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Research Article

INDIRECT CALORIMETRY IN THE ASSESSMENT OF THE ENERGY REQUIREMENT IN OVERWEIGHT AND OBESE WOMEN

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ABSTRACT

Individual total energy expenditure may be calculated as a sum of basal energy requirement and energy expenditure associated with physical activity. Measurement of basal energy requirement is not often conducted in dietetic practice, but may be applied using indirect calorimetry. The aim of the analysis was to present the possibilities of using the Fitmate PRO monitor in the assessment of resting metabolic rate and basal energy expenditure with a method of indirect calorimetry in a group of 91 overweight and obese women in various age. The mean results of the resting metabolic rate measured with method of indirect calorimetry using the Fitmate PRO monitor did not differ in the age groups of overweight and obese women. The results of the resting metabolic rate measured with method of indirect calorimetry using the Fitmate PRO monitor were correlated with body mass, height, fat mass, muscle mass and waist circumference. The Fitmate PRO monitor may be a valuable tool in everyday dietetic practice to assess the basal energy expenditure with method of indirect calorimetry in a group of overweight and obese women.

Keywords: energy requirement, energy expenditure, device, Fitmate monitor.

INTRODUCTION

Individual energy requirement, being equivalent to energy expenditure, is defined as such energy value of diet that allows to perform all everyday activities, simultaneously ensuring wellbeing (or preventing worsening of general condition) and stable body mass, while specified level of physical activity is observed. In case of individuals in specific conditions, energy requirement should also take into account the quantity of energy stored (children, pregnant women) or released (nursing mothers) [14]. For malnourished individuals and while intensive catabolism is observed, it should allow for reimbursement of deficiencies of energy or intensified losses [12].

Individual total energy expenditure may be calculated as a sum of basal energy requirement and energy expenditure associated with physical activity [4, 32]. The energy expenditure associated with physical activity may be estimated by using physical activity level (PAL) indexes that allow evaluating energy expenditure associated with physical activity, as a magnification of basic energy expenditure, by using physical activity recall or physical activity monitors [36]. However, as basal energy requirement is a predominant factor creating total energy expenditure, its proper estimation is especially important.

The report of Food and Agriculture Organization of the United Nations/ World Health Organization (FAO/ WHO) and United Nations University (UNU) experts published in 2004 [8] recommends to estimate basal energy requirement on the basis of the predictive formulas, taking into account gender, age and body mass (Table 1). Also other authors elaborated own predictive formulas to estimate basal energy expenditure [15,

Table 1. Predictive formulas to estimate basal energy requirement by Food and Agriculture Organization of the United Nations/ World Health Organization (FAO/ WHO) and United Nations University (UNU) [8]*

Age	Female	Male
< 3 years	(59.512 x body mass) – 30.4	(58.317 x body mass) – 31.1
3–10 years	(22.706 x body mass) + 504.3	(20.315 x body mass) + 485.9
10–18 years	(17.686 x body mass) + 658.2	(13.384 x body mass) + 692.6
18–30 years	(15.057 x body mass) + 692.2	(14.818 x body mass) + 486.6
30–60 years	(11.472 x body mass) + 873.1	(8.126 x body mass) + 845.6
> 60 years	(11.711 x body mass) + 587.7	(9.082 x body mass) + 658.5

* Body mass expressed in kg.

Table 2. Predictive formulas to estimate basal energy requirement*

Adult female	Adult male	Author
655 + (9.6 x body mass) + (1.8 x height) – (4.7 x age)	66 + (13.7 x body mass) + (5 x height) – (6.8 x age)	[15]
795 + (7.18 x body mass)	879 + (10.2 x body mass)	[26, 27]
9.99 x body mass + 6.25 x height – 4.92 x age – 161	9.99 x body mass + 6.25 x height – 4.92 x age + 5	[23]

* Body mass expressed in kg, height expressed in cm, age expressed in years.

23, 26, 27] (Table 2), as mentioned assessment is of great importance in body mass reduction of individuals. The presented formulas are most often used in dietetic practice to estimate energy requirement and, as a consequence, energy value of a weight-reducing diet [29].

As overweight and obesity have recently become a very serious problem, also energy value of weight-reducing diet is an important issue. Overweight and obesity are results of imbalance between the provided and utilized energy lasting for longer period of time, calculation of proper energy value of diet is of a great value [19].

According to the estimations by WHO, in case of over 1.4 billion of adults in the world, overweight is observed, while in case of 200 million of men and 300 million of women – even obesity [38]. Overweight is diagnosed when body mass index (body mass [kg]/ height^2[m^2]) is higher than 25 kg/m^2, while obesity – when it is higher than 30 kg/m^2 [39]. During the last 30 years, in the developed countries, constant increase of overweight and obesity incidence is observed, while in Europe during the last 20 years obesity incidence increased by twice [37].

