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Comparison between resting metabolic rate and indirect calorimetry in postmenopausal women

Comparação de equações preditivas de taxa metabólica de repouso com calorimetria indireta em mulheres pós-menopáusicas

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A B S T R A C T

Objective

To compare resting metabolic rate values determined by indirect calorimetry with values estimated using different predictive equations in lean and overweight postmenopausal women.

Methods

Twenty-four women, who had stopped menstruating for at least two years, were subjected to anthropometric measurements and indirect calorimetry after 12-hour overnight fasting to determine, mathematically and experimentally, resting metabolic rate values.

Results

There was no difference in the indirect calorimetry values between the groups evaluated. Difference values of resting metabolic rate were obtained with all equations used. For the lean women, there was no difference between the values obtained by indirect calorimetry and those estimated using the equations proposed by Food and Agricultural Organization, Fredix, Lazzer, and Schofield. However, in the overweight group, the resting metabolic rate values estimated using the Institute of Medicine, Berstein and Owen equations were different from those obtained by indirect calorimetry.

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Conclusion

This study suggests that differences in body composition in postmenopausal women influence the accuracy of predictive equations, demonstrating the need for more accurate estimation methods for resting metabolic rate in postmenopausal women with different body compositions.

Keywords: Basal metabolism. Calorimetry indirect. Menopause.

RESUMO

Objetivo

Comparar os valores de taxa metabólica de repouso determinados por calorimetria indireta com os valores obtidos utilizando diferentes equações preditivas em mulheres pós-menopausicas eutróficas e com sobrepeso.

Métodos

Vinte e quatro mulheres com pelo menos dois anos de menopausa foram submetidas à avaliações antropométricas e à calorimetria indireta após 12 horas de jejum para determinar, matematicamente e experimentalmente, a taxa metabólica de repouso.

Resultados

Os valores para calorimetria indireta não diferiram entre os grupos e a taxa metabólica de repouso predita por equações foi diferente para todas as equações usadas. Para o grupo de eutróficas, as equações que não foram estatisticamente diferentes da calorimetria indireta foram Food and Agricultural Organization, *Fredix, Lazzer e Schofield. No entanto, apenas as equações Berstein e Owen foram significativamente diferentes comparadas com calorimetria indireta para o grupo sobrepeso.*

Conclusão

O presente estudo sugere que diferenças na composição corporal em mulheres na pós-menopausa modificam a precisão de equações que predizem a taxa metabólica de repouso, demonstrando a necessidade de aprimorar métodos de estimação de taxa metabólica de repouso em mulheres pós-menopáusicas com diferentes composições corporais.

Palavras-chave: *Metabolismo basal. Calorimetria indireta. Menopausa.*

INTRODUCTION

Menopause progression leads to several changes in the hormonal profile, which exert impact on parameters related to Resting Metabolic Rate (RMR) and body composition, such as increased adipose tissue, increased central adiposity, and decreased lean mass, consequently increasing the risk of developing metabolic and cardiovascular diseases [1,2]. Thus, interventions based on the individual estimates of the energy requirements in terms of diet and exercise to determine an adequate energy balance should be recommended for health promotion in postmenopausal women [3].

Resting metabolic rate can be obtained by indirect calorimetry or predicted by different equations. Indirect calorimetry is a method by which metabolic rate is measured based on the oxygen consumption (O_2) and the production of carbon dioxide (CO_2), considering that the total O_2 consumed is related to the oxidation of macronutrients and the total CO_2 produced is detected during the test, allowing individual RMR measurement [4]. Although it is a reliable measurement method, indirect calorimetry is expensive, time consuming, and requires trained personnel to perform it [4].

For these reasons and due to their feasibility and low cost, predictive equations are widely used in clinical practice [5]. However, there is only one equation based on postmenopausal women characteristics [6]; most equations are based on studies that describe lean individuals and a broad age group [7]. Noteworthy, most of the existing equations are outdated and may not be compatible with the general population, considering that there has been an exponential increase in sedentary lifestyle and obesity, resulting in differences in body composition, which leads to changes in energetic demand [8].

