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ScienceDirect
Metabolism Clinical and Experimental 59 (2010) 1181 – 1189
Metabolism
Clinical and Experimental
www.metabolismjournal.com

Poor prediction of resting energy expenditure in obese women by established equations

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Received 15 May 2009; accepted 11 November 2009

Abstract

The objective of the study was to evaluate the accuracy of established prediction equations that calculate resting energy expenditure (REE) in obese women. This was a cross-sectional study. In 273 mildly to severely obese women (age, 41.7 ± 13.2 years; body mass index, 42.8 ± 7.0 kg/m^2), REE was measured by indirect calorimetry (mREE), along with fat mass (FM) and fat-free mass (FFM) by bioelectrical impedance analysis. Eleven established equations were used to predict REE (pREE), with 9 equations basing on the anthropometric parameters body weight and height and 2 equations including body composition parameters (FM, FFM). All equations provided pREE values that significantly correlated with mREE ($r > 0.66$, $P < .001$), although 8 equations systematically underestimated mREE ($P < .05$). Of note, even the best equation was not able to accurately predict mREE with a deviation of less than ±10% in more than 70% of the tested women. Furthermore, equations using body composition data were not superior in predicting REE as compared with equations exclusively including anthropometric variables. Multiple linear regression analyses revealed 2 new equations—one including body weight and age and another including FM, FFM, and age—that explained 56.9% and 57.2%, respectively, of variance in mREE. However, when these 2 new equations were applied to an independent sample of 33 obese women, they also provided an accurate prediction (±10%) of mREE in only 56.7% and 60.6%, respectively, of the women. Data show that an accurate prediction of REE is not feasible using established equations in obese women. Equations that include body composition parameters as assessed by bioelectrical impedance analysis do not increase the accuracy of prediction. Based on our results, we conclude that calculating REE by standard prediction equations does not represent a reliable alternative to indirect calorimetry for the assessment of REE in obese women.

1. Introduction

In light of the increased prevalence of obesity [1], a growing number of obese people participate in weight loss programs. To provide adequate dietary advice, it is necessary to estimate the amount of individual energy expenditure. Most obese people appear to have a relatively sedentary lifestyle [2,3], with resting energy expenditure (REE) accounting for 60% to 70% of total energy expenditure (TEE) [4]. Thus, assessment of REE is a most crucial step in the calculation of TEE.

Indirect calorimetry is commonly accepted as the criterion standard for measuring REE [5]. However, the regular use of this method in clinical practice is limited by its availability, relatively high costs, time required for measurement, and staff for technical assistance. For these reasons, REE is frequently calculated by using prediction equations [6-14]. Since the 1920s, many different prediction equations have been published [8]. The most widely used prediction equations are probably those by the World Health Organization (WHO) [6] and by Harris-Benedict [8]. Of note, the reference populations used to generate these and many other equations included only a very limited [12], if any, number of obese [9] and especially severely obese subjects [14]. Furthermore, most prediction equations account exclusively for anthropometric variables such as body weight and height. Considering that weight gain and obesity are associated with a disproportionate increase in fat mass (FM) [15-18] and that FM is metabolically less active than fat-free mass (FFM) [19,20], it can be assumed that most of the established REE

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doi:10.1016/j.metabol.2009.11.011

prediction equations will fail in obese subjects. Moreover, it is not even clear so far whether the accuracy of REE prediction equations can be improved by including body composition variables [13]. This question is of great clinical relevance because the anthropometric variables body weight and height can be measured much easier and with a higher accuracy than body composition, for example, by bioelectrical impedance analysis (BIA) in severely obese subjects.

Only 5 REE prediction equations generated from data sets including exclusively obese subjects have been published [9,13,14] so far. Importantly, 2 of these equations also included body composition variables [13,14]. However, before a general use of these equations can be recommended, their validity needs to be tested in further studies of larger samples sizes displaying comparable physical characteristics. Here we tested these 5 new obese-specific REE prediction equations along with 6 other established equations [6-14] in a sample of 273 mildly to severely obese women (study group). Besides the overall prediction accuracy of these equations in our sample, we also tested whether inclusion of body composition parameters deriving from BIA can improve the accuracy of REE prediction. Finally, we generated 2 new equations—one based exclusively on anthropometric data and one on body composition data—and tested these new equations in an independent sample of 33 obese women (validation group).

