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PREDICTING EQUATIONS AND RESTING ENERGY EXPENDITURE CHANGES IN OVERWEIGHT ADULTS

PREDIKTIVNE ENAČBE IN SPREMEMBE V PORABI ENERGIJE V MIROVANJU PRI PREKOMERNO HRANJENIH ODRASLIH

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ABSTRACT

Introduction: The aim of the study is to show the differences between the measured and estimated values of resting energy expenditure and any changes occurring after the 6-month weight loss intervention program.

Methods: We included 33 healthy adults aged 25–49 years with an average body mass index 29.1±2.7 kg/m 2 for female and 29.8±2.8 kg/m 2 for male. The measured resting energy expenditure was obtained by indirect calorimeter MedGem® Microlife and estimated resting energy expenditure by the Harris–Benedict equation, the Mifflin–St Jeor equation, the Owen equation, the Wright equation, and by the Tanita body composition analyser. All measurements and calculations were carried out before and after the 6-month intervention. Results were compared using paired t-tests. P value less than 0.05 was considered statistically significant.

Results: A comparison of the measured resting energy expenditure of female subjects with the estimated resting energy expenditure using the Harris–Benedict equation, the Mifflin–St Jeor equation and the Wright equation showed a statistically significant difference. A comparison of the measured resting energy expenditure of male subjects with the estimated resting energy expenditure using the Harris–Benedict equation and the Wright equation showed a statistically significant difference. There was a significant difference in the measured resting energy expenditure and estimated resting energy expenditure using Tanita.

Conclusions: We concluded that the most comparable equation for our sample was the Owen's equation. After losing weight, the measured resting energy expenditure has decreased, which must be taken into account in further diet therapy.

Keywords:
resting energy expenditure, energy expenditure, obesity, indirect calorimetry, predictive equations

IZVLEČEK

Uvod: *namen raziskave je bil prikazati razlike med merjenimi in ocenjenimi vrednostmi porabe energije v mirovanju ter spremembe v porabi energije v mirovanju po šestmesečni intervenciji za izgubo telesne mase. Vrednost porabe energije v mirovanju je pomemben podatek pri določanju energijskih in hranilnih potreb posameznika v procesu načrtovanja ustrezne prehrane. Vrednosti porabe energije v mirovanju lahko izmerimo z indirektnim kalorimetrom ali jo ocenimo z uporabo napovednih enačb. Zanimalo nas je, kakšna je razlika med merjeno in ocenjeno vrednostjo porabe energije v mirovanju ter kakšne so spremembe porabe energije v mirovanju po končani šestmesečni intervenciji za izgubo telesne mase.*

Metode: *20 zdravih žensk in 13 zdravih moških, starih od 25 do 49 let, s povprečnim indeksom telesne mase 29,1 ± 2,7 v kg/m2 za ženske in 29,8 ± 2,8 v kg/m2 za moške je zaključilo meritve porabe energije v mirovanju pred intervencijo in po njej. Porabo energije v mirovanju smo izmerili z indirektnim kalorimetrom Med Gem® Microlife, ocenjene vrednosti smo dobili z uporabo Harris-Benedictove enačbe, Mifflin-St Jeorove enačbe, Ownove enačbe ter Wrightove enačbe in iz izpiska poročila telesnega analizatorja Tanita. Ocena telesne sestave je bila opravljena z uporabo bioimpedance. Primerjavo smo naredili s parnim t-testom. Pri statističnih testih smo upoštevali stopnjo tveganja, nižjo od 5 % (p < 0,05).*

Rezultati: *primerjava med merjeno porabo energije v mirovanju pri ženskah in ocenjeno porabo energije v mirovanju s Harris-Benedictovo enačbo, Mifflin-St Jeorovo enačbo in Wrightovo enačbo je pokazala statistično značilne razlike, medtem ko primerjava med merjeno porabo energije v mirovanju pri ženskah in ocenjeno porabo energije v mirovanju z Ownovo enačbo ni bila statistično značilna. Ravno tako so se pri moških pokazale statistično značilne razlike med merjeno porabo energije v mirovanju in ocenjeno porabo energije v mirovanju s Harris-Benedictovo enačbo in Wrightovo enačbo. Statistično značilna razlika pri obeh spolih se je pokazala tudi pri merjeni porabi energije v mirovanju in ocenjeni porabi energije v mirovanju, pridobljeni s Tanito. Šestmesečna intervencija je vplivala na zmanjšanje porabe energije v mirovanju, vendar so bili rezultati statistično značilni le pri moških.*