Predictive equations generally consider patients' anthropometric variables such as weight, height, and age. Several studies report that when used for individuals with different levels of obesity, these equations usually overestimate RMR [9,10]. Recent literature investigating the applicability and reliability of the most commonly used equations, such as Harris-Benedict, Schofield, Food and Agriculture Organization of the United Nations (FAO), and Mifflin-St. Jeor, present conflicting results in different populations [11-14]. Studies evaluating elderly individuals often report an overestimation of RMR [11].

Therefore, this research is justified by the lack of studies involving postmenopausal women, the inclusion of less commonly used equations, and the conflicting available data on the efficacy and effectiveness of predictive equations when compared to more precise methods, such as indirect calorimetry, due to their importance since they are practical and inexpensive methods for clinical application.

Thus, the objective of the present study was to compare RMR values determined by indirect calorimetry to those obtained using different predictive equations in lean and obese postmenopausal women.

METHODS

Twenty-four postmenopausal women, who volunteered after seeing advertisements in local newspapers, participated in the study. Sample size calculations were performed using StatsDirect version 2.7.2 (Altrincham, United Kingdom) considering a possible sample loss of 20%. All participants signed a Free and Informed Consent Form. The volunteers had been diagnosed with menopause for at least two years. They had stable body weight, were sedentary (without previous exercise experience), non-smokers, did not have cardiovascular or metabolic diseases, insulin resistance, or type 2 diabetes, and were not undergoing hormonal replacement therapy. The participants were instructed to abstain from strenuous physical activity for 24 h before the tests. This study was approved by the Research Ethics Committee of the *Universidade Federal do Rio Grande do Sul*, according to Protocol nº 75681, and it was conducted in accordance with the provisions of the Declaration of Helsinki.

The participants attended the laboratory on two different occasions. The first visit consisted of instructions regarding the experimental procedures, signing the consent form, and performance of anthropometric measurements. The second visit included the determination of RMR. Participants were instructed to avoid physical activities and consumption of alcohol, caffeine, and any type of medication that could influence resting metabolism during the 24 hours preceding the test. In addition, they were instructed to sleep for at least eight hours on the night prior to the experiment and to fast for 12 hours before testing; they were allowed to drink water *ad libitum*. Finally, participants were told they should preferably travel to the laboratory via motorized transport to minimize energy expenditure before the evaluation.

Skinfold thickness was measured using a caliper (Cescorf, *Porto Alegre*, RS, Brazil). Bone diameter was determined using a plicometer (Cescorf, *Porto Alegre*, RS, Brazil). The waist circumference was measured using a metal anthropometric tape (Sanny, *São Bernardo do Campo, São Paulo*, Brazil). Weight and height were measured using a scale with attached stadiometer (model OS-180, *Urano, Canoas*, RS, Brazil). The marking of the anatomical landmarks and the skinfold measurements were performed according to the recommendations of the International Society for the Advancement of Kineanthropometry (ISAK) [15]. Body composition, fat mass, muscle mass, residual mass, bone mass, and skin mass were obtained based on the following variables: (1) body mass; (2) height; (3) skinfolds (triceps, subscapular, biceps, iliac crest, supraspinatus, abdominal, medial thigh, and calf); (4) perimeters (head, arm, thorax, waist, upper thigh, medial thigh, calf, hip, forearm, and ankle); and (5) specific osteometric measurements [14-16]. All measurements were performed by three different ISAK level anthropometrists with an estimated technical error of less than or equal to 1%. Body Mass Index (BMI) was calculated as body weight/height², and the participants were classified as lean and overweight individuals according to the recommendations of the Institute of Medicine [17].

All indirect calorimetry tests were performed between 07:30 am and 09:30 am in a room with controlled temperature (25°C), light, and sound.

The protocol consisted of a 20-min rest in supine position, followed by a 40-min of respiratory gas analysis using a breath-by-breath gas exchange analysis with a breathing mask connected to the pre-calibrated computerized gas analyzer (MedGraphics Cardiorespiratory Diagnostic Systems, Saint Paul, Minnesota, United States, CPX-D model) to measure the oxygen uptake (VO_2) and carbon dioxide output (VCO_2).