The basal energy requirement depends mainly on fat-free mass [22]. In spite of the fact that in obese individuals, both fat mass and fat-free mass are higher than in individuals characterized by proper body mass, fat-free mass is responsible for 25% of higher mass only [28]. As a consequence, in obese individuals using widely applied formulas to estimate basal energy requirement, may be associated with serious overestimation of energy expenditure. To avoid such a misestimation, in obese individuals energy requirement should not be estimated, but measured, if it is possible [5]. Such a measurement is not often conducted in dietetic practice, but may be applied using indirect calorimetry [1, 9].

Indirect calorimetry is the method of measuring the amount of heat generated in an oxidation reaction by determining the intake of oxygen or by measuring the amount of carbon dioxide/ nitrogen released, followed by translating these quantities into a heat equivalent [5]. Such measurement may be conducted in practice using various equipments – either metabolic chamber (small room where individual can live in for a 24 hour period) or ventilated hood, face mask and mouthpiece (demanding conducting measurement while an individual is sitting or lying) [6, 25]. While the measurement conducted in the metabolic chamber may be very onerous for a participant and requires a very expensive equipment, other devices, dedicated solely to basal energy requirement measurement may be very useful in everyday practice.

The aim of the analysis was to present the possibilities of using the Fitmate PRO monitor in the assessment of the basal energy expenditure with method of indirect calorimetry in a group of overweight and obese women.

MATERIALS AND METHODS

The measurement of the energy expenditure was conducted with a method of indirect calorimetry using the Fitmate PRO monitor (Cosmed Pulmonary Function Equipment Srl, Italy) in a group of 91 overweight and obese women (BMI >25 kg/m^2) in various age (24 individuals: <40 years, 44 individuals: 40–50 years, 23 individuals: >50 years).

Fitmate PRO monitor allows to assess resting energy requirement (basal energy requirement increased by energy requirement associated with being in the resting state – in a lying position without any movements) (Figure 1) and fitness assessment, associated with cardiorespiratory system (maximum volume of oxygen uptake – VO_{2max}). It also allows for the automatic generation of suggested individualized body mass reduction program (Figure 2).

The measuremet was conducted according to a widely applied methodology. In order to assess resting metabolic rate (resting energy requirement) [30], participants were to be in a fasting state (not eating for 12 hours), in the condition of thermal and psychological comfort (constant temperature in the room – 22 ± 1°C), in the semi-recumbent position (Figure 3) [24]. The disposable masks adhering face were used (with the possibility to breathe through the mouth and nose). The measurement lasted at least 20 minutes, after 5 minutes of adaptation (in such conditions coefficient of variance is lower than 10%) [5]. Additionally, participants were asked to avoid intensive physical activity during 24 hours before measurement, as well as smoking, drinking coffee and tea during 12 hours before measurement. Before measurement, to assess the daily calories and protein intake, 24-hour dietary recall was conducted [18].

The Fitmate PRO monitor conducts measurement every 30 seconds (for each breath) – it measures air flow and volume of oxygen in the breath [ml/ min], using Galvanic Fuel Cell (GFC), characterized by measurement range of 0–25% and accuracy of measurement of ± 0.02% [10]. The obtained values of the volume of oxygen accompanied by information about kcal and protein intake during the day before measurement may be used to calculate resting metabolic rate. Resting metabolic rate may be calculated using a modified Weir equation:

$$RMR = (3.941 \times VO_2) + (0.85 \times 1.106 \times VO_2) - (2.17 \times Un)$$

where: RMR – resting metabolic rate [kcal/24h]
VO_2 – volume of oxygen in the breath [ml/ min]