Zaključek: *ugotovili smo, da je bila Ownova enačba najbolj primerljiva z izmerjeno porabo energije v mirovanju (tako za moške kot tudi za ženske). Po izgubi telesne mase se poraba energije v mirovanju zmanjša, kar je treba upoštevati pri nadaljnjem načrtovanju prehranskega vnosa.*

Ključne besede:
poraba energije v mirovanju, debelost, energijske potrebe, indirektna kalorimetrija, prediktivne enačbe

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1 INTRODUCTION

Total energy expenditure (TEE) is the energy organisms need for daily functioning, which is largely spent on metabolic and physiological functions [1]. The assessment of TEE is one of the fundamental functions performed in studies of nutrition. The lack of balance between the energy consumed and the energy expanded causes changes in bodyweight. One of the components representing TEE is resting energy expenditure (REE). The REE is the largest component of TEE and accounts for about 60 to 75 % of total daily expenditure in individuals with a sedentary lifestyle [2–4]. Data on individual TEE is crucial in planning adequate energy and nutrient intake in weight management nutritional intervention. REE is the energy that a person needs to maintain a body at rest [4]. REE can be measured by indirect calorimetry [4–5]. This is the gold standard for REE measurement. With this method, energy expenditure is calculated from oxygen and carbon dioxide concentrations found in the expired air [4]. Energy metabolism can also be assessed by using various equations. The most widely-used equation for estimating REE is the Harris–Benedict equation (HB) [6–7]. Following the recommendations of the American Dietetic Association (ADA) [8] the Mifflin–St Jeor (MSJ) equation is more reliable, especially in obesity [9]. Both predictive equations and indirect calorimetry measurements are used to determine the REE but the most precise method is indirect calorimetry; though it is also more expensive and time-consuming. Many authors [10–12] have found that predictive equations are unsuitable for determining the REE in overweight people because it does not take into account lean body mass, metabolic imbalances or genetic factors of an individual. Extensive review of the literature has shown that the rate of errors in the application can be high, in some cases up to 20% [12].

Obesity intervention programs include physical activity to encourage energy consumption and enhance physical strength and muscles [13]. More muscle mass means higher values of REE [2, 14]. Therefore, in the process of weight management, it is important to maintain muscle mass and lose fat mass. Additionally, the rate of weight loss is also important as rapid weight loss may cause a decrease in lean body mass, which further decreases REE. This shows the importance of a good diet plan. Therefore, this paper aims to compare measured REE and the predicted REE from the selected equations in overweight adults. Additionally, we presented the changes of REE and body composition after intervention and changes in bodyweight. We were specifically interested in changes between different (measured and estimated) REE.

2 METHODS

2.1 Study Design

This retrospective study was conducted in 2012 at the Faculty of Health Sciences, University of Primorska, Izola, Slovenia. There were 33 subjects who fulfilled the following inclusion criteria and were included in the study. Inclusion criteria for participants were: (1) body mass index (BMI) higher than 25 and lower than 35; (2) aged 25–49; (3) healthy with no metabolic, cardiovascular, endocrine, and acute or chronic inflammatory diseases; (4) not taking medication for lipid metabolism; (5) reporting a stable weight within the previous 3 months.

The participants were evaluated at baseline and after a 6-month weight loss intervention program.

2.2 Resting Energy Expenditure (REE)

REE was measured with a hand-held indirect calorimeter MedGem Microlife (Medical Home Solutions, Inc., Golden, and CO). A selected hand-held indirect calorimeter has been clinically tested and already assessed [15–17]. It is a self-calibrating device that measures VO2 and uses a respiratory quotient of 0.85 to calculate REE. All REE measurements were performed in the morning between 7 a.m. and 8 a.m., after 8 hours of sleep. 12 hours before the REE assessments, participants were instructed not to consume any alcohol or drugs, not to consume any food or fluids (with the exception of water) and not to exercise. Measurements were carried out after auto-calibration of the device in a quiet thermo-neutral environment (20–22°C) [18].