The period before reaching a plateau in oxygen consumption was discarded, and the RMR was calculated using the mean values of VO_2 and VCO_2 (L/minutes) for each participant. Two experienced researchers determined the plateau. Values of kcal/day were obtained using the equation proposed by Weir [18]: $[(3.9 \times VO_2) + (1.1 \times VCO_2)]$ to obtain oxygen consumption per minute; the results were then multiplied by 1440 to obtain total oxygen consumption in 24 hours.

The resting metabolic rate values obtained by indirect calorimetry were compared with the values obtained using the following equations: Harris and Benedict in 1984 [3], Arciero *et al.* [6], De Lorenzo *et al.* [12], Luhrmann & Neuhaeuser Berthold [13], Institute of Medicine (IOM) [17], Berstein *et al.* [19], FAO [20], Fredix *et al.* [21], Harris & Benedict 1919 [22], Henry & Rees [23], Huang *et al.* [24], Johnstone *et al.* [25], Korth *et al.* [26], Lazzer *et al.* [27], Livingston [28], Mifflin *et al.* [29], Muller *et al.* [30], Owen *et al.* [31], and the two equations proposed by Schofield *et al.* [32]. The equations are shown in detail in Table 1.

The data normal distribution was verified by the Shapiro-Wilk test, and the homoscedasticity of the variances was evaluated by the Levene test. The predictive equations were compared with indirect calorimetry using the Bland-Altman method [33]. The Student's *t*-test for paired sample was used to compare each equation with indirect calorimetry; the Student's *t*-test for independent samples was used to compare the same equation between the groups. Correlations between RMR determined by indirect calorimetry and predictive equations were calculated using the Pearson's correlation coefficient; $p<0.05$ was considered as the level of statistical significance. Data analyses were carried out using the Statistical Package for Social Sciences (SPSS Inc, Chicago, Illinois, United States), version 18.0 for Windows, and the results were presented as mean ± standard deviation.

RESULTS

The participants' characteristics are shown in Table 2. All anthropometric measurements, except for bone mass, showed a statistically significant difference between the groups.

Tables 3 and 4 present the RMR values obtained by indirect calorimetry and by the

Table 1. Predictive Equations used in the present study.

