ENERGY EXPENDITURE AND INTAKE IN WOMEN WHO UNDERWENT OBESITY SURGERY TWO OR MORE YEARS AGO

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Abstract: The Resting Energy Expenditure (REE) assessed by indirect calorimetry of women who have undergone obesity surgery was compared with data estimated by predictive equations, while the estimated energy needs (NE) were confronted with energy intake (EI_int) and the correlation of the ratio EI_int/REE with energy spent on activities was investigated.

Keywords: resting energy expenditure, energy intake, physical activity

1. INTRODUCTION

The complexity of body weight regulation represents one of the greatest challenges for the understanding of the etiology, treatment and prevention of obesity [1]. Body weight is regulated by integrated and coordinated effects in energy consumption and expenditure. The high recurrence of weight gain among obese individuals who lose weight reflects a change in this process [2]. In this sense, food intake assessment is an extremely important factor for the assessment of an individual’s energy balance. However, one of the most challenging aspects of nutrition and dietetics theory and practice is the measurement of energy and nutrient intakes, because of the limitations of the methods currently available to measure food intake properly [3,4].

Dietary questionnaires are used as indirect methods to assess the nutritional status of individuals. However, these instruments are subject to errors inherent to the individual, to its administration and to data analysis [5,6]. Statistical techniques aim to reduce the gap between the information given by the respondents and the actual intake of nutrients and energy [7,6].

The challenges that must be faced when making food intake assessments range from obtaining reliable information, passes through the identification of under / overrecording, and goes all the way to estimating the required energy and nutrients in order to establish recommendations and interventions [8].

Significant problems that occur in food intake assessments are underreporting or underreporting food intake. Underreporting can result from: undereating or

underreporting. In underreporting, the individual reduces his or her dietary intake, often because he or she feels intimidated by the data-collecting instrument, and the data will then not be a good reflection of the individual’s current weight and dietary habits. Meanwhile, underreporting means that the individual does not report the foods that he or she indeed consumes, that is, he or she underreports his or her food consumption [9]. When an individual reports an energy intake that is not biologically plausible, he or she is identified as an underreporter [10].

The daily energy expenditure of an individual consists of the following: Resting Energy Expenditure (REE), which is the energy spent while resting in bed under comfortable environmental conditions. It represents 60-70% of the daily energy expenditure; thermogenesis induced by foods, which is the thermal effect of foods and corresponds to 5-15% of the energy expenditure; and energy spent on physical activities, considered the most variable component: it can contribute to a significant amount of the energy expenditure of very active individuals [11].

Underreporting is consistently more prevalent and severe among obese individuals than among normal weight individuals [12-14]. Some obese individuals repeatedly fail when they try to lose weight, despite reporting energy intakes lower than 1200 calories per day. But this failure may be related to an energy intake that is substantially higher than the reported intake and to an overestimation of the level of physical activity [15].

Goldberg et al. [16] proposed an alternative method by introducing the relationship between reported Energy Intake and Resting Energy Expenditure (EI_int:REE) as a way to detect under or overreporting. At energy balance (no weight change), EI_int:REE = TEE:REE. The TEE:REE ratio is also known as the PAL, which in generic terms, is nothing more than the Physical Activity Level. Under specific conditions, the equation may be written as EI_int:REE = PAL. But in practice, TEE, REE and EI are approximate values that depend on predictive equations (TEE and REE) and reported intake (EI). Thus, actual PAL can be determined only by measuring energy expenditure with calorimetry or an equivalent method.

In most studies, REE has been estimated by predictive formulas (regression equations derived from
indirect calorimetry). Indirect calorimetry has been used for almost 100 years as a reference for measuring energy intake in humans [17], whether at rest or during physical activity. Since the first equation proposed by Harris and Benedict in 1919 [18] many equations based on indirect calorimetry have been proposed for predicting REE and also for estimating Energy Requirement (ER) by aggregating REE with expenditure during physical activity [19].

Recently, the use of doubly labeled water emerged as a substitute for indirect calorimetry [20]. The method consists of ingesting a dose of water containing stable oxygen and hydrogen isotopes and later measuring these isotopes in the organic fluids (blood or urine). The principle is based on the dilution of the stable oxygen and hydrogen isotopes used as markers (H$_2$O and H$_2$^{18}O).

