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original article

Comparison of predictive equations for energy expenditure in pregnant women at rest and during exercise

Comparação entre equações preditivas do gasto calórico de gestantes em repouso e exercício

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Abstract – The regular changes that occur during pregnancy increase energy expenditure at rest and during exercise. Prediction models are practical tools that facilitate the estimation of energy expenditure. The objective of this study was to analyze the reliability of prediction models of energy expenditure for pregnant women in two situations, at rest and during light-intensity exercise, compared to indirect calorimetry. Energy expenditure was measured in 10 pregnant women during the second trimester of gestation (23.5 ± 3.7 weeks) at rest and during light-intensity treadmill walking (4 km/h) using indirect calorimetry and the prediction models proposed by Hronek (rest) and Pivarnik (exercise). The intraclass correlation coefficient (ICC) and Bland-Altman plots were used for comparison of the methods. A low correlation was observed at rest and during exercise [ICC=0.531 (-0.185; 0.814) and ICC=0.124 (-1.213; 0.653), respectively]. At rest, daily energy expenditure tended to be overestimated with increasing indirect calorimetry values. During exercise, the equation tended to underestimate the energy expenditure of pregnant women as it increased. In conclusion, the prediction models analyzed showed a low correlation with indirect calorimetry, overestimating daily energy expenditure at rest and underestimating energy expenditure during light-intensity exercise. Thus, practical and low-cost tools such as predictive equations cannot always be used safely in professional practice and care should be taken to apply them to groups with altered physiological conditions, such as pregnant women.

Key words: Energy metabolism; Exercise; Pregnant women.

Resumo – *As alterações naturais características da gestação resultam no aumento do gasto energético das mulheres, tanto durante o repouso quanto durante o exercício. As equações de predição surgem como ferramentas práticas para facilitar a estimativa desse dispêndio de energia, importante ao equilíbrio energético adequado e saudável deste período. O estudo teve como objetivo analisar a confiabilidade de equações de predição do gasto calórico desenvolvidas para gestantes no repouso e na atividade física de intensidade leve quando comparadas à calorimetria indireta. Obteve-se o gasto calórico de 10 mulheres no segundo trimestre gestacional (23.5±3.7 semanas), durante o repouso e na caminhada (4 km/h) por calorimetria indireta, comparando-o com o valor obtido nas equações de Hronek para o repouso, e de Pivarnik para a caminhada. Para a comparação, foi realizado o coeficiente de correlação intraclasse (CCI) e a análise gráfica de Bland & Altman. Observou-se baixa correlação tanto para o repouso (CCI=0.531[-0.185; 0.814]) quanto para o exercício (CCI=0.124[-1.213; 0.653]). No repouso, houve tendência de superestimar o dispêndio energético diário conforme aumentaram os valores obtidos pela calorimetria indireta. No exercício, a tendência da equação foi de subestimar o gasto calórico da gestante conforme ele aumentava. Concluiu-se que as equações de predição analisadas apresentaram baixa correlação com a calorimetria indireta, superestimando o dispêndio energético diário no repouso e subestimando o custo calórico na caminhada. Assim, nem sempre ferramentas práticas e baratas como as equações preditivas podem ser utilizadas na prática profissional com segurança. Deve-se ter cuidado ao empregá-las, especialmente, para grupos com condições fisiológicas alteradas, como as gestantes.*

Palavras-chave: *Exercício; Gestantes; Metabolismo energético.*

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INTRODUCTION

Important physiological changes that occur during pregnancy, such as weight gain caused by the enlargement of body tissues, fat deposition, fetal growth, placenta and amniotic fluid, result in higher energy expenditure[1]. According to Butte et al.[1], the traditional approach to the determination of nutritional requirements only considers the increase in the basal metabolic rate (BMR) of pregnant women, but may underestimate the true energy requirements since it does not consider energy expenditure during physical activity and the thermic effect of feeding. Thus, efforts have been made to determine not only the increase in the BMR during pregnancy, but also that resulting from physical exercise in order to potentiate its health benefits for the woman and child[1-5].