2. Methods

2.1. Subjects

Data of the study group were obtained from 273 obese (body mass index [BMI] >30 kg/m^2) women who were examined at the Interdisciplinary Obesity Center, Kantonspital St Gallen, Switzerland, between January 2006 and May 2008. The examination was part of a first visit at the Interdisciplinary Obesity Center before subjects were allocated to different weight reduction programs (eg, dietary counseling, cognitive-behavioral therapy, bariatric surgery). All subjects were tested for hypo- or hyperthyroidism by measuring thyrotropin levels. Subjects with thyrotropin levels exceeding the reference range (0.25-4 mU/L) were excluded from the study because altered thyroid function is well known to affect REE [21,22]. Furthermore, subjects taking drugs known to influence REE, for example, sibutramine, were excluded from the study.

The validation group consisted of 33 obese (BMI >30 kg/m^2) women who joined an 8-week weight reduction study at the University of Kiel, Germany, between August 2003 and June 2004 [23]. Data presented here were collected at baseline before starting weight reduction.

In the study group, all measurements were conducted between 8:00 and 11:00 AM, whereas measurements were conducted between 6:30 and 10:00 AM in the validation group. In both groups, subjects were tested after an overnight fast of more than 10 hours. All subjects were instructed to avoid brisk physical activity in the morning before the examination and arrived at the institute by car or bus.

2.2. Anthropometric characteristics and body composition

In both groups, body weight was measured to the nearest 0.1 kg on an electronic scale with subjects wearing light underwear or swimming suit. Height was measured without shoes on a stadiometer to the nearest 0.5 cm. Body composition was assessed by single-frequency BIA (study group: Akern RJL101S, Akern, Pontassieve, Italy; validation group: Nutriguard M, Data Input, Darmstadt, Germany).

Table 1
Established equations used to predict REE in obese women

Reference	Subject	Age	Anthropometric parameters	Weight status	REE prediction equations or women
WHO, 1985 [6]	M, F >11 000	18->60	Wide BMI range	NW, OW, OB	18-30 y: 13.3 × *W* + 334 × *H* + 35 30-60 y: 8.7 × *W* − 25 × *H* + 865 >60 y: 9.2 × *W* + 637 × *H* − 302
Mifflin, 1990 [7]	M: 251; F: 247	19-78	W: 46-143 kg	NW, OW, OB	9.99 × *W* + 6.25 × *H* − 4.92 × age + 166 × sex − 161
Harris-Benedict, 1919 [8]	M: 136; F: 103	21-70	W: 25.0-124.9 kg	NW, OW	665.0955 + 9.5634 × *W* + 1.8496 × *H* − 4.6756 × age
De Luis, 2006 [9]	F: 140	46.6 ± 17.5	BMI: 34.9 ± 5.2 kg/m^2	OB	1272.5 + 9.8 × *W* − 61.6 × *H* − 8.2 × age
Bernstein, 1983 [10]	M: 48; F: 154	M: 40.4 ± 12.6 F: 39.4 ± 12.0	W: 103.4 ± 26.0 kg	OW, OB	844 − 0.42 × *H* + 7.48 × *W* − 3.0 × age
Siervo, 2003 [11]	F: 157	18-35	W: 58.7 ± 6.0 kg W: 71.4 ± 7.8 kg W: 90.9 ± 10.6 kg	NW OW OB	542.2 + 11.5 × *W*
Owen, 1986 [12]	F: 44	18-65	W: 43-143 kg	NW, OW, OB	795 + 7.18 × *W*
Mueller, 2004 [13]	M: 99; F: 179	47.8 ± 13.8	BMI: 37.1 ± 7.2 kg/m^2	OB	(I) 0.05 × *W* + 1.103 × sex − 0.01586 × age + 2.924 (II) 0.05685 × FFM + 0.04022 × FM + 0.808 × sex − 0.01402 × age + 2.818
Lazzer, 2007 [14]	F: 91	19-60	BMI: 45.6 kg/m^2	OB	(I) 0.042 × *W* + 3.619 × *H* − 2.678 (II) 0.067 × FFM + 0.046 × FM + 1.568

Values are mean ± SD or range (minimum-maximum). For sex: female = 0 and male = 1; for all equations: age in years, weight in kilograms, height in centimeters, except for the WHO, de Luis, and Lazzer equations: height in meters, FM in kilograms, FFM in kilograms, REE in kilocalories per day, except for the Lazzer and Mueller equations: REE in megajoules per day. NW indicates normal weight; OW, overweight; OB, obese; F, female; M, male; W, weight; H, height.