The American equations derived from the studies with doubly labeled water consider the duration of the physical activities done throughout the day in the energy expenditure estimate, attributing values to the estimated Level of Physical Activity (PAL$_{est}$), that is, a level of expenditure estimate, attributing values to the estimated physical activities done throughout the day in the energy with doubly labeled water consider the duration of the physical activities done throughout the day in the energy expenditure estimate, attributing values to the estimated Level of Physical Activity (PAL$_{est}$), that is, a level of expenditure estimate, attributing values to the estimated physical activities done throughout the day in the energy expenditure estimate, attributing values to the estimated Level of Physical Activity (PAL$_{est}$), that is, a level of expenditure estimate, attributing values to the estimated physical activities done throughout the day in the energy expenditure estimate, attributing values to the estimated Level of Physical Activity (PAL$_{est}$), that is, a level of expenditure estimate, attributing values to the estimated physical activities done throughout the day in the energy expenditure estimate, attributing values to the estimated Level of Physical Activity (PAL$_{est}$), that is, a level of expenditure estimate, attributing values to the estimated physical activities done throughout the day in the energy expenditure estimate, attributing values to the estimated Level of Physical Activity (PAL$_{est}$), that is, a level of expenditure estimate, attributing values to the estimated physical activities done throughout the day in the energy expenditure estimate, attributing values to the estimated Level of Physical Activity (PAL$_{est}$), that is, a level of expenditure estimate, attributing values to

The DRI equations were derived from studies with normal weight, pre-obese and obese individuals. Although fat is less metabolically active than lean tissue, the differences in energy expenditure by unit of body mass between obese and normal weight individuals turns out to be small, since obese individuals consume more energy for locomotion. Common equations were then proposed to calculate the energy requirements of normal weight, pre-obese and obese individuals [20].

2. OBJECTIVE

The objective of this study was to discuss the limitations of the methods that assess energy metabolism, focusing on bariatric surgery, while investigating the agreement among the equations that predict energy expenditure by determining resting energy expenditure (REE) with indirect calorimetry; to compare the energy requirement (ER) estimated by a regression equation with the reported energy intake (EI$_{rep}$); and to correlate the estimated physical activity level (PAL$_{est}$) with the EI$_{rep}$/REE ratio in women who underwent obesity surgery more than two years ago.

3. METHODS

A cross-sectional study was done with 51 women aged 28 to 61 years who underwent bariatric surgery (banded or not Roux-en-Y gastric bypass, RYGB) 5.1±1.7 years ago, all of them with a stable weight. The REE was measured and the expenditure with physical activities and EI$_{rep}$ were estimated. The measured REE was compared with the values predicted by equations. The estimated energy intake was compared with the ER values. The relationship between PAL$_{est}$ and the EI$_{rep}$/REE ratio was also assessed. The study was approved by the Research Ethics Committee of the School of Pharmaceutical Sciences of UNESP in Araraquara, protocol CEP/FCF/CAr. nº 5/2006, opinion nº 24/2006.

Resting Energy Expenditure (REE): The REE was determined by indirect calorimetry. After performing the necessary steps, which included measuring body weight and height, the oxygen consumption ($V_O2$) and production of carbon dioxide ($V_CO2$) were measured at 60-second intervals during 35 minutes with the gas exchange system MedGraphics® (VO2000). The measurement of the REE per minute in kcal/min was obtained by the equation proposed by Weir, 1949. Total kcal = $3.9\times V_O2 + 1.1\times V_CO2$.

Predictive REE Equations: The REE obtained by calorimetry was compared with the following equations:

Harris & Benedict [18]:
$$REE = 655.095+ (9.5 \times \text{weight}) + (1.8 \times \text{height}) - (94.6 \times \text{age})$$

Scholfield [21]:
$$REE = (0.062 \times \text{weight}) + (2.036) \times 239.23$$

FAO1[19]:
18-30 years: $REE = (8.7 \times \text{weight}) + 829$
30-60 years: $REE = (14.7 \times \text{weight}) + 496$

FAO2[19]:
REE=18-30 years = (13.3 \times \text{weight}) + (334 \times \text{height}) + 35
REE=30-60 years = (8.7 \times \text{weight}) + (25 \times \text{height}) + 865

Owen [22]:
$$REE = 795+7.18 \times \text{weight}$$

Mifflin [23]:
$$REE = (9.99 \times \text{weight}) + (6.25 \times \text{height}) - (4.92 \times \text{age}) - 161$$

