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Original article

Validity of predictive equations for resting energy expenditure according to the body mass index in a population of 1726 patients followed in a Nutrition Unit

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SUMMARY

Background & aims: The resting energy expenditure (REE) predictive formulas are often used in clinical practice to adapt the nutritional intake of patients or to compare to REE measured by indirect calorimetry. We aimed to evaluate which predictive equations was the best alternative to REE measurements according to the BMI.

Methods: 28 REE prediction equations were studied in a population of 1726 patients without acute or chronic high-grade inflammatory diseases followed in a Nutrition Unit for malnutrition, eating disorders or obesity. REE was measured by indirect calorimetry for 30 min after a fasting period of 12 h. Some formulas requiring fat mass and free-fat mass, body composition was measured by bioelectrical impedance analysis. The percentage of accurate prediction (±10%/REE measured) and Pearson *r* correlations were calculated.

Results: Original Harris & Benedict equation provided 73.0% of accurate predictions in normal BMI group but only 39.3% and 62.4% in patients with BMI < 16 kg m^{-2} and BMI ≥ 40 kg m^{-2}, respectively. In particularly, this equation overestimated the REE in 51.74% of patients with BMI < 16 kg m^{-2}. Huang equation involving body composition provided the highest percent of accurate prediction, 42.7% and 66.0% in patients with BMI < 16 and >40 kg m^{-2}, respectively.

Conclusion: Usual predictive equations of REE are not suitable for predicting REE in patients with extreme BMI, in particularly in patients with BMI <16 kg m^{-2}. Indirect Calorimetry may still be recommended for an accurate assessment of REE in this population until the development of an adapted predictive equation.

1. Introduction

Resting energy expenditure (REE) contributes from 50% to 75% of total energy expenditure, depending of the physical activity level [1]. Therefore, the assessment of REE provides useful information for weight management and adequate nutritional strategies. REE can be measured using indirect calorimetry, a noninvasive method, which is based on the consumption of O_2 and the production of CO_2 [2]. However, the use of this method is limited because of the high cost of the equipment, and the need of trained personnel. Therefore, indirect calorimetry is hardly feasible in most clinical settings and is more frequently used in scientific research.

Alternatively, predictive equations which are usually based on the body weight, height, age and sex, are used to estimate the REE in clinical settings. Many studies have developed and validated those predictive equations [3]. However, the best formula to estimate REE is difficult to establish because of conflicting results [4,5]. Indeed, REE is influenced by age, sex, weight, height, body composition (fat-free mass: FFM and fat mass: FM), and ethnicity [6], and also by the metabolic stress, the muscle tonus, the body

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temperature and drugs. Therefore, REE predictive equation should be applied differently according to the characteristics of the target group.

Several studies have assessed the validity of REE predictive equations in overweight and obese subjects (Body Mass Index (BMI) >25 kg/m^2) [7,8], and in class III obesity (BMI > 40 kg/m^2) [9,10]. Weijs et al. [7] have validated Mifflin equation for a clearly defined overweight group of US adults aged 18–65 years with a body mass index of 25–40 [11]; in this latter study, Mifflin equation appeared to be no accurate for overweight and obese Dutch adults. However, recent evaluations in Belgian normal weight to morbid obese women [12] have shown that Harris–Benedict (HB) [13] and Mifflin equations [11] were adequate to REE measurements. Müller et al. have also found significant and systematic over – and underestimations between measured and predicted REE in German subjects [14]. To our knowledge, there was no large study in a French population.

In addition, fewer studies have examined the validity of REE predictive equations specifically in malnourished patients. Neelemaat et al. studied the validity of standard equations used to calculate energy expenditure in malnourished hospitalized older patients [15] and reported that the formulas were not adequate. This finding was also reported by Sherman et al. in patients with amyotrophic lateral sclerosis [16]. In these two studies, the majority of patients were either underfed or overfed. In clinical practice, an underestimation or overestimation of the energy expenditure contributes to inadequacy in dietary prescription, which can reduce patients' motivation and consequently lead to low adherence to a diet strategy in obese patients, or a failure in the dietary treatment in malnourished patients.

Therefore, we aimed to evaluate which predictive equations was the best alternative to REE measurements according to the Body Mass Index (BMI) in a population of patients followed in a Nutrition Unit for malnutrition, eating disorders or obesity in France.