Authors	Population	Equation
Arciero *et al.* [6]	N=75 F	7.8 x BM + 4.7 x HM -39.5 x MS + 143.5
Berstein *et al.* [19]	N=202 (154 F)	7.48 x BM - 0.42 x HCM – 3 x AGE + 844
Berstein *et al.* [19] (+FFM)	N=202 (154 F)	19.02 x FFM + 3.72 x AM – 1.55 x AGE + 236.7
De Lorenzo *et al.* [12]	N=320 (193 F)	46.322 x BM + 15.744 x HCM – 16.66 x AGE + 944
FAO (AGE >60 years) [20]	N=11.000	8.7 x BM – 25 x HM + 865
FAO (AGE >60 years) [20]	N=11.000	9.2 x BM + 637 x HM – 302
Fredix *et al.* [21]	N=40 (22 F)	1641 + 10.7 x BM – 9.0 x AGE - 203 x 2
Harris & Bennedict (1919) [22]	N=333 (103 F)	BM x 9.5634 + HCM x 1.8496 - AGE x 4.6756 + 655.0955
Harris & Bennedict (1984) [3]	N=337 (169 F)	9.247 x BM + 3.098 x HCM – 4.33 x AGE + 477.593
Henry & Rees [23]	N=10.552 (4702 F)	0.0342 x BM + 2.1 x HM + 0.0486 (30 to 60 years) 0.0356 x BM + 1.76 x HM + 0.0448 (60 + years)
Huang *et al.* [24]	N=1.088 (759 F)	10.158 x BM + 3.933 x HCM – 1.44 x AGE + 273.821 x SEX + 60.655
Huang *et al.* [24] (+FFM)	N=1.088 (759 F)	14.118 x FFM + 9.367 x AM – 1.515 x AGE + 220.863 x SEX + 521.995
Institute of Medicine [17]	N=405 (240 F)	247-2.67 x AGE + 401.5 x BM + 8.6 x AM
Johnstone *et al.* [25] (+FFM)	N=150 (107 F)	14.118 x FFM + 9.367 x AM – 1.515 x AGE + 220.863 x SEX + 521.995
Korth *et al.* [26]	N=104 (54 F)	90.2 x FFM + 31.6 x AM - 12.2 x AGE + 1613
Korth *et al.* [26] (+FFM)	N=104 (54 F)	41.5 x BM + 35.0 x HCM + 1107.4 x SEX – 19.1 x AGE - 1731.2
Lazzer *et al.* [27]	N=346 (182 F)	108.1 x FFM + 1231
Lazzer *et al.* [27] (+FFM)	N=346 (182 F)	0.042 x BM + 3.619 x HM – 2.678C
Livingston *et al.* [28]	N=655 (356 F)	0.067 x FFM + 0.046 x AM + 1.568
Luhrmann & Neuhaeuser Berthold [13]	N=355 (225 F)	248 x $BM^{0.43356}$ – AGE (5.09)
Mifflin *et al.* [29]	N=498 (248 F)	9.99 x BM + 6.25 x HCM – 4.92 x AGE + 166 x SEX – 161
Mifflin *et al.* [29] (+FMM)	N=498 (248 F)	19.7 x FFM + 413
Muller *et al.* [30]	N=2 528 (1501 F)	0.047 x BM – 0.01452 x AGE + 1.009 x SEX + 3.21
Muller *et al.* [30] (+FFM)	N=2 528 (1501 F)	0.05192 x FFM + 0.04036 x AM + 0.869 x SEX – 0.01181 x AGE + 2.992
Muller *et al.* [30] (+BMI>30)	N=2 528 (1501 F)	0.05 x BM – 0.01586 x AGE + 1.103 x SEX + 2.924
Muller *et al.* [30] (+BMI>30 +FFM)	N=2 528 (1501 F)	0.05685 x FFM + 0.04022 x AM + 0.808 x SEX - 0.01402 x AGE + 2.818
Muller *et al.* [30] (+BMI=25–30)	N=2 528 (1501 F)	0.04507 x BM – 0.01553 x AGE + 1.006 x SEX + 3.407
Muller *et al.* [30] (+BMI=25-30 +FFM)	N=2 528 (1501 F)	0.03776 x BM + 0.03013 x AM + 0.93 x SEX – 0.01196 x AGE + 3.928
Owen *et al.* [31]	N=104 (44 F)	BM x 7.18 + 795
Owen *et al.* [31] (+FFM)	N=104 (44 F)	19.7 x FFM + 334
Schofield *et al.* [32] (AG=30-60)	N=7 173 (2364 F)	0.034 x BM + 3.538
Schofield *et al.* [32] (AG>60)	N=7 173 (2364 F)	0.038 x BM + 2.755
Schofield *et al.* [32] (+BM +HM +AG=30-60)	N=7 173 (2364 F)	0.034 x BM + 0.006 x HM + 3.53
Schofield *et al.* [32] (+BM +HM +ID > 60)	N=7 173 (2364 F)	0.033 x BM + 1.917 x HM + 0.074

Note: AGE: Age in years; AM: Adipose Mass (kg); FFM: Fat-Free Mass (kg); HM: Height (meters); HCM: Height (centimeters); SEX: 0 for females; BM: Body Mass (kg); BMI: Body Mass Index; F: Number of females; MS: Menopause Status.

predictive equations for the lean and overweight groups, respectively. There was no difference in the values obtained by indirect calorimetry between the groups. Nevertheless, there was

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Table 2. Participants' characteristics (N=24).

Characteristics	Lean Group (n=12)		Overweight Group (n=12)	
	Mean	SD	Mean	SD
Age (years)	58.40	6.8	57.68	5.2
Body Mass (kg)*	56.76	4.2	76.53	6.2
Height (cm)	158.13	4.6	159.26	4.3
BMI (kg/m²)*	22.71	1.6	30.23	2.9
Fat-Free Mass (kg)*	35.57	3.8	46.12	4.7
Adipose Mass (kg)*	21.19	2.7	30.41	5.5
Muscle Mass (kg)*	20.17	2.8	27.48	3.0
Residual Mass (kg)*	5.97	1.3	8.20	1.5
Skin Mass (kg)*	2.97	0.2	3.44	0.2
Bone Mass (kg)	6.46	0.7	7.00	1.1
Waist circumference (cm)*	75.05	4.3	87.70	8.9
Sum of Skinfolds (mm)*	129.68	23.2	181.19	48.6

Note: *Significantly different between groups.
SD: Standard Deviation; BMI: Body Mass Index.

difference in the RMR calculated values between the groups for all equations used. In the lean group, the following equations did not show a significant statistical difference when compared to indirect calorimetry: FAO, Fredix, Lazzer, and Schofield. However, only the Berstein, Berstein + Fat-Free Mass (FFM) and Owen + FFM equations were significantly different when compared to indirect calorimetry for the overweight group.