Romero [24]:
$$REE = 1,272.5+(9.8 \times \text{weight})-(61.6 \times \text{height})-(8.2 \times \text{age})$$

Energy requirement (ER): The energy requirement was estimated by the DRI equation [20]:
$$ER = 354-6.91 \times \text{age} + \text{AF} \times (9.36 \times \text{weight} + 726 \times \text{height})$$

Estimated physical activity level (PAL$_{est}$) and activity factor (AF): A Physical Activity Diary was used to collect the physical activity data of three non-consecutive days when the 24-Hour Recalls were also filled out. The duration of all activities during a typical day was recorded. Data on the time spent sleeping, time spent sitting down, standing and walking at work, activity done on the way to and from work (driving, walking, bus, bicycle), physical activities at home (house chores), leisure activities, sports, exercises and time spent sitting at home watching TV, reading or using a
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The collected data were input in Excel® spreadsheets. They were then transferred to the software BioEstat®, version 3.0 [25] for the statistical analyses. The comparisons between the measured and estimated REE data were done by ANOVA, followed by the Tukey test. The agreement test was done with the intraclass correlation test in Excel®; \[ r = \frac{2 \sum (REE-Xm) \times (REE_{est}-Xm) \sqrt{\sum (REE-Xm)^2 + \sum (REE_{est}-Xm)^2}}{\sum (REE-Xm)^2 + \sum (REE_{est}-Xm)^2} \], with null \( < 0.31 \); weak \( 0.31 \leq r < 0.51 \); moderate \( 0.51 \leq r < 0.71 \); good \( 0.71 \leq r < 0.91 \); excellent \( r \geq 0.91 \). The comparison between ER and EI was done by the Student’s t-test. The correlation between PAL_{est} and EI_{rep} :REE was investigated by Pearson’s correlation coefficient. The significance level was set at 5%.

4. RESULTS

Figures 1 and 2 refer to the measured and estimated REE. Despite the excellent agreement between the data (Table 1), values obtained with indirect calorimetry were lower than those obtained with the predictive equations (Figures 1 and 2).

4.1. Comparison between the measured and estimated REE

When the results obtained with the equations were compared with each other, only the mean results obtained with Owen’s equation [22] were significantly lower than those obtained with the FAO 1 equation [19].

Table 1. Intraclass correlation coefficient between energy expenditure determined with indirect calorimetry (IC) and estimated by different equations in women two or more years after obesity surgery.

<table>
<thead>
<tr>
<th>Equations</th>
<th>r*</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harris &amp; Benedict</td>
<td>0.95414</td>
<td>Excellent</td>
</tr>
<tr>
<td>Schofield</td>
<td>0.95709</td>
<td>Excellent</td>
</tr>
<tr>
<td>FAO 1</td>
<td>0.95328</td>
<td>Excellent</td>
</tr>
<tr>
<td>FAO 2</td>
<td>0.95779</td>
<td>Excellent</td>
</tr>
<tr>
<td>Owen</td>
<td>0.97012</td>
<td>Excellent</td>
</tr>
<tr>
<td>Mifflin</td>
<td>0.96695</td>
<td>Excellent</td>
</tr>
<tr>
<td>Romero</td>
<td>0.94762</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

*p < 0.01 by ANOVA;
**p < 0.05 for FAO 1 and Romero by Tukey Test.

Figure 1. Comparison between the Resting Energy Expenditure determined by indirect calorimetry (IC) and those estimated by different equations for women two or more years after obesity surgery.

In Figure 1, the results were arranged in increasing order in relation to the indirect calorimetry result. This figure shows that there is great similarity in the behavior of the lines obtained from equations. The estimated REE was always above 1,200 Kcal, while the lowest measured result reached 500 Kcal.

Thirty-eight (77.5%) women presented a median REE determined by indirect calorimetry 20.8% lower (10-54%) than the REE estimated by the Harris & Benedict [18] equation and only one woman presented a value 10% greater than the estimated value.

