ARTÍCULOS ORIGINALES

Las comparaciones entre las ecuaciones de predicción de la tasa metabólica en reposo y la calorimetría indirecta en los adolescentes obesos

Comparisons between predictive equations of resting metabolic rate and indirect calorimetry in obese teenagers

ABSTRACT

Objective: To measure the accuracy of predictive equations of resting metabolic rate (RMR) in obese teenagers in relation to indirect calorimetry (IC). **Methods:** This study was conducted with 116 obese teenagers (60 males; 13.7 ± 1.1 years). The RMR was calculated from Harris and Benedict, Schofield, WHO, Henry and Rees equations. The RMR was measured by the QUARK-RMR system. The comparison between predictive equations and IC was by the Student's t test. The reliability of data between predictive equations and IC was verified by the typical error of measurement (TEM) and the coefficient of variation (CV%). **Results:** Henry's equation was significantly different from IC ($p < 0.02$). The CV% found for each equations compared to IC turned was low. However, when the TEM was measured it was considered high in absolute values which can cause errors when estimating the RMR. Therefore, it is important that specific predictive equations are developed for Brazilian obese teenagers.

Key words: obesity, teenagers, resting metabolic rate, indirect calorimetry, predictive equations.

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INTRODUCTION

Nowadays the increase in the prevalence of obese teenagers is alarming throughout the world (1). According to the Brazilian Ministry of Health (2), overweight and obesity have been increasing since the last 30 years in Brazil and the incidence in children is startling (3). Data from the Brazilian Institute of Geography and Statistics shows that 41.1% of teenagers are overweight, whereas obesity is present in 10% of this population (4).

The cause of obesity can be attributed to the imbalance of intake and energy expenditure resulting from physical inactivity and inadequate nutrition (5). Adolescence is related to the increase of food intake containing simple sugar and fat, such as soft drinks, candy, cookies and fast food, which contributes to the increase of caloric intake (6). On the other hand, this phase is related to glaring physiological changes such

as the maturation of body structures and organs, factors that contribute to an increase in energy expenditure (7).

In this context, the assessment of human energy requirements of obese teenagers becomes extremely important so that the best weight control alternative can be chosen in regards to the prescription of dietary interventions and the practice of physical activities (8,9).

An individual's total energy expenditure (TEE) is made out of three main components: the resting metabolic rate (RMR), the thermic effect of food (TEF) and the thermic effect of physical activity, whereas the first is responsible for 60 to 75% of TEE, especially regarding obese people (10) and is related to the maintenance of the majority of body functions (11).

Indirect calorimetry (IC) is used to estimate the human energy needs of an individual based on the individual's oxygen consumption and carbon dioxide production at rest, thus

being considered a procedure of high precision and sharpness (12). However, IC is a high-cost, sophisticated technique that requires technical maintenance and a proper environment of use, which can not be used under unfitting circumstances. Therefore, some predictive equations were developed to estimate people's RMR according to their gender, age and body mass (13-15).

Those equations were developed and tested in North American and European citizens and may not be fit for individuals living in different environments such as tropical areas (13-169). Research shows the limitations in the usage of the main predictive equations suggested for international use (17,18) due to factors of gender, maturation, age, climate and body composition which interfere with the resting energy expenditure (REE) (19). Authors point out that the RMR prediction is accepted within a coefficient of variation (CV%) from 5 to 10% from the IC measurement (8,9).

Therefore, the use of predictive formulas to estimate the RMR of obese teenagers must be carefully examined while taking into account all the characteristics of the population. The objective of this research was to measure the accuracy of different RMR predictive equations in obese teenagers and comparing the results to the values measured by IC and between the sexes.