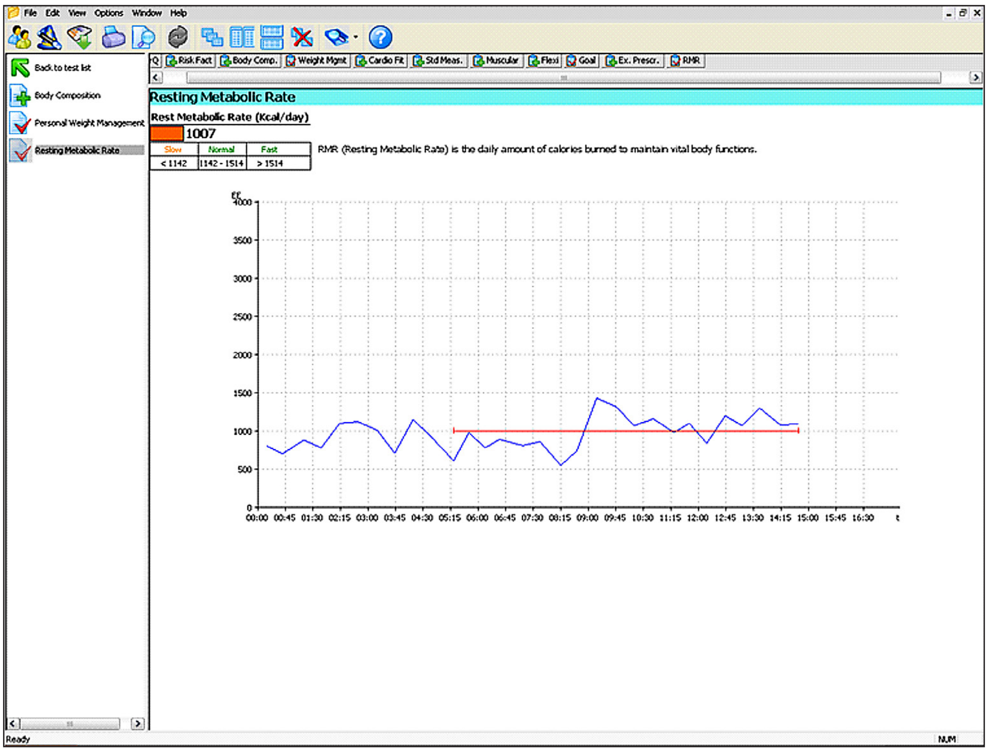

Fig. 1. The example of results of resting metabolic rate [kcal/ 24 h], measured using the Fitmate PRO monitor, in function of time, accompanied by calculated mean value

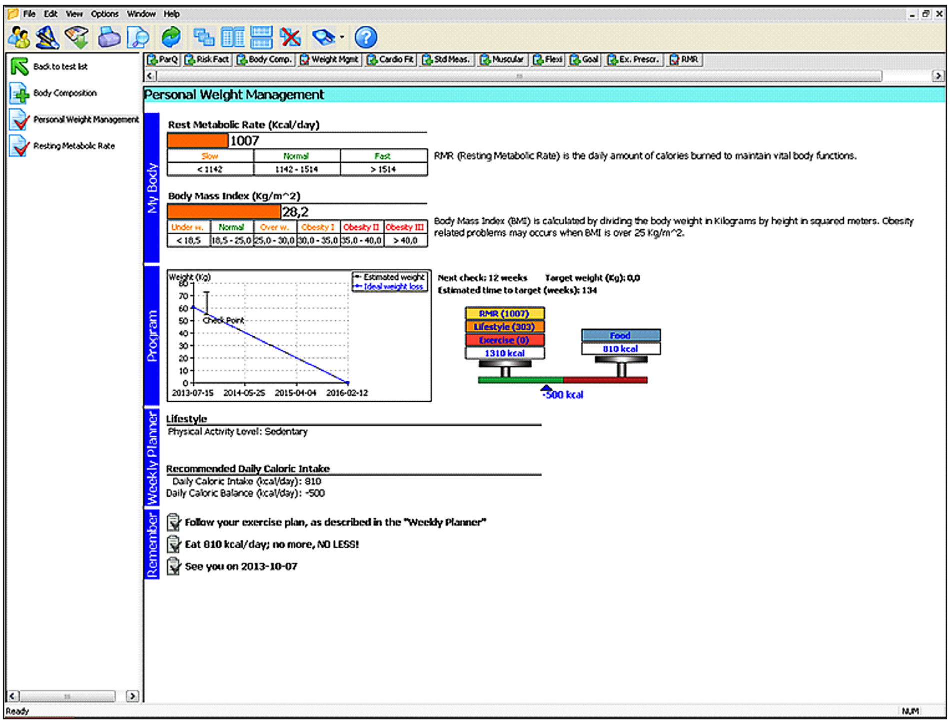

Fig. 2. The example of results of resting metabolic rate [kcal/24 h] measured using the Fitmate PRO monitor, in the aspect of body mass reduction (accompanied by BMI, expected pace of body mass reduction and suggested background of individualized body mass reduction program)

Fig. 3. The measurement of resting metabolic rate using Fitmate PRO monitor [photo: Roman Andrasik]

> *Un* – urinary nitrogen = [(kcal/24h×0.16)×4] /6.25 (in the case of western diet characterized by typical protein content) [33, 34].

The values for RMR are compared to the predicted ones, calculated using the Harris-Benedict equation, and classified according to the following scale of the peace of metabolism (being simultaneously the peace of body mass reduction):

- low – if the measured value is >14% lower than the predicted value,
- normal – if the measured value is between 86% and 114% of the predicted value,
- fast – if the measured value is >14% higher than the predicted value.