Estimated REE was calculated from selected equations that are more detailed and described below.

2.3 Anthropometric Measurements

All measurements were performed between 7 a.m. and 9 a.m. in standardised conditions by the same examiner after fasting overnight. The subject height was measured to the nearest 0.1 cm in a standing position, without shoes, using the Leicester height measure (Invicta Plastics Limited, Oadby, England). The bodyweight (kg) of the participants was measured with a 0.1 kg precision. BMI was calculated using the following formula: weight (kg)/ height (m2). Body composition, total body fat mass and fat free mass were assessed by using bioelectrical impedance analysis (BIA) Tanita BC 418MA (Tanita Corporation, Arlington Heights, IL) and data analysed with the software GMON Pro 3.2.1, provided by the same producer. From the bioelectrical impedance analysis of Tanita we also obtained information about an individual's minimum level of energy needs. BIA Tanita is using Tanita multiple regression analysis model, which includes adjusted Harris-Benedict equation and measured fat fee mass [19–20].

2.4 Predicted REE Calculation

REE was calculated using the Mifflin-St Jeor (MSJ)[9], the Harris–Benedict (HB)[19], the Owen (O) [21–22] and the Wright (W) [23] Equation (Table 1). Height, weight and age were used for the equations, calculated in kcal per day, and then expressed in kJ.

Table 1. Predictive equations for estimating the REE.

Reference	Female	Male
Mifflin-St Jeor [9]	(9.99 x w) + (6.25 x H) - (4.92 x A) - 161	(9.99 x W) + (6.25 x H) - (4.92 x A) + 5
Harris-Benedict [19]	655.09 + (9.56 x W) + (1.84 x H) - (4.67 x A)	66.47 + (13.75 x W) + (5 x H) - (6.75 x A)
Owen et al. [21], Owen et al. [22]	(7.18 x W) + 795	(10.2 x W) + 879
Wright et al. [23]	(9.02 x W) + (5.88 x H) – 7.47 x A + 110.76	(9.27 x W) + (4.58 x H) – (6.53 x A) + 451.44
Harris-Benedict adjusted from Tanita Corporation	655.10 + (9.56 x W) + (1.85 x H) – (4.68 x A)	66.47 + (13.75 x W) + (5 x H) - (6.76 x A)

Legend: A, age in years; H, height in cm; W, weight in kg

2.5 Intervention Program

To estimate TEE, individual REE (or a person's REE) (REE measured from indirect calorimetry) was multiplied by the appropriate activity factor (from 1.3 to 1.6) [24], then a reduction of 2,100 kJ (500 kcal) for all the participants was made. All subjects attended two educational sessions (2 h) about a healthy diet, nutritional composition, the correct timing of eating and the beneficial effects of daily intake of vegetables and fruit. Each group included 6–7 subjects. In addition, all subjects attended two sessions of one-on-one training about their prescribed individual diet plan (each subject was given a personalised diet). The diet plan consisted of 15–17% of energy from protein, 25–30% from fat and more than 50% from carbohydrates. Dietary fat composition was <10% of saturated fatty acid, at least 10% of monounsaturated fatty acid and 5% of polyunsaturated fatty acid. Subjects also received a list of food for each meal and the quantity of food in grams to choose from. Within the intervention, subjects were invited to attend a guided exercise program that included exercises for improving muscle function and strength and a Nordic walking course. The subjects also received a brochure with detailed instructions and recommendations for daily physical activity of moderate intensity. Intervention lasted six months. Measurements had been made before and after 6-month intervention.

2.6 Statistical Analyses

All analyses were carried out using the SPSS statistics version 23.0 (IBM, Chicago, IL). Means and standard deviation of the mean were determined at both baseline and after 6 months of intervention for all parameters. Using a paired t-test, we determined any statistical differences in the pre- and post-intervention period. We also conducted one sample t-test to evaluate the difference between the mREE and different eREE. Pearson's correlation coefficients were calculated to assess the relationships between the estimated REE and measured REE. Statistical significance was defined as $p<0.05$. We compared different results of selected predictive equations with measured REE with accuracy level ±10% of measured REE. This included predicted values of REE between 90% and 110% of measured REE.