Table 2 shows that mean EI_{rep} was roughly 50% of the mean ER, close to the mean REE determined by calorimetry. On the other hand, there was a weak correlation between PAL_{est} and EI_{rep} :REE (Figure 3).
5. DISCUSSION

The metabolic state can be classified as normal, hypermetabolic or hypometabolic, by comparing the measured REE with the mean REE estimated for a reference population [26]. According to Diener [26], an individual is considered hypermetabolic when the measured REE is 10% or more above the predicted mean value of the reference population. Individuals whose energy expenditure is below 90% of the predicted expenditure are considered hypometabolic [77.5%] because of their REE estimate by the equations and the REE determined by indirect calorimetry. All the predictive equations used in the present study take gender and weight into account; two of them include age (FAO 1 and FAO 2) and one includes height (FAO 2), yet many other factors can interfere with REE. Very low values, such as 500 Kcal, found in the present study deserve further investigation because they may be an adaptation to metabolic restriction after bariatric surgery.

Since the pioneering study done by Harris & Benedict [18] in 1919, approximately 138 equations were published by 40 different authors [27]. These equations are based on body mass (BM), height, age, gender and specific markers of body composition, such as body surface, lean mass (LM), fat mass (FM), total body potassium, among others [27]. The equations have been used in thin, overweight, obese and morbidly obese individuals and also in specific pathological conditions. However, interpersonal variation shows that much caution is needed when estimating REE with the existing predictive equations since it has been shown that they do not always estimate REE correctly [28], resulting in errors in the energy requirement estimates of individuals and populations [29]. More studies are necessary to affirm if the proportion of hypometabolism found among the women who underwent surgery was greater than that of the population who have not undergone surgery, whether obese or not, since there are not enough data on the population that lives in the same environmental conditions as those of the present study.

On the other hand, Table 2 and Figure 3 show that energy intake divided by resting energy expenditure (EI rep :REE) was not comparable with the level of physical activity (PAL est ) of the studied population. This can be partially explained by the overestimated ER that composed the PAL est calculation, especially considering that the REE corresponds on average to 70% of the ER and that, in this case, the ER was estimated by predictive equations (overestimation of the REE and AF). On the other hand, the low EI rep :REE ratio can also be related to a substantially greater energy intake than the reported intake. Although perfect agreement of this datum cannot be expected, since there are errors in the measurements of all the elements of this equation (EI rep :REE = PAL). The fact is that the women’s weights were stable and they reported consuming half of their estimated energy requirement (ER). This leads us to the generalization that the scale is still the best instrument to assess the adequacy of energy intake. In other words, if the individual is gaining weight, it is because he or she is consuming more energy than he or she should, and vice-versa. However, one should not give up trying to solve this difficult issue, that is, to know the values on both sides of the scale, which for now remain obscure. This information can help explain, for example, weight gain after bariatric surgery which most times involves an underreported intake.

In 1991, Goldberg et al [16] developed two cut-off points for the agreement between PAL est and EI rep :REE. The cut-off point of 1 assumes an PAL est of 1.35, representing a minimum plausible value for maintaining weight. That is, consumption below 1.35 x REE presented by individuals corresponds on average to 70% of the ER and that, in this case, the ER was estimated by predictive equations (overestimation of the REE and AF). On the other hand, the low EI rep :REE ratio can also be related to a substantially greater energy intake than the reported intake. Although perfect agreement of this datum cannot be expected, since there are errors in the measurements of all the elements of this equation (EI rep :REE = PAL). The fact is that the women’s weights were stable and they reported consuming half of their estimated energy requirement (ER). This leads us to the generalization that the scale is still the best instrument to assess the adequacy of energy intake. In other words, if the individual is gaining weight, it is because he or she is consuming more energy than he or she should, and vice-versa. However, one should not give up trying to solve this difficult issue, that is, to know the values on both sides of the scale, which for now remain obscure. This information can help explain, for example, weight gain after bariatric surgery which most times involves an underreported intake.

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Furthermore, the cut-off point of 1 proposed by Goldberg allows the occurrence of errors that are associated with the number of individuals, the number of days of dietary assessment and intra-individual variations of food intake, in addition to errors reported for the resting energy intake and physical activity [32]. This led Black [31] to recommend that this cut-off point should no longer be used to identify incorrect energy intake reports, and proposed the cut-off point of 2.
In the present study, the mean EI_{rep}:REE ratio was 1.27. If Goldberg’s et al [16] cut-off point of 1 had been used to analyze this datum, the mean intake reported by the women would probably not have represented their habitual energy intake correctly.