Tetrapolar BIA measurement of resistance and reactance was performed at 50 kHz and 0.8 mA between the wrist and ankle at the dominant site in supine position. In both groups, FFM, FM, and percentage FM (%FM) were calculated from BIA data by using Akern manufacturer's equation (Akern, BodyGram 1.31).

2.3. REE measurement

Resting energy expenditure was measured by indirect calorimetry (mREE) using ventilated hood systems (study group: Deltatrac II, MBM 200, Hoyer, Bremen, Germany; validation group: Vmax 29n, SensorMedics, Höchberg, Germany) for 20 to 30 minutes at constant humidity (55%) and room temperature (study group: 20°C-23°C; validation group: 22°C). Before each measurement, both gas analyzers were calibrated with standard gas concentrations (study group: 95% O_2 + 5% CO_2; validation group: 16% O_2 + 4% CO_2, 26% O_2). During measurement, subjects were laying in a supine position awake, quiet, and motionless. Data were collected every 1 minute (study group) and every 20 seconds (validation group), respectively. For both groups, V_{O_2} and V_{CO_2} were converted to REE by using the abbreviated Weir equation [24].

2.4. REE prediction equations

Table 1 provides an overview of the 11 established prediction equations [6-14] that were used to calculate REE (pREE). Nine of the 11 REE prediction equations (WHO, Mifflin, Harris-Benedict, de Luis, Bernstein, Siervo, Owen, Mueller I, Lazzer I) are based on anthropometric parameters, that is, body weight and height, whereas the other 2 equations (Lazzer II, Mueller II) include body composition variables. In the reference population providing the data for the generation of the respective REE prediction equations, FM and FFM were assessed either by BIA (Lazzer II) or by BIA and skinfold thickness measurement (Mueller II). Of note, the equations of de Luis, Mueller, and Lazzer were developed from data sets of exclusively obese women.

2.5. Statistical analysis

Statistical analyses were performed by using SPSS for Windows (Version 12, SPSS, Chicago, IL). All data are presented as mean ± SD. Paired *t* test was used to determine significant differences between mREE and pREE. In addition, the 95% confidence intervals (CIs) of the difference between measured and predicted vales were calculated for bias estimation. Prediction accuracy was calculated as percentage of mREE. Prediction accuracy between 90% and 110% of mREE was considered satisfactory. Prediction values less than 90% or more than 110% of mREE were classified as under- or overestimation, respectively. Pearson correlation coefficients were calculated for relationships between mREE and pREE. Bland-Altman analysis was used to test for the difference between mREE and pREE [25]. The root mean squared prediction error (MSPE) was used to indicate how well the model predicted in our data set. To develop a new REE prediction equation, stepwise multiple linear regression analyses were performed with mREE as the dependent variable and anthropometrical parameters (model I) or body composition variables (model II), respectively, and age (both models) as independent variables. Subsequently, the newly developed as well as the established equations were tested by using data of the validation group. A *P* value of less than .05 was considered significant.

We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research. Furthermore, the study protocol was approved by the ethical committee of the Kantonsspital St Gallen and the University of Kiel, respectively; and all subjects gave written informed consent.

Table 2
Characteristics of the study group and the validation group

	Study group (n = 273)	Validation group (n = 33)	*P*
Age (y)	41.7 ± 13.2 (18-77)	40.4 ± 8.0 (25-57)	.587
Height (cm)	163.0 ± 6.8 (144-182)	166.9 ± 5.8 (152-177)	**.002**
Weight (kg)	113.9 ± 19.6 (74.0-178.0)	103.9 ± 15.9 (76.7-145.6)	**.005**
BMI (kg/m^2)	42.8 ± 7.0 (30.4-69.5)	37.2 ± 4.6 (30.3-46.5)	**<.001**
FM (kg)	56.1 ± 14.8 (22.5-102.0)	48.8 ± 11.5 (31.6-77.3)	**.008**
FM (%)	48.7 ± 6.1 (29.3-67.3)	46.4 ± 4.2 37.6-55.1	**.007**
FFM (kg)	57.7 ± 8.0 (42.8-87.4)	55.3 ± 5.6 (40.8-68.3)	.102
mREE (kcal/d)	1930.1 ± 306.5 (1070-2810)	1947.5 ± 286.9 (1462-2382)	.755

All values are mean ± SD (minimum-maximum). *P* values derive from unpaired Student *t* tests. Significant values are indicated in bold.

