equipment was automatically calibrated with the air in the room immediately after each evaluation. Patients sat in a comfortable armchair where they were indicated to reach maximal relaxation for a period between 15 to 20 minutes while wearing a mask attached to the equipment. During this time, oxygen consumption and carbon dioxide production were measured in 15-second intervals. Based on readings of oxygen consumption and carbon dioxide production –except for data from the first 5 minutes- average oxygen consumption, average carbon dioxide production, respiratory quotient and BMR were gathered.

Results from indirect calorimetry were compared with those obtained by formulae for BMR estimations (HB, MSJ, Owen and Schofield) for all subjects. These were compared, also, by weight classification (normal and overweight). Predictive equations by Harris Benedict, OWEN, Mifflin-St. Jeor and Schofield [9] are shown in table 1.

Results

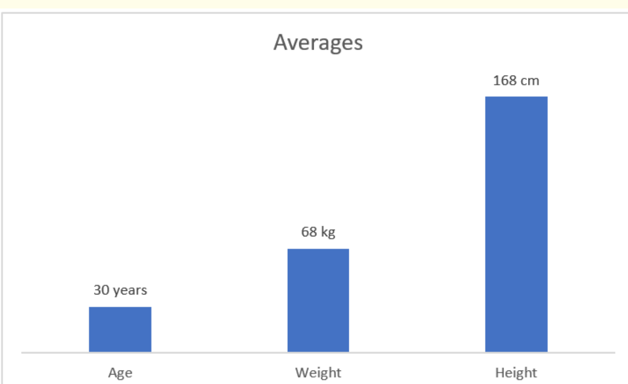
First, a data base was created using Microsoft Excel, for further analysis with SPSS statistic package version 22.0. Statistical de-

Predictive Equations	Formulae
Harris-Benedict	Men = 66.7 + (13.75 x weight) + (5 x height) – (6.76 x age) Women = 665.1 + (9.6 x weight) + 1.85 x height) – (4.68 x age)
Owen	Men = 879 + (10.2 x weight) Women = 795 + (7.18 x weight)
Mifflin-St, Jeor	Men = 9.99 x weight+ 6.25 x height – 4.92 x age + 5 Women = 9.99 x weight+ 6.25 x height – 4.92 x age - 161
Schofield	10 a 18 years = 8.4 x weight+ 4.5 x height + 200 18 a 30 years = 13.7 x weight+ 2.8 x height + 99 30 a 60 years = 8.2 x weight+ 0.01 x height + 847

Table 1: Predictive equations for BMR calculations.

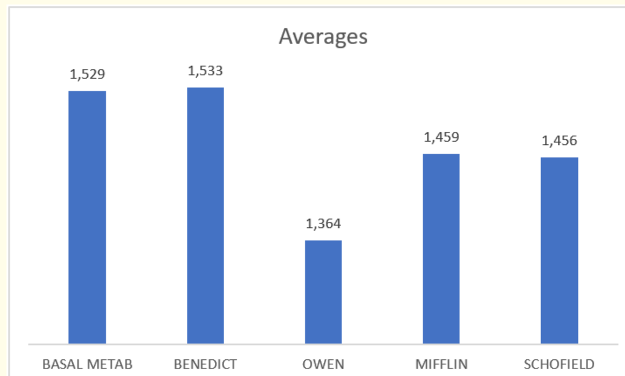
scriptions, normality tests, and the Wilcoxon test were carried out for group comparisons.

Average weight among participants was of 67.74 kg (SD ± 11.86), average height reached 167.68 cm (SD ± 9.1) and BMI of 24.00 (Graph 1).



Graph 1: Statistical descriptions.

Furthermore, the average of basal metabolic rate turned out to be of 1,529.17 (SD± 324.19), Harris-Benedict formula, 1,533.24 (SD ± 235.47), Owen 1,364.09 (SD ± 215.48), Mifflin 1,459.48 (SD ± 230.35) and Schofield 1,455.87 (SD ± 155.16) (Graph 2). The difference is only 4 calories (0.2%) between the average metabolic rate by indirect calorimetry and the Harris-Benedict formula, whereas the difference with the other formulae, Owen, Mifflin-St Jeor and Schofield is of 165.08 (10.7%), 69.6 (4.5%) and 73.3 (4.7%) calories, respectively.



Graph 2

For comparison of repeated measurements, the Wilcoxon signed-rank test was used (Table 2).

	Difference	Z	Asymptotic (bilateral)
Basal Metabolic Rate - Benedict	4.07	-.329	0.742
Basal Metabolic Rate - Owen	-165.08	-5.61	0.000
Basal Metabolic Rate - Mifflin	-69.69	-2.69	0.007
Basal Metabolic Rate - Schofield	-73.30	-2.25	0.024

Table 2: *Wilcoxon signed-rank test.*

Upon comparing the BMR formula with the Harris- Benedict formula ($z = -0.329$; $p = 0.742$) no significant differences were found.

On the other hand, when comparing basal metabolic rate with the Owen formula ($z = -5.61$; $p = 0.000$), Mifflin ($z = -2.69$; p =

0.007) and Schofield (z = -2.25; p = 0.024) differences found were statistically significant.

Discussion

It is of primary importance that predictive results obtained through equations are the closest possible to those gathered with indirect calorimetry, given that measurements of the latter kind are expensive and take a considerable amount of time [10].

Results of this study show the Harris-Benedict predictive formula yields the most similar values, with a difference of 4 calories (0.2%) regarding those obtained by indirect calorimetry, for a target population of Paraguayan recreational athletes, healthy, in weight ranges within normal and overweight. This outcome differs from the one by Ruiz & Rodríguez (2014) [11], done with a sample of 65 women (young adults and elderly) in the city of Chillán, Chile, which showed a significant difference from the BMR by indirect calorimetry. Moreover, this study yielded a closer value for the Mifflin-St. Jeor, with the smallest difference.

In the study by Parra and Perez (2012) [10], with 150 Mexican women within normal, overweight and obesity levels of BMI, the HB and MSJ equations were significantly correlated with the indirect calorimetry values. However, those were not the highest yields, being the one by the Institute of Medicine (IOM) the most adequate formula for that target population.

Brunetto., *et al*. (2010) [12] compared BMR obtained with indirect calorimetry with results from predictive equations by the OMS and the Henry and Rees formula on 48 Brazilian University-level students, concluding that BMR through indirect calorimetry and predictions by both equations show no significant differences.

Lee and Kim (2012) [9] obtained similar results to the ones from this study. They measured the RMR of 28 police officers, male, healthy, by indirect calorimetry and several predictive equations for RMR estimations (Harris-Benedict, Schofield (W)/(WH), FAO/WHO/UNU (W)/(W/H), Cunningham, Mifflin, Liu, Owen, IMNA y Henry (W)/(WH)). The Harris-Benedict equation obtained a precision rate in prediction of 35.7%, being the most precise.

The Reneau., *et al.* study (2019) [13] showed the two biggest predictors of RMR, which must be included in predictive formulae, are fat-free mass and race, reason for which knowing the formula that best adjusts to our population is of great importance.

Conclusion

There are no statistically significant differences among measurements with indirect calorimetry and results from the Harris-Benedict formula, which would deem said formula the most appropriate for RMR calculations in the Paraguayan population.

On the other hand, significant differences were found with the Owen, Mifflin and Schofield formulae, which could mean these outcomes are not adjusted to those from indirect calorimetry. This renders these formulae unfit for Paraguayan population.

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