In 2000, Black [31] stated that Goldberg’s et al. [16] articles had not been written as a practical guide for the investigation of underreporting. The method presents limitations and the concepts have not been completely understood or correctly applied [32]. However, the principles of Goldberg’s cut-off point for the assessment of underreporting were recently reassessed, and its use and technical limitations were fully discussed [31].

The cut-off point of 2 differs from the cut-off point of 1 in that its value varies depending on the actual energy expenditure of the studied individuals. It involves a statistical comparison between EI_{rep}:REE and approximation to the actual PAL value, taking into account the biological variability of the components of the equation and the measurement errors. Goldberg’s et al [16] original study showed the derivation of the cut-off point of 2, however the information needed for using the concept is not easy to extract and the key statistics for the derivation of the equation was relegated to the appendix [31]. Based on these equations, a cut-off point is found (lower confidence limit - 95%) at the individual and group level, below which it is statistically improbable that the reported mean energy intake represents the actual intake.

When the level of physical activity is known or presumed based on information about the individuals’ levels of physical activity, an upper limit can also be calculated. The upper and lower limits for the cut-off point of 2 derive from the statistical comparison between EI_{rep}:REE and PAL_{est} representing an upper and lower confidence limit of 95% respectively, for the difference between EL_{rep}:REE and PAL_{est}. The actual values for the upper and lower limits of the cut-off point of 2 will depend on the level of physical activity of the individuals under study to detect the under- and overreporters.

In the cut-off point of 2, each element of Goldberg’s equation must be replaced by the correct values for the study that is being done in order to maximize the sensitivity and the specificity of the cut-off point [31].

**Goldberg’s Principles, 1991 (cut-off point of 2):**

To determine if a given mean value of the EI:REE ratio in “n” subjects is acceptable, the following formula should be used:

\[
EI_{rep} : REE > PAL_{est} \times \exp \left\{ s.d._{min} \times \frac{S}{100} \right\}
\]

\[
\sqrt{n}
\]

Where:

- \( EI_{rep} : REE \) is the ratio of energy intake to resting energy expenditure.
- \( PAL_{est} \) is the estimated physical activity level.
- \( s.d._{min} \) is the minimum standard deviation for the estimated activity level.
- \( S \) is the standard error of the estimate.
- \( n \) is the number of subjects in the study.

\( S = \sqrt{\frac{VC^2_{wEI} + VC^2_{wB} + VC^2_{tP}}{d}} \)

Where:

- \( VC_{wE} \) is the intra-individual coefficient variation of energy intake.
- \( d \) is the number of days the questionnaire will be used.
- \( VC_{wB} \) is the intra-individual coefficient variation of the repeated REE measurements or accuracy of the estimate in comparison with the measured REE.
- \( VC_{tP} \) is the variation of the PAL_{est} among individuals.

Studies have already suggested the hypotheses that there is a greater prevalence of food underreporting among older females who have a lower education level and excess weight. Yet, among morbidly obese individuals before and after bariatric surgery, the magnitude of underreporting and its determinants have been poorly explored. Additionally, studies with specific cut-off points that are also sensitive to assess underreporting in this population group have not been found. Thus, other statistical treatments would be necessary (using the principle of the cut-off point of 2 of Goldberg, 1991) to find cut-off points that are specific for this population.

Another aspect of special interest is that the existing studies refer only to individuals with stable weight, while the diagnosis of underreporting is especially interesting in studies of obesity, where weight gain is a constant.

Studies of this nature are already being done by our research group since they are important for the improvement of techniques that assess food intake, especially among individuals whose information regarding energy balance become a more important indicator of intervention results, especially in the case of obesity.

6. CONCLUSION

Although much has been done since Harris Benedict in 1919, the current formulas for estimating resting energy expenditure (REE) and total energy expenditure (TEE) that take into account expenditure during physical activities are limited and tend to overestimate the results. There is a built-in error in the REE estimate regarding the intra-individual variation of the energy metabolism during rest. Among women who underwent obesity surgery, 77.5% were considered hypometabolic. In these women, the estimated ER was twice as high as the energy intake (EI_{rep}); however, they presented a steady weight. The correlation between PAL_{est} and the EI_{rep}/REE ratio was weak, evidencing errors in the two components of the ratio. These results indicate that one should be cautious when using predictive equations for the assessment of the energy metabolism of women.
subjected to bariatric surgery and they invite specialists to study this further.

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