SUBJECTS AND METHODS

Subjects

To develop this research, 116 obese teenagers (60 males and 56 females) have been measured according to Cole et al. classification (20), residing in Presidente Prudente, São Paulo, Brazil, aged 12 to 16 (13.7 ± 1.1 years). The volunteers were properly informed of the procedures and objectives of this research, and after agreeing with the requirements, since they are underage, their parents or legal guardians signed a term of consent. This research was approved by the Comitê de Ética em Pesquisa da Universidade Estadual Paulista "Júlio de Mesquita Filho". Protocol nº 07/2009.

Anthropometric measures

The total body mass was measured by an electronic platform Filizola scale, with 0.1 kg precision and 150 kg maximum capacity. A Sanny stadiometer with 0.1 cm precision and 2.20 m maximum extension was used to measure the height (21).

Based on the body mass and height measurements, the Body Mass Index (BMI) was calculated using the following formula: individual's body mass (kilograms), divided by square height (meters), hence the values are accounted in kg/m^2 .

Resting Metabolic Rate through indirect calorimetry

The RMR was defined by the measurement of oxygen consumption (O_2) and carbon dioxide production (CO_2) using the QUARK-RMR (COSMED, Rome, Italy) device. The device was calibrated with concentrations of known gases (17% O_2 e 5% CO_2) according to the manufacturer specifications. The RMR was gathered under fitting conditions: in a quiet room, temperature from 21 to 24°C, low lightning and no noises. The oxygen consumption (VO_2) and carbon dioxide production (VCO_2) have been measured for 30 minutes, and that the first five minutes were discarded until the individual reaches steady state while the volunteer remained in supine position, awakeduring all the evaluation. The teenagers were previously advised to fast for six hours before the data gathering as well as to not practice any physical activities one day before the exam. Weir's equation (22): $[(3.941 \times \text{VO}_2) + (1.106 \times \text{VCO}_2)] \times 1440$ was adopted to calculate the human energy requirements of individuals at rest (kcal/day).

Predictive Equations

The following RMR predictive formulas recommended and used in teenager research were used (table 1).

Statistical analysis

Descriptive statistics were used and the values were accounted in average and standard deviation (SD). The Kolmogorov-Smirnov test was used to measure the normality of data. Student's t test was used to compare male and female independent data. The comparison between predictive equations and IC was carried out by Student's t test for dependent samples. CV% between measurements was used to assert data reliability between the predictive equations and IC and typical error of measurement (TEM), established by Hopink (23), was used to measure in absolute values the variation of CI regarding the prediction equations. The statistical significance was established in $p < 0.05$, and all analysis were conducted using the Statistical Package for Social Science (SPSS version 17.0 [Inc. Chicago. IL]) software.

TABLE 1

Resting metabolic rate predictive equation formulas for teenagers

	Age range	Equations
Harris and Benedict (kcal/day)	15-75	$M = 66.4730 + 13.7516 \times (\text{BM}) + 5.0033 \times (\text{HT}) - 6.7550 \times (\text{AG})$ $F = 655.0955 + 9.5634 \times (\text{BM}) + 1.8496 \times (\text{HT}) - 4.6756 \times (\text{AG})$
Schofield (MJ/day)	10-18	$M = 0.074 \times (\text{BM}) + 2.754$ $F = 0.056 \times (\text{BM}) + 2.898$
WHO (MJ/day)	10-18	$M = 0.0732 \times (\text{BM}) + 2.72$ $F = 0.0510 \times (\text{BM}) + 3.12$
Henry and Rees (MJ/day)	10-18	$M = 0.084 \times (\text{BM}) + 2.122$ $F = 0.047 \times (\text{BM}) + 2.951$

WHO= world health organization, M= male, F= female, kcal= kilocalories, MJ= millijoule, BM= body mass (kg), HT= Height (cm) and AG= age. To convert MJ/d into kcal/d multiply the result times 238.