2. Subjects and methods

2.1. Subjects

The subjects were included at the Department of Clinical Nutrition (University Medical Center, Rouen, France). The inclusion criteria were: being followed for malnutrition, eating disorder or obesity, above the age of 18 years, without acute diseases or chronic high-grade inflammatory diseases. Both weight and height were measured under standardized conditions, by the same operator, in the morning, after a fasting period of 12 h, in light clothes without shoes. BMI was calculated as body weight divided by squared height. Patients were evaluated on an outpatient basis according to routine procedures in the Nutrition Unit of Rouen University Hospital and all patients agreed to participate.

2.2. Indirect calorimetry and body composition

REE was measured by indirect calorimetry (Deltatrac II or Cosmed Quark RMR) for 30 min after a fasting period of 12 h. A calibration with a gas of known and certified CO_2 and O_2 composition was completed before starting the assessment (for Deltatrac II: 4.99% CO_2, balanced with O_2; for Quark RMR: 5% CO_2, 16% O_2, balanced with nitrogen). Measurements were standardized by internal guidelines. Subjects had not been physically active before the measurement and the evening before. The subjects were in supine position and awake, with the head placed in a clear ventilated canopy. Oxygen consumption and carbon dioxide production were measured and energy expenditure was calculated by the Weir formula [17].

Body composition, fat-free mass (FFM) and fat mass (FM), was determined using multifrequency bioelectrical impedance analysis (BIA, Bodystat Quadscan 4000) as previously described [18] and according to the manufacturer's recommendations. Although the Quadscan 4000 device records impedance at four frequencies (5, 50, 100 and 200 kHz), the manufacturer's manual states that only the 50 kHz impedance is used for the calculation of total body water, on which estimations for FFM are based using proprietary equations.

2.3. REE predictive equations

The predictive equations for REE used in our study were obtained by screening previous publications and summarized in Table 1. We selected REE predictive equations based on the following criteria: equations based on body weight, height, age, sex, and/or FM and FFM; developed in adults. The REE was predicted for each equation with the actual body weight and height at the time of the indirect calorimetry and body composition measurements.

2.4. Data analysis

Predicted REE was compared with REE measured by indirect calorimetry. When predicted REE ranged between 90 and 110% of measured REE, it was considered as accurate predicted REE. Predicted REE lower that 90% of measured REE was considered as an underprediction and predicted REE higher that 110% of measured REE as an overprediction. The mean percentage difference between predicted REE and measured REE (bias) was calculated. Pearson correlations were also performed. Data were analyzed using GraphPad Prism 5.0 (GraphPad Software, Inc, San Diego, CA).

3. Results

The descriptive characteristics of the study population are shown in Table 2. A total of 1726 patients were evaluated between July 2006 and December 2012 (321 men and 1405 women), with BMI ranged from 11.56 to 77.52 kg m^{-2}, and age ranged from 18 to 85 years. Then, we analyzed predicted REE compared with measured REE according with following BMI classes: BMI < 16, 16 ≤ BMI<18.5, 18.5 ≤ BMI < 25, 25 ≤ BMI < 40 and BMI ≥ 40. Fat and fat-free mass were also displayed in Table 2.

As shown in Supplemented Table 1, predictive equation of Harris & Benedict (1919; HB1919) gave the best score of accurate prediction (72.9% of patients) with bias lesser than 1%. In contrast in patients with low BMI, HB1919 equation only accurately predicted REE in 51.8% of patients with BMI ranging from 16 to 18.5 kg m^{-2} (Supplemented Table 2) and in 39.3% of patients with BMI lesser than 16 kg m^{-2} (Table 3). A similar trend for a decrease of accurate prediction with HB1919 equation for overweight and obese patients was observed but it was less marked. Indeed the percents of patients with accurate prediction were, respectively, 68.5 and 62.4 for BMI ranging from 25 to 40 kg m^{-2} (Supplemented Table 3) and BMI higher than 40 kg m^{-2} (Table 4). Interestingly false prediction using HB1919 was mainly related to an overprediction (51.9%) in patients with BMI lesser than 16 kg m^{-2} (Table 3). In patients with BMI higher than 40 kg m^{-2} (Table 4), an overprediction was only observed in 19% of patients.

In patients with BMI ranging from 25 to 40 kg m^{-2} (Supplemented Table 3), Müller equations gave the best percent of accurate prediction (>70% of patients), especially Müller equations using body composition. In patients with BMI higher than 40 kg m^{-2} (Table 4), Müller equations also gave high percent of accurate prediction (approximately 64%) but the best accurate prediction was obtained with Huang equation (65–66% of