3 RESULTS

Thirty-three individuals (20 female and 13 male), aged 39.5±6.5 years, completed the whole intervention program. Table 2 presents participant characteristics.

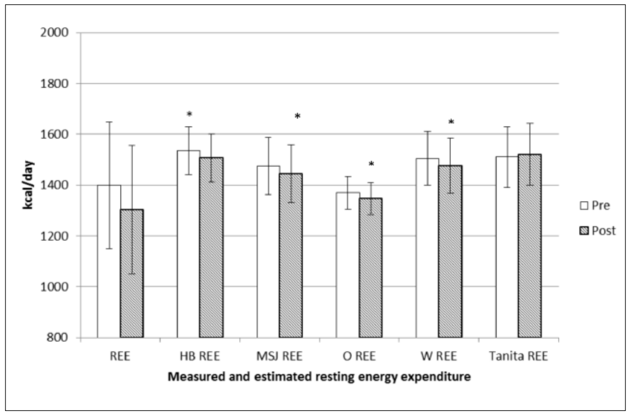
Table 2. Characteristics of the participants.

Characteristic	Mean±SD		
	Female (n=20)	Male (n=13)	Total (n=33)
Age	40.5±6.4	37.92±6.6	39.5±6.5
Height	165.7±5.2	180.0±6.5	171.3±9.1
Weight (kg)	80.1±9.1	96.4±8.1	86.5±11.8
Fat mass (%)	38.2±3.1	24.2±3.5	32.7±7.6
Fat-free mass (kg)	49.3±4.0	72.6±4.5	58.5±12.3

Legend: n, the number of subjects

For the comparison of different predictive equations, we used equations from Table 1. Weight, BMI, fat mass and fat free mass were statistically significantly, reduced after 6 months in both genders (Table 3 and Table 4). Mean and standard deviations of REE, weight, body mass index, fat free mass and total fat of the female are summarised in Table 3.

All estimated REE were significantly lower after the intervention (with the exception of mean estimated REE by Tanita). REE by Tanita in female predicted a higher REE after the intervention (but that was not significant) by one percentage point. The mean measured REE was lower after the intervention, but it was not statistically significant (Table 3 and Figure 1).



Legend: REE, measured resting energy expenditure; HB, Harris-Benedict's method; MSJ, Mifflin-St Jeor's method; O, Owen's method; W, Wright's method.* The difference before and after the intervention was statistically significant in females at the level of p<0.05.

Figure 1. Comparison of different methods for determining female subjects' REE before and after the 6-month intervention.

Table 3. Female subject's characteristics comparison, before and after 6-month intervention.

Female (n=20)	Mean±SD		R
	Before intervention	After intervention	%
REE (kcal/day)	1400±256	1305±260	-7
REE (kJ/day)	5864±1072	5465±1089	-7
HB REE (kcal/day)	1536 ±95	1507±95*	-2
MSJ REE (kcal/day)	1475±115	1445±116*	-2
O REE (kcal/day)	1370±65	1348±64*	-2
W REE (kcal/day)	1505±110	1477±111*	-2
Tanita REE (kcal/day)	1511±122	1520±124	+1
Weight (kg)	80.1±9.1	77.0±9,0*	-4
BMI (kg/ m2)	29.1±2.7	28.0±2.6*	-4
Fat free mass (kg)	49.3±4.0	48.3±3.9*	-2
Total fat (kg)	30.8±5.6	28.7±5.8*	-7

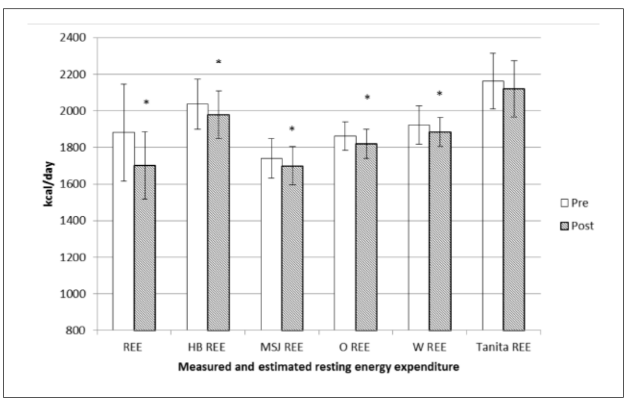
Legend: n, the number of subjects; BMI, body mass index; R, the difference in percentage points.*
The difference before and after the intervention was statistically significant in females at the level of p<0.05.

