Validity of the equation of Henry and Rees that estimates the resting metabolic rate in male adolescents

Validade da equação de Henry e Rees que estima a taxa metabólica de repouso em adolescentes masculinos

Validez de la ecuación de Henry y Rees que estima la tasa metabólica de reposo en adolescentes masculinos

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ABSTRACT

Objective: To evaluate the validity of the equation proposed by Henry and Rees (1991) to predict resting metabolic rate in adolescent boys.

Methods: This cross-sectional study enrolled 52 boys aged ten to 17 years on a random convenience sample. The variables measured were: body mass and indirect calorimetry. Body mass was replaced in the equation of Henry and Rees to determine the predicted resting metabolic rate. The indirect calorimetry was determined by the values of O_2 consumption and CO_2 productions, in order to calculate Weir's equation (1949), considered in this study as the standard method to calculate resting metabolic rate. All measurements were performed in the supine position and at rest, in the morning after a six-hour fast. Statistical analysis included paired t-test; constant error (with a tolerable difference between the means <5%) and Bland and Altman graphic analysis.

Results: The equation proposed by Henry and Rees did not show significant difference in relation to the standard method and the constant error between the means was <5%. However, Bland and Altman analysis did not show agreement between the studied equation and the standard method.

Conclusions: Henry and Rees equation should be used with caution to calculate resting metabolic rate in adolescent boys with similar characteristics of the studied group.

Key-words: energy metabolism; child health (Public Health); adolescent.

RESUMO

Objetivo: Analisar a validade da equação de predição da taxa metabólica de repouso proposta por Henry e Rees (1991) em adolescentes do sexo masculino.

Métodos: Estudo transversal, com amostra de conveniência constituída de 52 meninos, entre dez e 17 anos, sendo mensuradas a massa corporal e a calorimetria indireta. A massa corporal foi substituída na equação de Henry e Rees para determinar a taxa metabólica de repouso predita. A calorimetria indireta foi determinada pelos valores do consumo de O_2 e produção de CO_2, e usada na equação de Weir (1949), considerada método padrão para o cálculo da taxa metabólica de repouso. Todas as medidas foram realizadas pela manhã, com o indivíduo em jejum de seis horas, em posição supina e em repouso muscular. Realizaram-se os seguintes procedimentos estatísticos: teste *t* pareado; erro constante (com diferença aceita entre as médias <5%) e, para análise da concordância entre os dois métodos, o procedimento gráfico de Bland e Altman.

Resultados: A equação proposta por Henry e Rees não apresentou diferença significativa em relação ao método padrão, assim como o erro constante entre as médias foi <5%.

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Porém, a análise gráfica de Bland e Altman revelou que não há concordância entre a equação e o método padrão.

Conclusões: A equação de Henry e Rees deve ser utilizada com prudência no cálculo da taxa metabólica de respouso para adolescentes com características similares as do grupo estudado.

Palavras-chaves: metabolismo energético; saúde da criança; adolescente.

RESUMEN

Objetivo: Analizar la validez de la ecuación de predicción de la tasa metabólica de reposo (TMR) propuesta por Henry y Rees (1991) en adolescentes del sexo masculino.

Métodos: Estudio transversal, con muestra de conveniencia constituida por 52 niños, entre 10 y 17 años, siendo medidas las variables a continuación: masa corporal y calorimetría indirecta (CI). La masa corporal fue sustituida en la ecuación de Henry y Rees (1991) para determinar la TMR predicha. La CI fue determinada por los valores del consumo de O_2 y producción de CO_2 y usada en la ecuación de Weir (1949), considerada como método estándar de la TMR. Todas las medidas fueron realizadas por la mañana, con el individuo en ayuno de 6 horas, en posición supina y en reposo muscular. Se realizaron los siguientes procedimientos estadísticos: prueba "t" pareada; error constante (EC - con diferencia aceptada entre los promedios menor que 5%) y, para análisis de la concordancia entre los dos métodos, el procedimiento gráfico de Bland y Altman.