3. Results

3.1. Characterization of the study group and validation group

Anthropometric, body composition, and REE data of the study group and validation group are summarized in Table 2. Both groups were comparable for age, FFM, and mREE ($P > .101$ for all comparisons), although women of the study group were shorter ($P = .002$) but displayed a higher body weight ($P = .005$), BMI ($P < .001$), FM ($P = .008$), and %FM ($P = .007$) than the women of the validation group.

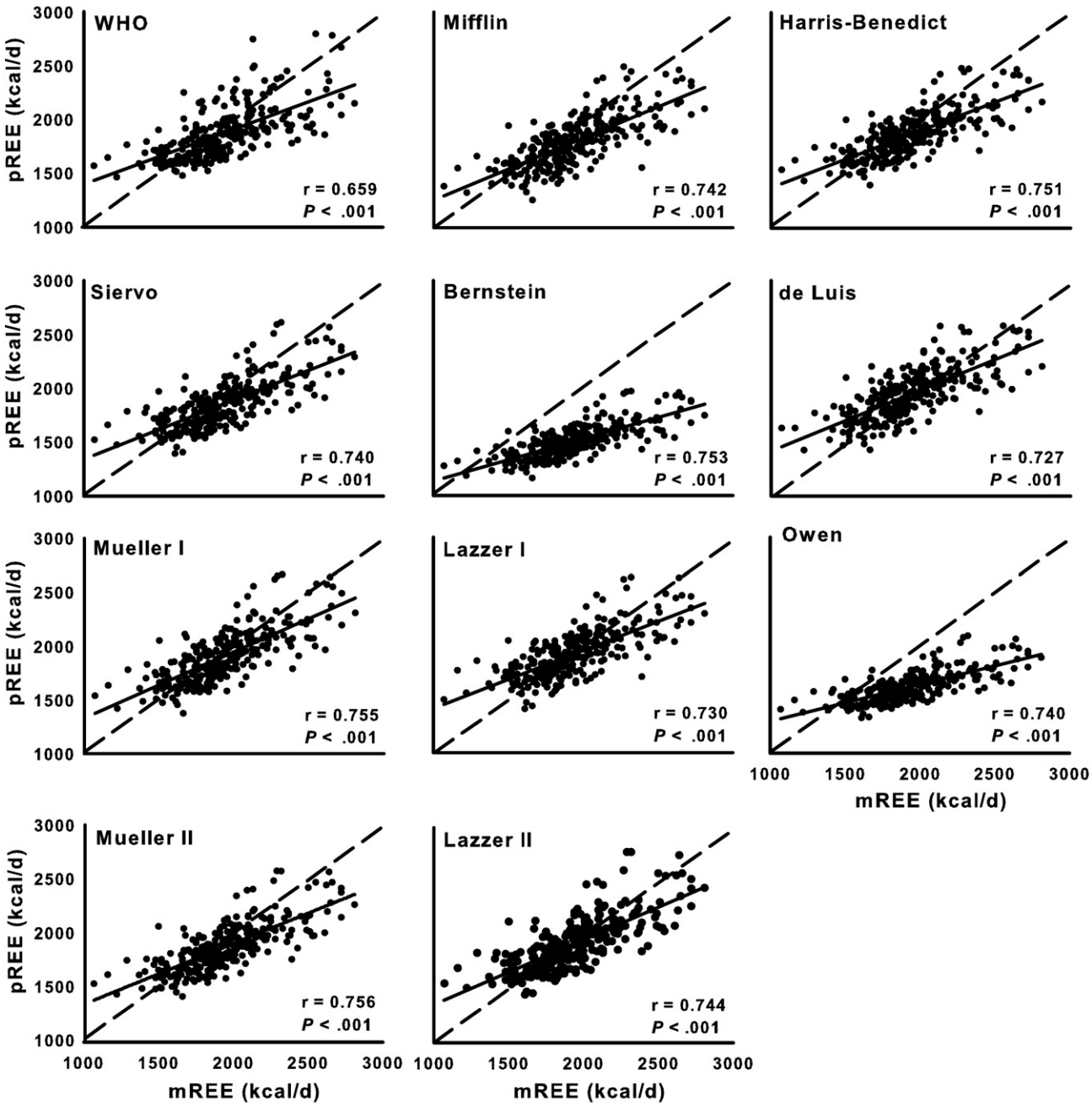

Fig. 1. Relationship between mREE and pREE deriving from 9 prediction equations based on anthropometric parameters and 2 equations based on body composition parameters in the study group. Scattered lines indicate lines of identity.