Mean and standard deviations of REE, weight, body mass index, fat free mass and total fat of the male are summarised in Table 4. Estimated REE (except results obtained from the Tanita scale) were significantly lower after the intervention. However, again the results we obtained from Tanita did not show any statistically significant difference (Figure 2).

Table 4. Male subjects' characteristics comparison, before and after 6-month intervention.

Male (n=13)	Mean±SD		R
	Before intervention	After intervention	%
REE (kcal/day)	1882±275	1700±191*	-10
REE (kJ/day)	7884±1154	7123±801*	-10
HB REE (kcal/day)	2036±144	1979±136*	-3
MSJ REE (kcal/day)	1740±114	1699±110*	-2
O REE (kcal/day)	1862±82	1820±83*	-2
W REE (kcal/day)	1922±109	1884±102*	-2
Tanita REE (kcal/day)	2161±158	2120±160	-2
Weight (kg)	96.4±8.1	92.3±8.1*	-4
BMI (kg/ m2)	29.8±2.8	28.5±2.6*	-4
Fat free mass (kg)	72.6±4.5	71.0±4.4*	-2
Total fat (kg)	23.5±4.9	21.3±5.7*	-10

Legend: n, the number of subjects; BMI, body mass index; R, the difference in percentage points.*
The difference before and after the intervention was statistically significant in males at the level of p<0.05.



Legend: REE, measured resting energy expenditure; HB, Harris-Benedict's method; MSJ, Mifflin-St Jeor's method; O, Owen's method; W, Wright's method.* The difference before and after the intervention was statistically significant in males at the level of p<0.05.

Figure 2. Comparison of different methods for determining male subjects' REE before and after the 6-month intervention.

We also compared the measured REE with different REE assessments (Table 5 and Table 6). Using the Pearson's correlation coefficient, we demonstrated a significantly moderate relationship between the measured REE and selected REE assessment methods for female subjects.

Table 5. Comparison of measured REE and estimated REE in females.

Measured REE vs. Method comparison	Mean difference±SD	t(p)	Pearson r (p)
Tanita	-215.9±214.7	-4.5 (0.000)*	0.571 (0.009)**
HB	-202.9±218.6	-4.1 (0.001)*	0.582 (0.007)**
MSJ	-140.5±211.2	-3.0 (0.008)*	0.604 (0.005)**
O	-43.6±226.1	-0.86 (0.399)	0.614 (0.004)**
W	-173.0±218.1	-3.5 (0.002)*	0.559 (0.010)*

Legend: HB, Harris-Benedict's method; MSJ, Mifflin-St Jeor's method; O, Owen's method; W, Wright's method.** Correlation is significant at the 0.01 (2-tailed),* correlation is significant at the 0.05 level (2-tailed).

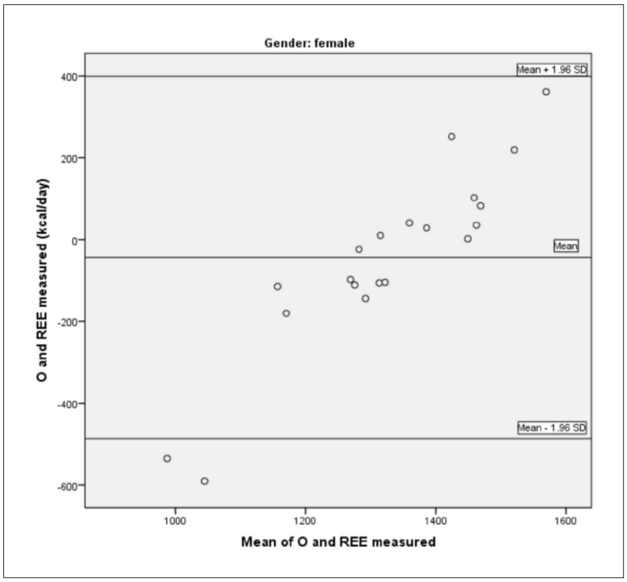


Figure 3. Bland-Altman plot showing the agreement between predicted REE with Owen (O) equation and measured REE for female.