RESULTS

The anthropometric and energy expenditure variables are described in table 2. Differences statistically significant between body mass (85.4 ± 19.4 versus 77.9 ± 13.3 , $p < 0.05$), height (163.4 ± 8.1 versus 159.3 ± 7 , $p \leq 0.01$), RMR measured by IC (2100.8 ± 566 versus 1723.5 ± 479.6 , $p \leq 0.01$) and estimated by formulas between genders were noted (table 2).

The comparative analysis in table 3 between predictive equations: Harris and Benedict ($p = 0.15$), Schofield ($p = 0.41$), WHO ($p = 0.59$), Henry and Rees ($p = 0.13$) and IC showed that there is no difference between them regarding males, furthermore, regarding females only Henry's equation showed statistics differences from IC ($p = 0.02$). The CV% found for each comparison was low, according to the literature (8,9). However, the TEM found for each one of the predictive equations compared to calorimetry is considered high (table 3).

DISCUSSION

Obese teenagers have been constantly researched by specialists and the RMR knowledge of highly precise measurements at a low cost became extremely important to develop treatments. With that in mind, this research measured the precision of four different RMR predictive equations: Harris

and Benedict (1919), Schofield (1985), World Health Organization WHO (1985), Henry and Rees (1991), compared to the values measured by IC in obese teenagers.

The comparison results between these predictive equations and IC suggest that: 1) there have been differences in the RMR of obese teenagers when males were compared to females, 2) Henry's equation is unfit for female teenagers, 3) the predictive equations showed a CV% was low within the established limits when compared to IC, however, when this data is analyzed in a clinical way and with TEM support discrepancies between measurements are confirmed.

The average RMR found in this research was higher than the values reported by other authors when they measured children and teenagers who were overweight or obese. In an article published by Benedetti et al²⁴, has concluded after assessing 23 overweight teenagers with IC that the resting energy expenditure (REE) of these teenagers was 1.697 kcal/day. Another research has also obtained a result that is inferior to Dorothy et al²⁵, which analyzed the RMR of 100 obese children and found the 1.689 kcal/day value.

The results of this research verified that the average RMR measured in male obese teenagers was 2,100 kcal/day. This value was compared to the other four predictive equations

TABLE 2

Comparison between anthropometric variables, RMR determined by IC and predictive equations between male and female obese teenagers.

	Male (n=60)	Female (n=56)
Body mass (Kg)	85.4 ± 19.4	$77.9 \pm 13.3^*$
Height (cm)	163.4 ± 8.1	$159.3 \pm 7^+$
BMI (kg/m ²)	31.7 ± 5.8	30.5 ± 3.9
RMRCI (kcal/day)	2100.8 ± 566	$1723.5 \pm 479.6^+$
RMRBENEDICT (kcal/day)	1967.4 ± 292.2	$1630.4 \pm 136.8^+$
RMRSCHOFIELD (kcal/day)	2160.1 ± 343.1	$1728.5 \pm 178.4^+$
RMRWHO (kcal/day)	2135.8 ± 339.4	$1688.6 \pm 162.5^+$
RMRHENRY (kcal/day)	2213.1 ± 389.4	$1574.2 \pm 149.7^+$

BMI: body mass index, RMR: resting metabolic rate, Kg: kilograms, cm: centimeters, m²: square meter, Kcal: kilocalorie, * $p < 0.05$, + $p \leq 0.01$.

TABLE 3

Results from the comparisons between predictive equations and IC in obese teenagers.

	Male (n=60)			Female (n=56)		
	RMR _{IC} p	RMR _{IC} TEM (kcal/day)	RMR _{IC} CV%	RMR _{IC} p	RMR _{IC} TEM (kcal/day)	RMR _{IC} CV%
RMR _{BENEDICT}	0.06	374.8	9.2	0,15	340.1	10.1
RMR _{SCHOFIELD}	0.41	390.0	9.2	0,94	343.2	10.0
RMR _{WHO}	0.62	389.3	9.2	0,59	341.0	10.0
RMR _{HENRY}	0.13	400.0	9.3	0,02*	339.4	10.3

RMR= resting metabolic rate, IC= indirect calorimetry, TEM= Typical error of measurement, CV%= coefficient of variation between measurements, * $p < 0.05$.

in table 3 and no statistically significant differences between them have been found. In literature, Van Mil et al (26), have found that WHO's equation overestimated the human energy expenditure of obese males. Another research published by Schneider e Meyer (12), using Henry and Rees equation, has also verified that the result overestimated the human energy expenditure of males, aging from 12 to 17.