Therefore, the Bland-Altman method was used to compare each predictive equation with indirect calorimetry in both groups (Tables 3 and 4), allowing the identification of the five most adequate equations. The Fredix equation was the most accurate for the lean participants, with a difference of 1.7%. The Lazzer equation showed a difference of 3.2%. The FAO and the Schofield equations (1 and 2) showed a difference within the range from 5 to 8 percent (5.8%, 7.7% and 7.1%, respectively). The Huang, Henry, and IOM equations were the most accurate for the overweight individuals, when compared to indirect calorimetry with differences of 0.2%, -0.5%, and -0.5%, respectively. The Arciero and IOM equations showed a difference of 1%.

DISCUSSION

In the present study, RMR values were determined by indirect calorimetry in lean and overweight postmenopausal women, and the results were compared with the values obtained using different predictive equations. The main finding is that the differences in body composition in postmenopausal women affect the accuracy of equations that predict the resting metabolic rate, such as reported in other studies with different populations [14,24]. Although indirect calorimetry did not differ between the groups, surprisingly, the calculated RMR showed difference between lean and overweight women for all equations.

The equations commonly used in clinical practice for nutritional assessment of postmenopausal women are usually extrapolated since these equations were developed based on the evaluation of young individuals. Menopause causes changes in body composition that may cause overweight, and the literature on the efficacy of predictive equations corroborates this finding for this population. It is worth mentioning that in the present study, different equations

Table 3. Comparison between Indirect Calorimetry (IC) and predictive equations (kcal/day) in lean women.

IC or Predictive Equation values (kcal/day)	Lean Group (n=12)		
	Mean	SD	%
Indirect calorimety	1343.31	138.7	–
Arciero *et al*. [6]*	1210.90	47.1	9.9
Berstein *et al*. [19]*	1026.94	36.5	26.2
Berstein *et al*. [19] (+FFM)*	901.47	71.7	39
De Lorenzo *et al*. [12]*	1215.43	62.2	9.6
FAO [20]	1272.37	74.2	5.8
Fredix *et al*. [21]	1316.72	74.8	1.7
Harris & Bennedict [22] (1918)*	1217.32	54.2	9.4
Harris and Bennedict (1984) [3]*	1239.44	54.9	7.6
Henry and Rees [23]*	1213.06	76.7	9.8
Huang *et al*. [24]*	1175.02	54.4	12.9
Huang *et al*. [24] (+FFM)*	1134.14	55.7	16.5
Institute of Medicine [17]*	1214.07	48.4	9.7
Johnstone *et al*. (+FFM) [25]*	1141.03	82.7	16
Korth *et al*. [26]*	1204.32	74.4	10.6
Korth *et al*. (+FFM) [26]*	1212.05	98.1	10.1
Lazzer *et al*. [27]	1296.30	70.3	3.2
Lazzer *et al*. (+FFM) [27]*	1176.27	62.7	12.9
Livingston *et al*. [28]*	1142.30	57.7	15.8
Luhrmann & Neuhaeuser Berthold [13]*	1221.08	55.7	9.1
Mifflin *et al*. [29]*	1106.97	68.6	18.9
Mifflin *et al*. [29] (+FMM)*	1113.63	74.9	18.4
Muller *et al*. [30]*	1201.09	52.5	10.7
Muller *et al*. [30] (+BMI>30)	NC	NC	NC
Muller *et al*. [30] (+BMI>30 +FFM)	NC	NC	NC
Muller *et al*. [30] (+FFM)	1195.00	52.6	11.3
Owen *et al*. [31]*	1202.52	30.5	10.6
Owen *et al*. [31] (+FFM)*	1034.63	74.9	25.6
Schofield *et al*. [32] (AG=30-60)*	1239.29	79.1	7.7
Schofield *et al*. [32] (+BM +HM +ID > 60)	1246.78	77.4	7.1