Resultados: La ecuación propuesta por Henry y Rees (1991) no presentó diferencia significativa respecto al método estándar, así como el error constante entre los promedios fue inferior a 5%. Sin embargo, el análisis gráfico de Bland y Altman revela que no hay concordancia entre la ecuación y el método estándar.

Conclusiones: La ecuación de Henry y Rees (1991) debe ser utilizada con prudencia en el cálculo de la TMR para adolescentes semejantes al grupo estudiado.

Palabras clave: metabolismo energético; salud del niño; adolescentes.

Introduction

Basal metabolic rate (BMR) is defined as the minimum energy consumption needed to sustain all cellular functions and is responsible for 60 to 70% of humans' daily energy expenditure[1]. It therefore represents the principal component of total energy consumption[2], particularly when one is determining the day the energy needs of inactive people[3].

In 1951, Quenouille *et al* proposed to the World Health Organization (WHO) the hypothesis that BMR could be useful for estimating the energy requirements of population groups and that BMR could be multiplied by factors representing different levels of physical activity[4].

In 1985, the WHO[5] proposed new equations in response to the impossibility of measuring BMR by direct calorimetry. These equations originated from a review of studies analyzed by Schofield[6], including approximately 11,000 BMR measurements taken using indirect calorimetry. However, several studies demonstrated that those equations overestimated BMR when used with different ethnic groups[7,8].

In 1991, in response to the evidence that BMR was overestimated by the WHO[5] equations and by the Schofield equations[6], particularly in tropical regions, Henry and Rees[9] derived equations for people living in the tropics. They conducted a literature review for which they only accepted studies of statistical merit, and selected 2,822 BMR measurements from both sexes, in the following age groups: 3 to 9 years, 10 to 17, 18 to 29 and 30 to 60 years.

The equations suggested by Henry and Rees[9] for adolescents living in the tropics did not gain the same attention as the equations published by Schofield[9-16] or the WHO proposals[11,12,14-18] in terms of analysis of their validity in different populations. Only one study, conducted by Schneider and Meyer[16], has attempted to verify the applicability of this equation in Brazilian adolescents. It should, however, be pointed out that even that study was restricted to adolescents with overweight and obesity.

Given the need for precise BMR estimates in adolescents, use of these equations should be reexamined[19], since a precise measure of BMR is necessary to determine the efficacy of nutrition plans[20,21]. It is in this context that the objective of this study is to analyze the validity of the equation proposed in 1991 by Henry and Rees[9] for predicting BMR in male adolescents, comparing it with calculated indirect calorimetry (IC), according to the 1949 Weir method[22].

Method

This research project and its free and informed consent form were approved by the Research Ethics Committee at the *Universidade Federal de Santa Catarina*.

The study sample was a sample of convenience selected by chance, comprising 52 boys aged 10 to 17 years, using the age group recommended by the WHO[5] and classified according to their Body Mass Indexes as underweight, healthy weight, overweight or obese[23]. Since the control variables are imposed on the study, no sample size calculation was performed because it would have been unfeasible to recruit enough participants. This sample is not therefore representative of the population, but an attempt was made to assess a larger number of people than previous studies with the same objective[11-14,16,18]. The following exclusion criteria were adopted: age outside the range of 10 to 17 years, not having fasted for a minimum of six hours, reporting not having slept well the night before the evaluation, smokers, amputees, wheelchair users or sufferers of any disease that could influence BMR, such as diabetes, asthma or anemia.

Evaluations were conducted four participants at per session at the Physical Effort Laboratory (PEL) at the *Universidade Federal de Santa Catarina*, between May and November of 2006, always in the morning.

On the assessment day, adolescents and their parents were given the free and informed consent form and the Research Ethics Committee protocol which explains that the study does not put participants' physical or psychological integrity at risk. Assessment at the PEL comprised the following steps: first a patient history was taken, covering identification data, how well they had slept the night before and morbidity. Any adolescents who were unable to answer the questions were helped by their parents and the researchers. Next, body mass (BM) was measured on a digital balance (Plenna MEA- 03140, USA) and the result was input into the Henry and Rees equation[9] for boys aged 10 to 17: BMR (MJ/d) = 0.084*(BM) + 2.122. Since the BMR results were to be analyzed in kcal per day, the result in MJ/day was converted by multiplying it by 239.