Since the leisure physical activity most commonly performed by women during pregnancy is walking[6], studies have investigated the energy expenditure of women during this type of exercise. Using indirect calorimetry, DiNallo et al.[7] found no difference in energy expenditure of healthy pregnant women at 20 and 32 weeks gestation. Self-reported physical activity is commonly used in these studies to estimate energy expenditure, which is calculated indirectly using the multiple of MET by consulting the Compendium of Physical Activity[8]. However, Forsum et al.[2] observed that the total energy expenditure of 15 healthy pregnant women at 32 weeks gestation predicted with the standard MET system was underestimated – multiplying BMR by the MET value and by the duration of the activity – when compared to the values obtained with the gold standard (doubly labeled water method).

The intensity and energy expenditure at rest and during exercise have also been estimated using physiological indicators, such as heart rate and the rate of perceived exertion to quantify training and the level of physical activity in adults[9]. Predictive equations for energy expenditure appear as a practical and easy tool for the determination of basal energy expenditure and energy expenditure during exercise. Exercise and regular physical activity have been encouraged in pregnant women and it is therefore important to determine their energy expenditure in a practical and applicable manner. Within this context, Hronek et al.[10] developed an equation for the calculation of resting energy expenditure in pregnant women, and Pivarnik et al.[11] proposed equations for the indirect calculation of energy expenditure during walking according to trimester of gestation.

The objective of the present study was to analyze the application of these equations proposed in the literature to women in the second trimester of gestation at rest and during light physical activity.

METHODOLOGICAL PROCEDURES

In a cross-sectional study, data were collected from 10 women with a gestational age of 23.5 ± 3.7 weeks, calculated as the difference between the date of last menstrual period and the date of data collection. For characterization of the sample, body weight (kg) and height (cm) were measured according to ISAK standards (2001). These measures were used for the calculation of the body mass index (BMI, (kg/m^2) using the curve of Atalah et al.[12]. Additionally, fat percentage of the women was determined with a bioimpedance scale (Tanita, model 2001 W-B).

The participants were evaluated regarding their health condition and exclusion criteria were the presence of diseases restricting physical activity and the use of medication. Energy expenditure is influenced by mechanical efficiency and the level of physical fitness. A questionnaire (IPAQ)[13] was applied to minimize this interference and the sample was confirmed to consist of insufficiently active women.

To analyze the applicability of the equations, indirect calorimetry was performed to permit comparison between true and predicted energy expenditure. For indirect calorimetry, expired gases were collected with a K4 b^2 apparatus (COSMED), which converts the data obtained into kilocalories. The heart rate was measured with a Polar heart rate monitor (T-31 Transmitter, simple).

Data collection was performed on two different days of the same week, with a duration of approximately one hour per day, at a similar time of the day to avoid variations due to circadian rhythm[14]. The women were instructed to eat at least 2 hours before the time of data collection and not to consume coffee, tea or alcohol, not to smoke, not to use medications and not to perform any type of light, moderate or intense exercise during the 24 hours prior to data collection.

The women rested for 20 minutes in two positions: 1) sitting and 2) lying down (lateral decubitus). After rest, data were collected over 20 minutes of light exercise (3 METs) according to the Compendium of Physical Activity[4], i.e., walking on a treadmill at 4 km/h or cycling at 50 watts on a electromagnetic bicycle (Monark). Data collection was performed on 2 days in such a way that on the first day one resting position and one type of exercise were performed, and on the second day the other resting position and the second type of exercise.

The equation proposed by Hronek et al.[10] was used to predict resting energy expenditure (REE), which clinically corresponds to the BMR[10].

1) Equation of Hronek et al.[10]:

REE (kcal/day) = 346.43943 + 13.962564 x W + 2.700416 x H – 6.826376 x A, where W = weight (kg), H = height (cm), and A = age (years).