Note: *Significantly different from indirect calorimetry.
NC: Not Calculated; FFM: Fat-Free Mass; BMI: Body Mass Index; FAO: Food and Agriculture Organization of the United Nations.

showed poor accuracy for lean participants and curiously high accuracy in the presence of overweight or obesity. These results are in agreement with the concept that the difference between the RMR measured and predicted by equations is related to the absolute values of the RMR measured [13]. In older adults, predictive equations provide a valid estimation of RMR; however, individual errors should be considered in clinical practice [13].

The most accurate equation for lean women was that proposed by Fredrix [21], which was developed based on healthy older men and women. The authors estimated a 10-20% individual error range between measured values and the predicted values,

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Table 4. Comparison between Indirect calorimetry and predictive equations (kcal/day) in overweight women.

IC or Predictive Equation values (kcal/day)	Overweight Group (n=12)		
	Mean	SD	%
Indirect calorimetry	1398.61	218.0	
Arciero *et al.* [6]	1370.47	53.5	1.0
Berstein *et al.* [19]*	1176.55	45.2	16.1
Berstein *et al.* [19] (+FFM)*	1137.67	87.0	19.6
De Lorenzo *et al.* [12]	1441.31	65.2	-4.0
FAO (AGE >60 years) [20]	1469.72	58.0	-6.0
Fredix *et al.* [21]	1534.80	70.5	-10.3
Harris & Bennedict [22] (1918)	1411.90	56.3	-2.0
Harris and Bennedict (1984) [3]	1428.93	54.0	-3.2
Henry and Rees [23]	1390.64	62.5	-0.5
Huang *et al.* [24]	1381.39	63.1	0.2
Huang *et al.* [24] (+FFM)	1370.62	71.1	1.0
Institute of Medicine [17]	1390.61	49.6	-0.5
Johnstone *et al.* [25] (+FFM)	1440.09	99.3	3.8
Korth *et al.* [26]	1413.06	61.7	-2.0
Korth *et al.* [26] (+FFM)	1484.56	121.2	-6.7
Lazzer *et al.* [27]	1504.43	74.5	-8.2
Lazzer *et al.* [27] (+FFM)	1446.43	82.3	-4.3
Livingston *et al.* [28]	1345.97	57.9	2.8
Luhrmann & Neuhaeuser Berthold [13]	1459.83	71.3	-5.3
Mifflin *et al.* [29]	1315.16	59.3	5.1
Mifflin *et al.* [29] (+FMM)	1321.60	92.5	4.7
Muller *et al.* [30]	1425.54	67.0	-2.9
Muller *et al.* [30] (+FFM)	1410.71	57.2	-2.3
Muller *et al.* [30] (+BMI>30)	1410.17	54.5	-1.9
Muller *et al.* [30] (+BMI>30 +FFM)	1416.77	65.8	-1.9
Owen *et al.* [31]	1344.51	44.3	2.9
Owen *et al.* [31] (+FFM)*	1242.60	92.5	10.9
Schofield *et al.* [32] (AG=30-60)	1466.64	50.1	-5.8
Schofield *et al.* [32] (+BM +HM +AG=30-60)	1352.96	133.0	2.5

Note: *Significantly different from calorimetry.
FFM: Fat-Free Mass; SD: Standard Deviation; FAO: Food and Agriculture Organization of the United Nations.

considering that individuals' energy needs could only be measured individually in this population. Other commonly used equations, such as FAO [20] and Schofield *et al.* [32], were considered to be accurate without statistical difference when compared to indirect calorimetry. Santos *et al.* [34] reported high RMR estimation accuracy for the FAO equation and poor accuracy for the Schofield equation in climacteric stage women. However, their study included lean and overweight women in the same group, which could explain the divergent results found in this study.