Next, the indirect calorimetry measurements were made using the resting gas analysis method (Aerosport, TEEM – 100,USA) and minute by minute readings were taken for VO_2 and VCO_2, in liters per minute, for the last 10 minutes, after 20 minutes' at rest, making a total test time of 30 minutes. Measurements were taken with the subject having fasted for six hours, in the supine position and with musculature at rest[24]. Parents' help was solicited to control the fasting period as much as possible. Adolescents who did not respect the six hour period and traveled to the laboratory where indirect colorimetry was conducted walking, running or by bicycle had their assessment canceled and another appointment made for a later date. Once mean VO_2 and VCO_2 for the last 10 minutes of the assessment had been recorded, the Weir equation[22], which is considered the standard method for estimating BMR[25] could be calculated:

$$\text{BMR (Kcal/min)} = 3.942*VO_2\text{ (L/min)} + 1.106*VCO_2\text{ (L/min)}$$

$$\text{BMR (Kcal/day)} = \text{BMR (Kcal/min)}*\ 1.440.$$

The following statistical procedures were used to analyze the validity of the Henry and Rees equation[9] in terms of the standard BMR measurement: the paired *t* test, to measure the difference between the mean results of the equations and the standard BMR result, with a significance level of $p<0.05$; the constant error (CE), which is the mean raw difference between the BMR measurement estimated by the equation and the BMR measurement assessed by the standard method and which has a criterion of acceptance of variation of difference less than 5%[19], i.e., taking as an example a mean estimated BMR of 1500 Kcal/day and multiplying it by 5%, the CE can vary within an acceptable difference of 75 Kcal/day above or below the mean. Finally, Bland and Altman's graphical proposal was (1986) adopted to analyze agreement between the two methods[26]. Statistical procedures were carried out using SPSS 10.0 for Windows.

Table 1 - Distribution of participants by age and body mass index

Body Mass Index	Boys								Total
	Age								
	10	11	12	13	14	15	16	17	
Underweight (≤ P15)	1	0	2	1	1	0	0	1	6
Healthy weight (P16-P85)	2	2	6	10	2	4	1	1	28
Overweight (>P85)	0	0	1	3	2	0	0	1	7
Obese (>P95)	0	0	3	1	4	2	1	0	11
Total	3	2	12	15	9	6	2	3	52

P: percentile.

Results

Adolescents aged 10 to 17 years were recruited. Their age distribution and nutritional status can be seen in Table 1. Table 2 lists the O_2 consumption and CO_2 production results, measured by indirect calorimetry and used in the equation proposed by Weir (1949)[22] to calculate BMR. Table 2 also provides the body mass result used in the Henry and Rees BMR prediction equation[9].

Table 3 lists the results for the criteria adopted to test the equation's validity. The *t* test shows that there was no statistical difference between results using the equation proposed by Henry and Rees[9] and the results using Weir's standard equation[25]. The mean difference between the two equations was also below the 5% minimum limit of acceptability set for the study, which corresponds to 65.6 Kcal/day.

Finally, Figure 1 illustrates the dispersal of the data in the form of a Bland-Altman plot[26]. In this analysis, for each of the 52 adolescents a mean is calculated from the BMR result according to the two equations (Henry and Rees + Weir/2) and plotted on the horizontal axis, while the difference between the two values (residual) is plotted on the vertical axis. The greater the number

Table 2 - Figures for O_2 consumption and CO_2 production by indirect calorimetry, the temperature and humidity during indirect calorimetry and the body mass of the sample

	Mean ± SD
VO_2 (L/min)	0.214±0.058
VCO_2 (L/min)	0.177±0.050
Humidity (%)	70.5±10.4
Temperature (°C)	22.2±4.0
Body mass (kg)	52.8±15.6

Table 3 - Basal metabolic rate results for adolescents boys

Equations	Mean±sd	CE Kcal/day	CE %	t (p)
Weir (1949)	1502±412	-		-
Henry and Rees (1991)	1568±214	65.6	4.3	-1.310 (0.196)

sd: standard deviation; CE: constant error; t: t test; p: significance.