The regression equation proposed by Pivarnik et al.[11], who studied the relationship between heart rate and oxygen consumption in pregnant women, was used for the prediction of energy expenditure during walking. This equation refers to pregnant women at 20 weeks gestation

2) Equation of Pivarnik et al.[11]:

VO_2 (ml.kg^{-1}.min^{-1}) = (HR x 0.27) – 17.5, where HR = heart rate (bpm).

The same procedure as adopted in the study of Stein et al.[4] was used to convert the value of the unit of the Pivarnik et al.[11] equation from $ml.kg^{-1}.min^{-1}$ to $kcal.day^{-1}$, multiplying the result of the equation by 4.86 kcal/l O_2 and correcting for weight and time.

Means and standard deviations were calculated for descriptive statistics. The applicability of the equations was evaluated using the intraclass correlation coefficient (ICC) and Bland-Altman plots[15].

The study was approved by the Ethics Committee of Escola de Educação Física e Esporte, Universidade de São Paulo (Protocol No. 2009/29).

RESULTS

The participants did not differ significantly in terms of age (31 ± 6.2 years) or body weight (59.6 ± 8.3 kg). All women were eutrophic (25.2 ± 3.8 kg/m^2) and had a fat percentage of 33.3 ± 6.4%.

Table 1 shows the ICC between energy expenditure at rest and during exercise measured by indirect calorimetry and predicted with the equations. A low correlation was observed for both the resting and exercise situation.

Table 1. Intraclass correlation coefficient between energy expenditure at rest and during exercise obtained by indirect calorimetry and with the predictive equations.

Measurement situation	ICC	95% CI	
		Lower	Upper
Rest	0.531	-0.185	0.0814
Exercise	0.124	-1.213	0.653

ICC = intraclass correlation coefficient; CI = confidence interval.

Figures 1 and 2 show the Bland-Altman plots of the mean difference in energy expenditure measured by indirect calorimetry (K4 b^2 equipment) and compared with the predictive equations at rest proposed by Hronek et at.[10] (Figure 1) and during exercise proposed by Pivarnik et at.[11] (Figure 2).

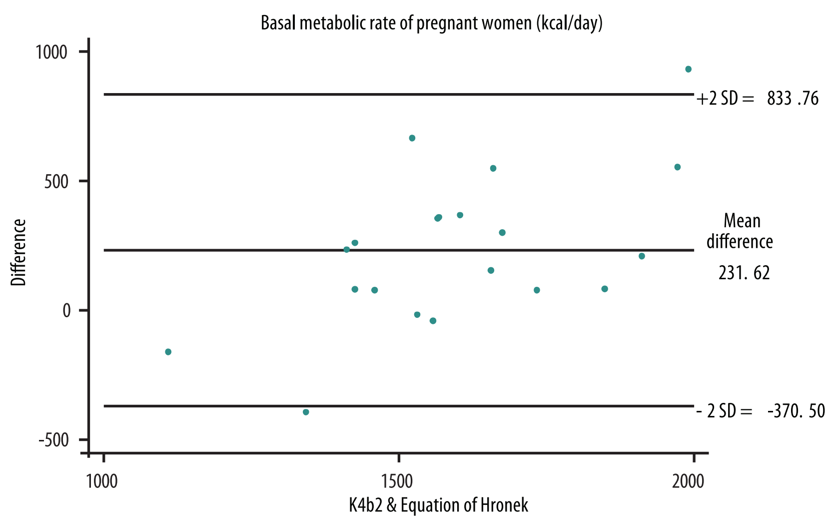

Figure 1. Comparison of the basal metabolic rate between indirect calorimetry (K4 b2) and the equation of Hronek et al.10.

The dispersion diagram showed that the mean difference in the BMR of pregnant women between the predictive equation and indirect calorimetry was different from zero (231 kcal/day). The limit was higher than 800 kcal/day and the distribution of individual differences within a confidence interval of two standard deviations showed dispersion, tending to increase with increasing values.