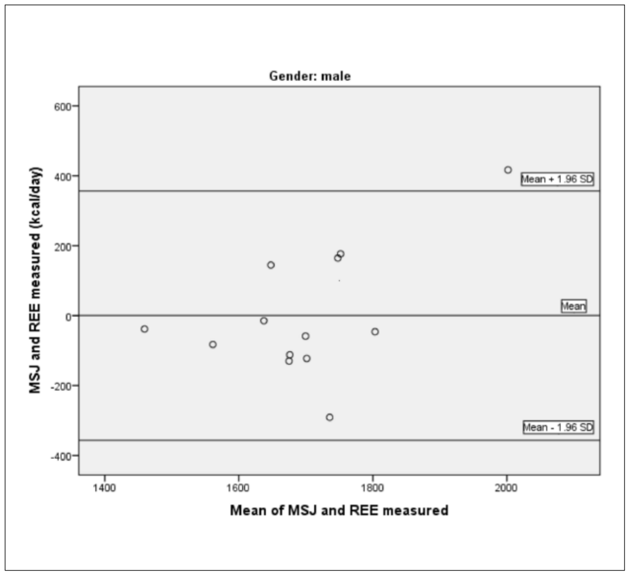


Figure 4. Bland-Altman plot showing the agreement between predicted REE with Mifflin-St Jeor (MSJ) equation and measured REE for male.

Table 6. Comparison of measured REE and estimated REE in male.

Measured REE vs. Method comparison	Mean difference±SD	t(p)	Pearson r (p)
Tanita	-419.9±218.5 *	-6.9 (0.000)*	0.235 (0.440)
HB	-297.4±195.9*	-5.1 (0.000)*	0.322 (0.284)
MSJ	0.553±181.7	0.011 (0.991)	0.373 (0.210)
O	-120.5±201.2	-2.2 (0.052)	0.094 (0.761)
W	-183.8±179.8*	-3.7 (0.003)*	0.377 (0.205)

Legend: HB, Harris-Benedict's method; MSJ, Mifflin-St Jeor's method; O, Owen's method; W, Wright's method.** Correlation is significant at the 0.01 (2-tailed),* correlation is significant at the 0.05 level (2-tailed).

4 DISCUSSION

The present study compared the different methods for obtaining REE in overweight subjects. The commonly used predictive equations are less appropriate in comparison to a hand-held calorimeter [17, 25]. In comparison to a hand-held calorimeter, predictive equations do not account for differences in body composition and other conditions that also affect REE. Furthermore, a hand-held calorimeter can be more practical for use in a clinical environment. However, some authors reported that a hand-held calorimeter could be less accurate in determining REE than predictive equations in healthy people [26].

Following the recommendations of the American Dietetic Association (ADA) [8] and the Dietitians of Canada [27], the Mifflin–St Jeor (MSJ) equation is considered more reliable, especially in obesity. We were interested in the results of comparisons between measured and different predictive equations for estimating the REE.

Our results have shown statistically significant differences in a few of the observed parameters between, before and after intervention (Table 3 and Table 4). There was a statistically significant difference in the predicted REE values before and after intervention calculated with the Harris–Benedict equation, the Mifflin–St Jeor equation, the Owen equation and the Wright equation both in females and males. However, we could not find any significant changes in the measured REE in females; other studies also support these findings [28–29]. Furthermore, the results we obtained from the Tanita scale did not show any statistically significant differences in REE values before and after the intervention (in females and males). A possible reason for this could be that the Tanita scale was calibrated for a normal, healthy population (and not for overweight adults), therefore, this could be a reason for results that are different from others. After a 6-month intervention and significantly lower bodyweight, the REE was not statistically different in women. On the other hand, the measured REE in male participants was statistically different after intervention.