Regarding females, only Henry's equation has showed differences statistically significant when compared to IC ($p < 0.02$), underestimating the teenagers' RMR. Rodrigues et al (27) have showed that Schofield's equation superestimates 10.5% of energy expenditure when applied to females. On the other hand, Tverskaya et al (28) have verified through the same formula of Schofield's that the results found in obese females aging from 11 to 18 underestimated IC. These results can be explained due to the fact that the predictive equations were not intended for groups of obese teenagers, but for physically active youngsters and adults (16). Thus, it is important to be careful when applying RMR predictive equations, since the results can be different from one population to another.

According to various authors (12,26) male individuals show higher RMR when compared to females, this is due to the fact that males possess more lean body mass (LBM) than females, since it is key to metabolic expenditure because it is a tissue which is more metabolically active. According to Trevisan and Burini (29) for each kilogram of LBM there is a TEE increase of 50 kcal/day, while the maintenance of muscle mass can help avoid the RMR drop, support the maintenance of body weight and prevent visceral adiposity.

Our results match with the aforementioned, in which the males' RMR was higher than the females', therefore, gender is an important factor to be considered in the RMR results. The same can be noted in a research published by Tverskaya et al (28), which reports that the gender explains 84% of variation in the RMR of teenagers.

When the genders were analyzed separately, the results of this research were superior for males in relation to other literary articles. This can be verified by Schneider & Meyer (11) who measured 35 overweight and obese males, aging from 12 to 17, where an energy expenditure of 1.900 Kcal/day was reported. For the RMR measured by IC in females the values found were higher, varying from the result reported by Fonseca et al (31) who have assessed 51 female teenagers aging from 10 to 17 and the energy expenditure found was 1.292 Kcal/day.

The CV% was low for each equation in regards to IC, however, when analyzed the absolute values of each prediction equation through TEM and compared with the IC was verified statistics differences (table 3) the IC compared to all equations regardless of gender showed a minimum variation of 339.4 kcal/d to 400 kcal/d.

In conclusion the TEM was considered high in absolute values that can cause errors when estimating the RMR. Therefore, it is important that specific predictive equations are developed for Brazilian obese teenagers.

RESUMEN

Objetivo: Medir la precisión de las ecuaciones predictivas de la tasa metabólica de reposo (TMR) en los adolescentes obesos en relación con la calorimetría indirecta (CI). **Métodos:** El estudio se realizó en 116 adolescentes obesos (60 niños, 13,7 $\pm$ 1,1 años). La TMR se calculó a partir de las ecuaciones predictivas de Harris y Benedict, Schofield, OMS, Henry y Rees. La TMR se midió por el sistema de QUARK-TMR. La comparación entre las ecuaciones de predicción y IC se realizó

mediante el test t de Student. La fiabilidad de los datos entre IC y ecuaciones de predicción fue verificada por el error típico de la medición (TEM) y el coeficiente de variación (CV%). **Resultados:** La ecuación de Henry fue significativamente diferente de IC ($p < 0,02$). El CV% encontrado para cada ecuación en comparación con IC fue bajo; no obstante, cuando se midió el TEM, este fue considerado alto en valores absolutos que puede provocar errores al estimar la TMR. Por lo tanto, es importante que ecuaciones de predicción específicas sean desarrolladas para adolescentes obesos brasileños.

Palabras clave: obesidad, gasto metabólico de reposo, calorimetría indirecta, ecuaciones predictivas.

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