3.2. mREE in comparison with pREE as derived by 11 prediction equations in the study group

All equations revealed that pREE values highly correlated with mREE values (all $r > 0.658$, $P < .001$, Fig. 1), but the deviation of pREE from mREE appeared to increase with increasing mREE. In fact, Bland-Altman regression of difference between pREE and mREE on averaged pREE and mREE values revealed a systematic error for all prediction equations (all r greater than −0.295, $P < .001$, Fig. 2). However, for most equations, except for the Bernstein ($r = −0.157$, $P = .009$) and the Owen equation ($r = −0.159$, $P = .008$), no association was found between %FM and the mean deviation of pREE and mREE ($r < 0.09$, $P > .173$), indicating that differences between predicted and measured REE values were not depending on a disproportionate increase in FM.

Mean pREE values obtained by established equations along with mean deviations from mREE and 95% CI are summarized in Table 3. Seven of the 9 equations based on anthropometric parameters (WHO, Mifflin, Harris-Benedict, Bernstein, Siervo, Owen, Mueller I) provided pREE values that were significantly lower than mREE (all $P < .05$). Despite

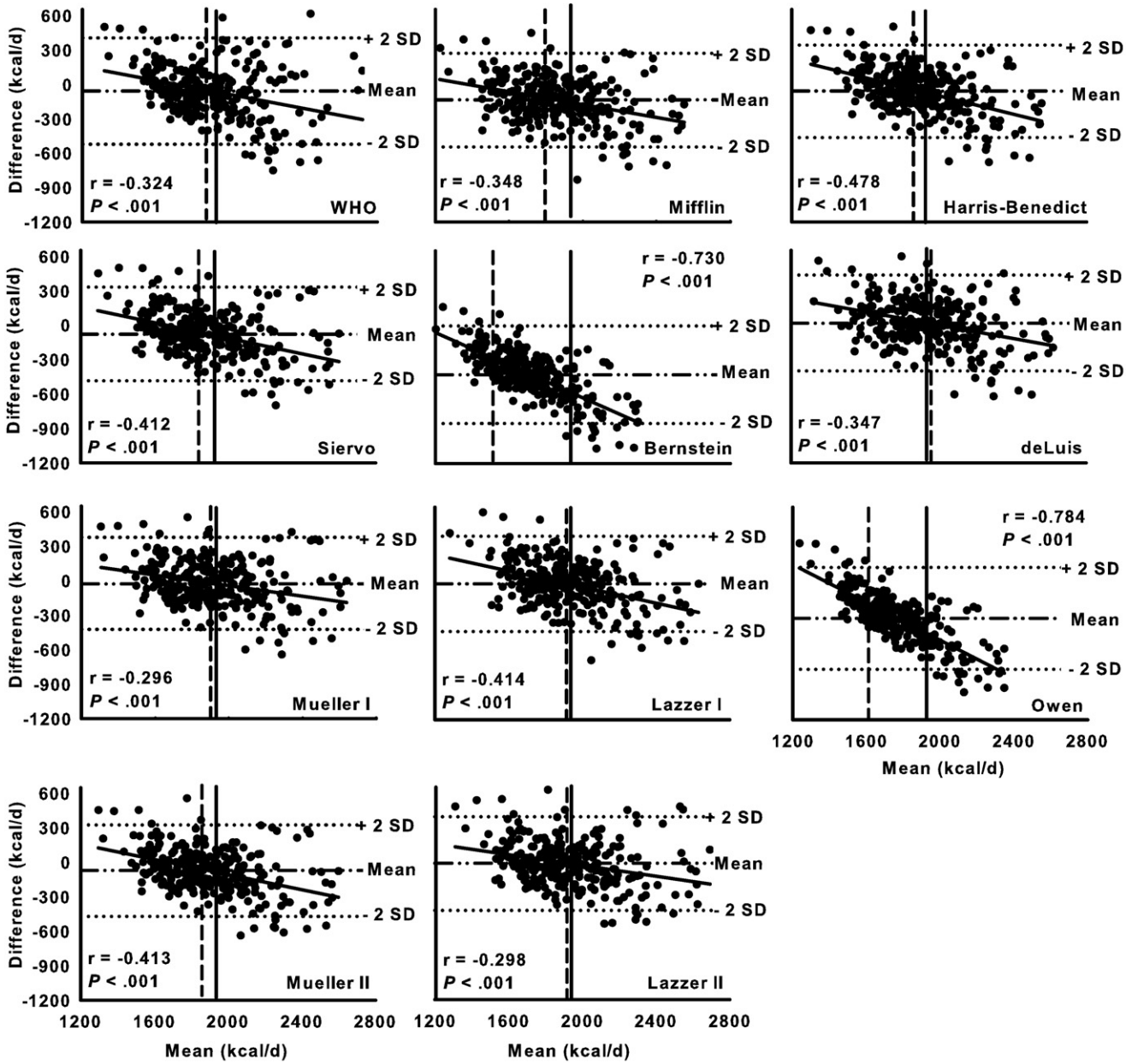

Fig. 2. Bland-Altman regression of the difference between pREE and mREE deriving from 9 prediction equations based on anthropometric parameters and 2 equations based on body composition parameters in the study group. Solid vertical line denotes mean mREE of the study group; dashed vertical line denotes mean pREE calculated by the equation. Difference = pREE − mREE; kcal/d; mean = 0.5 × (mREE + pREE); kcal/d.

Table 3
Comparison between mREE and pREE by using 11 established equations in the study group

	pREE (kcal/d)	Difference			±10% of mREE (%)	MSPE (kcal/d)
		(kcal/d)	95% CI	*P*		
Anthropometric parameters						
WHO	1871.6 ± 235.5	−58.5 ± 231.2	−86.0 to −30.9	**<.001**	62	238
Mifflin	1790.5 ± 237.6	−139.6 ± 204.0	−163.9 to −115.3	**<.001**	58	247
Harris-Benedict	1868.1 ± 213.7	−62.0 ± 201.3	−86.0 to −38.0	**<.001**	70	210