The comparison of the measured REE and the selected predictive equations (Table 5 and Table 6) showed different results for females and males. The one-sample t-test that was conducted in female REE showed a statistically significant difference between the measured REE and four out of five selected predictive equations (Table 5). All the selected equations have overestimated measured REE. Furthermore, all the selected equations (with the exception of Owen's equation) showed a significant difference with the measured REE. The results that we obtained from the Owen's equation are also considered as accurate predicted values because they were within ±10% of the value of the measured REE. A correlation analysis conducted between indirect calorimetry and predicted equations showed the strongest correlation with the Owen equation ($r=0.614$, $p<0.005$); all other correlations were strong and significant. Our findings are inconsistent with other studies, which found that HB and MSJ equations are a reliable tool for predicting REE [30–31]. In male participants (Table 6) the difference was significant between the measured and predicted REE with Tanita, Harris–Benedict and Wright equations. The most suitable one for male participants was the MJS equation (the calculated value of REE was -1%) and the Owen equation (the calculated value of REE was +7%). The values fell within ±10% of the value of the measured REE. Although other authors [32–33] demonstrated great accuracy also for the HB equation, we could not confirm this (percent of predicted REE was not within ±10% of the measured REE neither for females nor males). Recently published studies that compare different predictive equations and measured REE on healthy adults also came to the conclusion that the most suitable predictive equation for overweight Caucasian adults would be Owen's equation [23, 34].

Other authors [6, 31] demonstrated that the HB predicted REE was higher than the measured REE; the same results were obtained in our study. The correlation between the predicted Harris–Benedict equation and the measured REE in females was 0.58. On the other hand, there are a few studies concluding that the equations (by HB, O and MJS) underestimated the REE measured with indirect calorimetry [7, 10, 35].

The present study has limitations. This is a study with a small sample, because it's an intervention-based study on human subjects. This diminishes the strength of conclusions, which is usual for such studies. For this reason, we rely on clear statistical tests. Another limitation of the study is the fact that we did not use any gold standard method to measure REE. Usually, such methods are not available to dietitians in practice and, consequently, not in line with the study purpose. The strength of the study is that it takes account of real problems and limitations, so the results could provide a rationale for developing better prediction equations and for validating other portable indirect calorimeters to use in practice.

5 CONCLUSION

With the development of a practical and simple device for indirect calorimetry the necessity for using indirect calorimetry in obesity prevention has emerged.

One of the most important outcomes of the nutritional intervention is weight loss [13]. Since obesity intervention programs include physical activity that increase muscle mass, it can be assumed that the REE also increases. But this is not so. The results after our intervention program showed reduced fat mass, fat-free mass and REE. Reduced REE occurred despite the fact that we added physical activity to our intervention [13, 36]. Not only is the degree of energy deficit important, but the distribution of macronutrients and the amount of protein per kilogram of bodyweight is also of great importance in determining fuel substrate utilisation [36]. We were interested in the various predicted equations so that we could find the most suitable one to use when indirect calorimetry is not available. We have demonstrated that the most comparable equation for our participants was the Owen equation (both for females and males). This equation gave us the most comparable results with the measured REE. According to our data, which is also confirmed by some studies [23, 34], Owen's equation can be used in predicting REE in overweight adults. This protocol can be used in clinical and non-clinical environments, in environments that can't afford handheld calorimeters, and where the predictive equation is the only way to estimate REE.

In conclusion, the energy deficit, macronutrient distribution and the rate of weight loss may be key factors in the retention of fat-free mass and REE. Dietary information should be prescribed and described on an individual basis. Because of the differences that occur in the literature, there is plenty of space for further research.

CONFLICTS OF INTEREST

The authors declare that no conflicts of interest exist.

FUNDING

There is no financial interest or risk.

ETHICAL APROVAL

The protocols and procedures of this study were in agreement with the ethical guidelines on biomedical research on human subjects and the study was approved by the Republic of Slovenia National Medical Ethics Committee on 6.1.2012 (No.: 56/08/11 bus). Written consent was obtained from all the subjects.

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