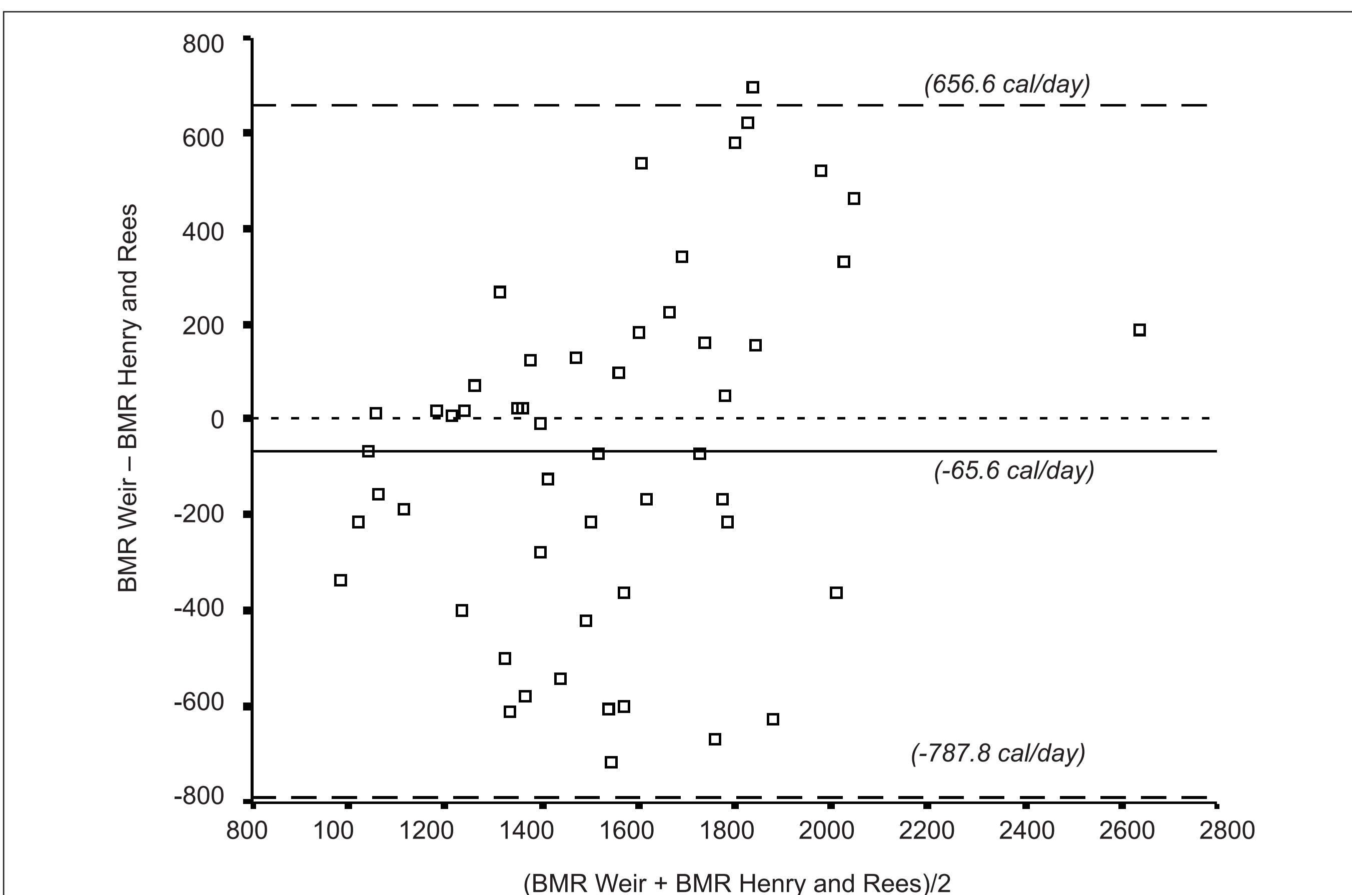

Figure 1 - Bland-Altman plot for equation proposed by Henry and Rees for boys plotted against Weir method results.