de Luis	1946.4 ± 236.3	16.3 ± 209.1	−8.6 to 41.2	.199	66	209
Bernstein	1502.3 ± 157.9	−427.8 ± 212.1	−453.1 to −402.6	**<.001**	7	477
Siervo	1851.6 ± 225.2	−78.5 ± 204.3	−102.8 to −54.1	**<.001**	65	219
Owen	1612.5 ± 140.6	−317.6 ± 221.0	−343.9 to −291.2	**<.001**	20	387
Mueller I	1903.9 ± 248.2	−26.2 ± 200.3	−50.0 to −2.3	**.032**	70	202
Lazzer I	1913.0 ± 223.8	−17.1 ± 207.7	−41.8 to 7.7	.176	66	208
Body composition parameters						
Mueller II	1857.8 ± 226.7	−73.5 ± 198.8	−97.2 to −49.7	**<.001**	66	211
Lazzer II	1916.2 ± 247.0	−15.1 ± 204.0	−39.5 to 9.2	.222	67	204

All values are mean ± SD. mREE = 1930.1 ± 306.5 kcal/d (95% CI, 1894-1966 kcal/d). Difference (in kilocalories per day) = numerical difference between pREE and mREE. *P* values derive from paired Student *t* test between pREE and mREE. Significant values are indicated in bold. ±10% of mREE = percentage of subjects with satisfying prediction within ±10% of mREE.

the statistical significance of all of these deviations, their clinical impact substantially varied across equations. For instance, the mean pREE by Mueller I deviated only by a negligible amount from mREE (−26 kcal/d), whereas the Bernstein or Owen equation provide pREE that deviated on average by −428 kcal/d and −318 kcal/d, respectively, from mREE. Only pREE values calculated by the equations of de Luis ($P = .199$) and Lazzer I ($P = .176$) did not significantly deviate from mREE. Interestingly, both equations as well as Mueller I with a negligible deviation were developed from data sets exclusively including obese subjects. Regarding the 2 body composition–based equations, which also derived from data sets of exclusively obese subjects, the Mueller II equation again showed a rather small mean deviation of −74 kcal/d ($P < .001$); and the Lazzer II equation showed a nonsignificant deviation of −15 kcal/d ($P = .222$). The 95% CI of the differences included zero only when pREE values were calculated by the equations by de Luis, Lazzer I, and Lazzer II, indicating that there was no bias between pREE and mREE for these 3 equations.