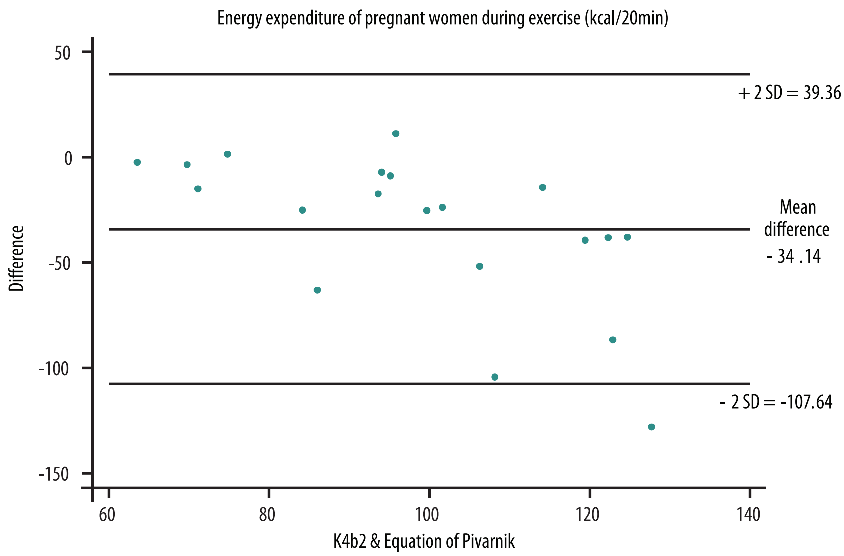

Figure 2. Comparison of energy expenditure during exercise between indirect calorimetry (K4 b2) and the equation of Pivarnik et al.11.

Similarly, analysis of the diagram regarding the predictive equation for energy expenditure during 20 minutes of exercise showed that the mean difference between the equation and indirect calorimetry was different from zero, with a difference of -34.1 kcal. Furthermore, the distribution of individual differences within a confidence interval of two standard deviations tended to decrease with increasing values in the equation of Pivarnik et al.[11]

DISCUSSION

The BMR of women increases continuously during pregnancy[2], a fact reflecting both the need for higher energy consumption to meet metabolic needs and increased total energy expenditure. Furthermore, it is estimated that a body weight gain of approximately 12 kg until birth is safe for the woman and necessary for adequate development of the fetus[16]. Therefore, to ensure an adequate energy balance combined with a healthy lifestyle, including regular exercises, accurate determination of the energy expenditure of pregnant women at rest and during exercise is important. Furthermore, higher total energy expenditure during pregnancy is associated with a lower risk of pre-eclampsia[17].

Within this context, mathematical models appear as an inexpensive and practical tool in everyday professional application to establish energy expenditure during pregnancy. However, the predictive equations for energy expenditure used here had low accuracy in the pregnant women participating in the study. The results obtained suggested a weak correlation between energy expenditure measured by indirect calorimetry and that predicted with the equations of Hronek et al.[10] for BMR and of Pivarnik et al.[11] for exercise.

For the development of the predictive equation for resting energy expenditure, Hronek et al.[10] followed up 31 women throughout pregnancy and validated the equation in 121 pregnant women. The authors evaluated the women at four different times during pregnancy: up to 20 weeks gestation; between 21 and 29 weeks; between 30 and 36 weeks, and between 37 and 39 weeks. The second time point evaluated by Hronek et al.[10], between 21 and 29 weeks of gestation, corresponds to the period studied here and the women therefore had a similar gestational age. The studies were also similar in terms of nutritional status. Although Hronek et al.[10] used women in the three trimesters of gestation for the development and validation of the equation, no indicator variable such as gestational week was included since its addition did not significantly increase the prediction accuracy. The pattern found in present study for pregnant women in the second trimester resulted in an overestimated BMR of the woman with increasing energy expenditure. In contrast, in a study involving obese women, Wilms et al.[18] observed that eight of 11 predictive equations systematically underestimated BMR. Although the authors indicated that fat mass was not associated with BMR, the three equations that did not show a significant difference were developed specifically for the nutritional status studied. The authors raised concern regarding the use of predictive equations with low accuracy, especially for clinical application to the population studied whose recommendations of energy expenditure and consumption are based on predictions of BMR. Hronek et al.[19] found no variation in BMR according to fat-free mass, a fact permitting the comparison of pregnant and non-pregnant women. On the other hand, variables such as height, weight, fat mass, body water, skinfolds and circumferences or pregnancy parameters such as gestational age did not increase the accuracy of predicting BMR during pregnancy.