The Mifflin-St. Jeor equation has been shown to be adequate to estimate RMR in non-obese individuals [35], and in obese and overweight individuals with different characteristics [36]. The Mifflin-St. Jeor equation was derived from data collected from a sample that included a wide variety of ages and body compositions [29]. A recent study evaluating non-obese and sedentary postmenopausal women demonstrated that predictive equations overestimate RMR, showing that the FAO equation has the highest overestimation of RMR, and that the Mifflin-St. Jeor equation had the greatest accuracy [11]. These findings are contrary to those of the present study, considering that in this study, postmenopausal women were analyzed separately according to their BMI, and the predictive equations were evaluated including muscle mass. The overweight postmenopausal women results indicate that the predictive equations provide reasonable results to estimate RMR, but for lean postmenopausal women the equations generally underestimate RMR. The opposite phenomena has been described for data from older and overweight women, and only the FAO and Schofield equations underestimated RMR, while the other equations provided an adequate estimate of RMR in lean elderly women [13]. However, the present study included both lean and overweight women, and the Bland-Altman method was used to better understand how different equations estimate RMR, considering the differences in body composition in this population. These methodological variations could explain the divergent results.

Noteworthy, for overweight postmenopausal women both the Huang equation [24], which is derived from obese elderly patients, and the equation proposed by Arciero [6], developed for postmenopausal women showed the best accuracy. The Berstein equation for obese women, Owen's equation, and the IOM equation, which include overweight and obesity factors, produced RMR results different from those measured by indirect calorimetry. Although, in the present study, most of the predictive equations showed a difference in RMR estimation below ± 5% for the overweight group, Luhrmann *et al.* [13] reported that the FAO equation overestimated RMR in lean and overweight elderly women. The authors stated that the differences between the predicted and the measured RMR depended on the absolute values of the RMR measured and that predictive equations are specific for the population from which they were derived. This hypothesis is reinforced by Schusdziarra *et al.* [37], who argued that different equations provide accurate estimates in older and obese individuals. These authors added that although the equations are valid for group analysis, prediction is generally invalid for individual evaluations. Currently used equations provided an unreliable estimate in postmenopausal women and a less accurate estimate in lean women. Therefore, for a more accurate RMR estimate in postmenopausal women, the use of predictive equations should consider the individual characteristics. Furthermore, these equations do not provide an accurate estimate, which reinforces the need to develop a specific predictive equation for postmenopausal women, considering body composition, especially BMI. In addition, based on results obtained and on the results from previous studies [11,34], a careful validation of RMR predictive equations in the South American population still remains a perspective for future studies.

Indirect calorimetry is considered a precise method to measure resting metabolism rate and can be used to determine the amount of kcal used in 24 hours, *i.e.* twenty-four hour energy expenditure [38]. It is worth mentioning that in the present study the body composition measurements were made according to the multicomponent ISAK protocol [15], which results in a more accurate assessment of muscular and adipose tissue. Since muscle tissue is commonly regarded as the main determinant of RMR [39], it is accepted that interindividual differences in body composition are not sufficient to explain the total variance in RMR [40]. However, it is important to consider the difference in methodologies when comparing data from the present study with those of

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previous studies involving RMR estimation and body composition in different populations.

In conclusion, differences in body composition in postmenopausal women affect the accuracy of equations that predict resting metabolic rate. Although the indirect calorimetry values were not different between the groups, the RMR estimated using the predictive equations was significantly different between the lean and overweight groups for all equations. The equations proposed by Fredix, FAO, and Schoefield provided an accurate estimate for lean women, whereas most of the predictive equations showed good accuracy for the overweight group, and the Huang and Arciero equations were the most accurate in the present study. Considering the importance of accurate RMR estimation in terms of health promotion strategies for this population, the results obtained reinforce that in order to obtain a more accurate estimation of RMR in postmenopausal women, the use of predictive equations should consider their nutritional status and body composition parameters, such as BMI.

CONTRIBUTORS

RB CARTERI contributed to the experimental design of this study, patient selection, experiment applicability evaluation, data analysis, and manuscript preparation and writing. M FELDMANN and AL LOPES contributed to data analysis and manuscript preparation and writing. JS GROSS and RL KRUGER contributed to the collection of anthropometric and indirect calorimetry data and general data analysis. A REISCHAK-OLIVEIRA supervised the research project and contributed to the experimental design by reviewing and supervising all stages of conception and the procedures of the study.

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