Focusing on the distribution of individual mREE values revealed that REE could not be accurately (±10%) predicted by any of the established equations in at least 30% of the obese women (Table 3). Seven of the 9 anthropometric equations (WHO, Mifflin, Harris-Benedict, de Luis, Siervo Mueller I, Lazzer I) and the 2 body composition equations accurately predicted REE in 58% to 70% of the women, whereas the proportion of accurate predictions was less than 20% when the equations of Bernstein and Owen were used.

The MSPE, as presented in Table 3, varied from 201.7 to 477.3 kcal/d, with the lowest values for Mueller I equation and the highest RMSE values for Bernstein equation.

3.3. Two new REE prediction equations

Multiple linear regression analyses on study group data were used to develop new REE prediction equations. One equation was computed by exclusively including anthropometric parameters (body weight, height) and age in the regression model (model I), whereas another equation was developed by including body composition parameters (FFM, FM) in addition to age as independent variables (model II). For model I, body weight solely accounted for 54.8% of the variance in mREE ($P < .001$). By adding women's age to the model ($P < .001$), explained variance increased to 56.9%, whereas adding height did not further improve the model ($P = .639$). Computing model II, FM turned out to be the strongest predictor of mREE, accounting for 44.0% of its variance ($P < .001$). However, inclusion of FFM ($P < .001$) and age ($P = .001$) further improved the model, explaining 57.2% of variance. The 2 final regression models revealed the following equations:

$$\text{Model I: REE (kcal/d)} = 816.714 + 11.035 \times \text{weight} - 3.435 \times \text{age}$$
$$\text{Model II: REE (kcal/d)} = 750.967 + 10.303 \times \text{FM} + 12.771 \times \text{FFM} - 3.248 \times \text{age}$$

3.4. Testing the new equations within an independent validation group

The 2 newly developed equations as well as the established equations were tested within the validation group (Table 4). Both new equations (models I and II) revealed pREE values that were significantly lower than mREE ($P < .004$). In addition, both

Table 4
Comparison between mREE and pREE by using 11 established and 2 new equations in the validation group

	pREE (kcal/d)	Difference		±10% of mREE (%)
		(kcal/d)	*P*	
Anthropometric parameters				
WHO	1784.9 ± 223.8	−162.6 ± 233.1	**<.001**	64
Mifflin	1882.4 ± 207.2	−65.0 ± 207.9	.082	70
Harris-Benedict	1775.7 ± 181.7	−171.8 ± 208.7	**<.001**	52
de Luis	1856.7 ± 196.0	−90.8 ± 210.2	**.019**	64
Bernstein	1469.8 ± 131.7	−477.7 ± 218.7	**<.001**	3
Siervo	1736.9 ± 183.1	−210.6 ± 211.2	**<.001**	52
Owen	1543.0 ± 114.6	−404.5 ± 225.5	**<.001**	18
Mueller I	1790.4 ± 207.3	−157.1 ± 208.9	**<.001**	55
Lazzer I	1846.5 ± 194.0	−101.0 ± 209.3	**.009**	55
Model I	1824.4 ± 191.5	−123.1 ± 208.8	**.002**	58
Body composition parameters				
Mueller II	1760.0 ± 191.1	−187.4 ± 207.6	**<.001**	52
Lazzer II	1798.7 ± 203.6	−148.7 ± 209.5	**<.001**	52
Model II	1828.8 ± 193.0	−118.7 ± 207.5	**.003**	61

All values are mean ± SD. mREE = 1947.5 ± 286.9 kcal/d. Difference (in kilocalories per day) = numerical difference between pREE and mREE. *P* values derive from paired Student *t* test between pREE and mREE. Significant values are indicated in bold. ±10% of mREE = percentage of subjects with satisfying prediction within ±10% of mREE.

new equations provided accurate (±10%) predictions of REE in only 57.6% (model I) and 60.6% (model II) of the tested women. However, prediction accuracy of all but 2 of the established equations ranged from 50% to 70% and thus was not strikingly superior as compared with the new equations. As in the study group, the equations by Bernstein and Owen poorly predicted REE within the validation group, with an accurate prediction (±10%) in less than 20% of the obese women.