of points that fall close to the zero line, (i.e. where the residual is zero), the greater the agreement. Analysis of this graph demonstrates that the residuals exhibit a tendency to increase, which indicates that the hypothesis of homogeneous variance is disproved, since the greater the value of BMR the greater the residual difference and the greater the Henry and Rees equation's prediction error[9]. This being so, the BMR results estimated using the Henry and Rees equation[9] do not exhibit agreement with the BMR estimates calculated using the Weir standard[22].

Discussion

Analysis of the profile of the group of adolescents studied here revealed that they had a wider range of body mass (27.1kg – 101.4kg) than those on whom the original article by Henry and Rees[9] had been based (20kg – 66kg). This difference in relation to the body mass of the group analyzed and the group from which the equation was derived may explain possible errors in the Henry and Rees equation[9], since there is a strong relationship between body components and BMR results[8,18], The presence of boys who were beyond the upper body mass limit in the original study could be considered a limitation of this study, but they were kept in the sample in order to preserve external validity. This choice is justifiable because adolescents who are above or below the ideal body mass seek health professionals more often. In this case, it is this group of adolescents who would be most compromised by an erroneous BMR estimate.

It will be noted that the equation proposed by Henry and Rees[9] did not exhibit a significant difference, according to the *t* test, with relation to the Weir equation[22], since the difference, on average, was below 5%. However, analysis of the Bland-Altman plot[26] indicates that there was not strong agreement between the equation and the standard method. Good agreement would have produced a graph with the subjects in the sample distributed close to the zero line of the y-axis. In contrast, a wide variation is evident, unacceptable for clinical purposes and increasing as BMR increases. Taken together, the results show that there was no difference in the mean results of the two methods for this group, but in terms of agreement between the individual participants there was great variability.

Reviewing the national and international literature revealed that there is only one article that has attempted to analyze the validity of the Henry and Rees equation[9] for male adolescents. A study undertaken by Schneider and Meyer[16] tested the applicability of this equation with a group of male adolescents from the city of Porto Alegre who were overweight or obese. The office found that the Henry and Rees equation[9] overestimated by 9.5% in relation to indirect calorimetry. Their result is well above what was found in this study, where the observed difference was 4.3% of BMR, which was within acceptable limits. One explanation for these discrepancies between the equations could be the presence of overweight and obese individuals. The Henry and Rees equation[9] was derived from a population of boys who weighed a maximum of 66kg and the equation is therefore unable to correctly estimate BMR in adolescents who have body mass, especially fat mass, above this level.

Assessment by gaseous exchange indirect calorimetry is extremely sensitive and the results are subject to modification by interfering variables. Attempts were made in this study to control these variables to the maximum, however, it is known that race affects BMR and, within the practical constraints to which this research was subject, it was not possible to classify the participants by race. The seasonal influence on BMR is also a limitation of the study, since assessments were conducted from May to November, including the Brazilian winter and spring. Attempts were made to standardize as much as possible temperature and humidity in the room that was used for indirect calorimetry, in order to minimize the seasonal effects of BMR.

Therefore, taking into consideration the limitations of this study and in contradiction of the original study hypothesis, it is concluded that the utilization of BMR results estimated with the Henry and Rees[9] equation to determine physical activity levels and for nutritional interventions designed to maintain, increase or reduce body weight is compromised, since the equation did not demonstrate its validity. It is therefore recommended that the Henry and Rees[9] equation should be treated with caution when calculating BMR for male adolescents with similar characteristics to the group analyzed here.

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