In professional practice, the use of equations to predict energy expenditure may affect the determination of BMR, especially in the third trimester when the increase in basal energy expenditure should be one-fourth of the pregestational value[16]. Furthermore, this overestimated pattern of BMR may lead to the recommendation of greater calorie intake, shifting the energy balance toward excessive weight gain, a current public health problem[20,21].

With respect to the predictive equation for energy expenditure during exercise, Pivarnik et al.[11] investigated heart rate/oxygen consumption (VO_2) calibration curves and their effect on energy expenditure during exercise. The study involved 52 pregnant women, including 27 women who had been physically active in the last 6 months. According to the authors, most women had returned to their exercise programs after 20 weeks gestation, a factor that was considered for choosing the starting point of the analyses. The data were collected by calorimetry at two time points during pregnancy (20 and 32 weeks) and at 12 weeks postpartum. After 30 minutes of rest, the women walked for 15 minutes on a treadmill, first at 3.2 km/h and then increasing to two higher intensities and varying the slope (5 minutes at each velocity). The level of comfort of the woman was used as a parameter for adjustment. In contrast to the present study that did not involve physically active women, Pivarnik et al.[11] combined active and sedentary pregnant women to determine the influence of pregnancy on energy expenditure during exercise because they had not found a significant difference between these two groups. However, in the present study the equation proposed for women at 20 weeks gestation exhibited a descending pattern in the diagram (Figure 2) when the participants walked on the treadmill at the same pre-defined intensity sustained for 20 minutes. Thus, for the women participating in this study, the equation proposed by Pivarnik et al.[11] underestimated their true energy expenditure, which actually increased during walking as demonstrated by indirect calorimetry. This underestimation may be explained by the lack of standardization in the analysis of exercise intensity and the inconsistency in the classification of the women as active, knowing that they had interrupted their exercise routine. If this mathematical model were employed in professional practice, this underestimation of calorie loss may lead to an energy imbalance in the pregnant woman, affecting the necessary accumulation of energy and appropriate weight gain during pregnancy.

Some limitations of the present study should be addressed. One limitation is the small number of participants and the restriction of the sample to insufficiently active women. However, observing the diagrams (Figures 1 and 2), a larger sample size should improve variability of the measurement, but important errors of individual determination would remain. Another limitation is the cross-sectional design of the study, recruiting exclusively women in the second trimester of gestation in the absence of any other type of follow-up during pregnancy. In a recent literature review, Sallys et al.[22] questioned cross-sectional studies and indicated that some longitudinal studies initiated during the pregestational period found no significant differences until the second trimester of gestation. The authors discussed the importance of adequate evaluation since, like in the sample studied here, women interrupt their exercise program during the first trimester and are therefore classified as insufficiently active. Although we believe that the equations would continue to show a low correlation with indirect calorimetry even for physically active and sedentary pregnant women, further studies are needed to confirm this assumption.

CONCLUSION

In this study, the predictive equations for BMR and energy expenditure during light walking in pregnant women in the second trimester of gestation showed a low correlation with indirect calorimetry. Furthermore, the equation used to predict energy expenditure during exercise underestimated the energy requirements of pregnant women during physical activity. It is therefore important to exercise caution when some existing tools are used to determine energy expenditure and intensity during physical activities. Although these tools are easily accessible and of low cost, the results obtained are not always consistent with reality. Additionally, increased attention should be paid to groups with peculiar characteristics, such as pregnant women since the control of energy expenditure and adequate exercise are important for the health of the woman and child.

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