4. Discussion

Our results are of high clinical relevance because they show that REE cannot be accurately predicted in at least 30% of obese women. Considering that average REE was about 1900 kcal, a prediction error of 10% would translate into a 190-kcal deviation from real REE. Our results are even more alarming considering that the calculation of TEE is mostly based on calculated REE multiplied by an estimated physical activity level. When a 10% REE estimation error of 190 kcal is multiplied by physical activity level of 1.6, as recently described in obese women [26], the TEE of an average woman of our sample could vary from about 2740 to 3340 kcal. Given a variation in TEE of 600 kcal that can be expected upon our results in 30% or even more of obese women, it appears overall questionable whether adequate dietary advice can be made based on calculated TEE values.

A most interesting finding of our study is that including body composition data by means of FFM and FM did not improve the predictive accuracy of respective equations. Furthermore, inclusion of %FM in respective regression models was unable to further explain the interindividual variation in REE. Here, it should be noted that BIA is not a very reliable method to measure body composition in obese women [27,28], which, of course, could account for the lack of any further explanation of REE variation by variables deriving from this technique. However, it is also reasonable to assume that a further differentiation of FFM into different specific tissue types is required to more reliably predict REE [29]. The present, although at the first glance surprising, finding of FM being a better predictor of REE than FFM may further support this assumption. Fat-free mass comprises very different organs that vary widely in their tissue-specific metabolic rates, for example, skeletal muscle (about 13-15 kcal/kg) vs kidney (about 440 kcal/kg) [30]. With increasing body weight, different components of FFM will disproportionally rise, thereby leading to a great variation in composite FFM metabolic activity. On this background, it appears reasonable that FM, displaying a much more consistent metabolic rate (4-5 kcal/kg), explains more of the REE variation in severely obese women than FFM.

In light of the poor prediction accuracy of the established equations, it could also be questioned whether the variation in REE results from inaccuracies of indirect calorimetry measurements. In this context, it is noteworthy that Bader et al [31] recently showed a day-to-day variation of REE measured by indirect calorimetry less than 5% and that even the type of protocol for data analysis (standard vs optimized) and a reduction in the duration of the analyzed period from standard 15 minutes to optimized 12 minutes do not greatly affect results of the measurements. Thus, it can be expected that only a negligible part of the variation results from inaccuracy of indirect calorimetry.

In principle, the found differences between measured and predicted REE could result from a nonlinearity of the REE-FFM relationship. However, recent models on the REE-body composition relationship revealed a linearity of the REE-

FFM function in the FFM range of 40 to 80 kg [32]. Given that the FFM range of our study population (42.8-87.4 kg, Table 2) largely overlapped with this range, a major contribution of a failure of linearity of the function to the found differences between measured and predicted REE appears unlikely. Rather, we assume that the great variability in REE is explained by other physiologic factors that have not been assessed in our study. Supporting this view, a recent study reported on significant associations between REE and measures of blood pressure, insulin and glucose, and the homeostasis model assessment as a marker of insulin resistance that were independent of any body composition measure and age [33].

Prediction equations that were developed upon REE data deriving from obese samples [9,13,14] appeared to provide slightly more accurate pREE values than those deriving from normal- or overweight samples, at least when the mean deviation from mREE was considered. However, they were not much more satisfying in predicting individual mREE values in our obese women especially when compared with the classic Harris-Benedict equation. Interestingly, our newly developed equations based on our obese study population did not perform better than the other equations in our obese validation study sample. Thus, it remains an open question whether it will be helpful to define body weight or adiposity ranges for specific equations.

Of note, prediction accuracy of some equations greatly varied between the study and the validation sample (Tables 3 and 4). Given that the direction of increasing or decreasing accuracy between the 2 samples was rather balanced, it appears unlikely that the differences in accuracies derived from a systematic bias caused by the use of different indirect calorimetry devices. Keeping in mind that average body weight and height were not identical in the 2 samples (Table 2) and that one sample was recruited in Switzerland (study sample) and the other in the northern part of Germany (validation sample), it appears more likely that the differences in accuracies between the different equations are based on some biological factors that cannot more closely be defined here. If this assumption holds true, this would further support the notion that specific REE prediction equations cannot simply be transferred from one population to another, that is, a procedure that is widely done in current clinical practice.

In conclusion, our results show that predicting REE upon anthropometric or body composition data as derived from BIA is not feasible in obese women. Including more variables like insulin resistance [33,34] or quantitative amounts of specific tissues of FFM [29] might improve the prediction accuracy of future equations. However, considering that it will be quite costly to measure such variables in clinical practice and that it appears unlikely that a single variable will explain a large amount of REE variation, we conclude that REE should be measured by indirect calorimetry whenever it is necessary to know the REE of an obese woman.

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