The experimental protocol were approved by the Bioethical Commission of the Warsaw Food and Nutrition Institute (date: 29.10.2009).

To verify the normality of distribution, the W Shapiro-Wilk test was used. Differences between groups were assessed using analysis of variance and post-hoc LSD test. The analysis of correlation was conducted using Pearson's correlation coefficient. The level of significance α = 0.05 was used. Statistical analysis was conducted using Statistica software version 8.0 (StatSoft, Tulsa, Oklahoma, USA).

RESULTS AND DISCUSSION

The study examining the validity and reliability of handheld calorimeters for measuring resting energy expenditure on the basis of the published literature concludes that handheld calorimeters are very useful in clinical practice [31]. They are more accurate than predictive equations based on gender, age, and ethnicity for determining resting metabolic rate and are therefore a viable alternative for clinical evaluation of the hospitalized patient [20].

The resting metabolic rate measured with method of indirect calorimetry using the Fitmate PRO monitor is not the same as the basal energy requirement estimated on the basis of the predictive formulas. It must be emphasized, that the value of resting metabolic rate should be higher than the value of basal energy requirement. However, the mentioned value is also useful, as it allows to approximate the energy value of the weight-reducing diet for overweight and obese individuals.

It was observed that the mean results of the resting metabolic rate measured with method of indirect calorimetry using Fitmate PRO monitor did not differ in the age groups of overweight and obese women. For the age <40 years it was 1413.7 ± 219.6 kcal/24h, for the age ϵ <40–50 years> it was 1471.6 ± 259.6 kcal/24h, and for the age > 50 years it was 1367.8 ± 303.7 kcal/24h. For the $\alpha = 0,05$ in the case of analysis of variance and post-hoc LSD test, no significant differences between groups were observed. Also analysis of correlation between resting metabolic rate and age (conducted using Pearson's correlation coefficient) revealed no significant relationship. The presented results seem to be quite typical, as in other research, results observed for female individuals are similar [16]. Also in the case of formerly obese individuals, the resting metabolic rate is similar [2], while in case of morbid obesity it may be even higher [13]. It may be associated with the fact that resting metabolic rate depends on body mass index and for obese individuals it is higher than for overweight individuals, while per kg of body mass, opposite relationship is observed [35].

Simultaneously, the correlations between resting metabolic rate and other factors were analysed. It was concluded, that the results of the resting metabolic rate were correlated with body mass (p=0.0000, R=0.47), height (p=0.0143, R=0.26), fat mass measured using the bioimpedance method (p=0.0000, R=0.44), muscle mass measured using the bioimpedance method (p=0.0003, R=0.37) and waist circumference (p=0.0000, R=0.43). All the mentioned correlation were observed for Pearson's correlation coefficient.

The general limitations of the indirect calorimetry method in the assessment of basal energy expenditure are associated with a few factors. The measurement is conducted for the whole body, as the sum of all active tissues in body, not just contracting skeletal muscle [3, 21]. The measurement can only be accurately used for metabolic intensities, economy, efficiency, and energy expenditure during steady state [7]. Moreover, the method may be highly sensitive to measurement error [17]. Simultaneously, it needs sophisticated and expensive equipment (either metabolic chamber or ventilated hood, face mask, mouthpiece) and may be in various extent onerous for participant and expensive, however, this aspect is important mainly in the case of metabolic chambers [11].

On the other hand, taking into account a significant correlation of the resting metabolic rate measured with method of indirect calorimetry using Fitmate PRO monitor with body mass, fat mass, muscle mass and waist circumference, it seems to be an important possibility in planning the diet reduction therapy, especially in a group of overweight and obese individuals. Moreover, taking into account the problems mentioned in assessing basal metabolic rate in the case of overweight and obese individuals, estimating the resting metabolic rate would be of a great value. It may be concluded, that if Fitmate PRO monitor is available, such measurement would enable better adjustment of background of body mass reduction program in an individual case.

CONCLUSIONS

1. The mean results of the resting metabolic rate measured with method of indirect calorimetry using Fitmate PRO monitor did not differ in the age groups of overweight and obese women.
2. The results of the resting metabolic rate measured with method of indirect calorimetry using Fitmate PRO monitor were correlated with body mass, height, fat mass, muscle mass and waist circumference.
3. Fitmate PRO monitor may be a valuable tool in everyday dietetic practice to assess the basal energy expenditure with method of indirect calorimetry in a group of overweight and obese women.

All experimental protocols were approved by the Bioethical Commission of the Warsaw Food and Nutrition Institute (date: 2009.10.29).

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