Iran J Public Health, Vol. 44, No.6, Jun 2015, pp.822-829

Original Article

Comparison of Indirect Calorimetry and Predictive Equations in Estimating Resting Metabolic Rate in Underweight Females

Soghra ALIASGHARZADEH [1], *Reza MAHDAVI [2], Mohammad ASGHARI JAFARABADI [3], Nazli NAMAZI [2]

1. *Student Research Committee, Faculty of Nutrition, Tabriz University of Medical Science, Tabriz, Iran*
2. *Nutrition Research Center, Faculty of Nutrition, Tabriz University of Medical Science, Tabriz, Iran*
3. *Traffic Injury Prevention Research Center, Faculty of Health, Tabriz University of Medical Sciences, Tabriz, Iran*

***Corresponding Author:** Email: Mahdavirez@hotmail.com

(Received 08 Oct 2014; accepted 10 Mar 2015)

Abstract

Background: Underweight as a public health problem in young women is associated with nutritional deficiencies, menstrual irregularity, eating disorders, reduced fertility, etc. Since resting metabolic rate (RMR) is a necessary component in the development of nutrition support therapy, therefore we determined the accuracy of commonly used predictive equations against RMR measured by indirect calorimetry among healthy young underweight females.

Methods: This cross-sectional study was conducted on 104 underweight females aged 18-30 years old with body mass index (BMI) <18.5 kg/m² in 2013 . After collecting anthropometric data, body composition was measured by bioelectric impedance analysis (BIA). RMR was measured by using indirect calorimetry (FitMate™) and was estimated by 10 commonly used predictive equations. Comparisons were conducted using paired *t*-test. The accuracy of the RMR equations was evaluated on the basis of the percentage of subjects' predicted RMR within 10% of measured RMR.

Results: The mean BMI of subjects was 17.3±1.3 kg/m². The measured RMR ranged 736-1490 kcal/day (mean 1084.7±175 kcal/day). Findings indicated that except Muller and Abbreviation, other equations significantly over estimated RMR, compared to measured value (P<0.05). As an individual prediction accuracy, these predictive equations showed poor performance with the highest accuracy rate of 54.8% for Muller equation (22.1% under and 23.1% over-prediction) and 43.3% for Abbreviation equation (31.7% under and 25% over-prediction), the percentage bias was 1.8% and 0.63% and RMSE was 162 and 173 kcal/d, respectively.

Conclusion: Although Muller equation gave fairly acceptable prediction, more suitable new equations are needed to be developed to help better management of nutritional plans in young underweight people.

Keywords: Resting metabolic rate, Predictive equation, Indirect calorimetry, Underweight

Introduction

In spite of increasing the prevalence of overweight worldwide, underweight remains a major public health problem in the developing countries (1). Underweight might actually be more frequent than obesity (2). Underweight is associated with nutritional deficiencies, negative body image, fatigue, menstrual irregularity, eating disorders and may also predict an increased risk of osteoporosis and reduced fertility as an adult (3-5). In addition, 81% of non-western societies prefer plump or moderately fat women (6). Therefore, in these societies underweight has been linked to body image dissatisfaction which induces a tendency to achieve desirable body weight and shape by self-diet management or consulting the dietitian.

Measurement of resting metabolic rate (RMR), as a major component of energy expenditure, plays a critical role in the development of nutrition support therapy to estimate total energy requirements (7-9). Indirect calorimetry is the reference standard for measurement of RMR in research studies (10, 11). However due to complexity, high cost of application, lack of skilled staff, hard feasibility and time consuming, is not always possible to be used in clinical settings (12, 13). Various studies have been undertaken to develop some predictive equations for estimating RMR such as Harris-Benedict, Mifflin, WHO/FAO/UNU, Muller, Owen, Schofield and Liu formulas (14-20). These equations are based upon regressive analysis of body weight, height, sex, age, fat free mass, fat mass, body surface area as independent variables. Besides, it has been reported that ethnicity is an effective factor in RMR prediction (20). Therefore determination of the most appropriate equations that can accurately predict RMR for different ethnic groups has been suggested (20, 21). Frankenfield and colleagues identified that there are disparities in knowledge regarding the applicability of current metabolic rate prediction equation in different populations and suggested validation studies in different racial/ethnic populations (10). More recently, several authors have validated RMR predictive equations in healthy subjects with different weights and races/ethnicities. They have indicated that several commonly used equations such as Harris-Benedict, FAO/WHO/UNU, Mifflin and Owen et al formulas may not be appropriate for metabolic rate prediction in certain different weights and racial/ethnic groups (17, 21- 23). In addition, most of the commonly used predictive equations were developed from studies in normal, overweight and obese subjects and such equations were less accurate for underweight subjects (16). Therefore, they developed different formulas for different ranges of body mass index, including one for BMI <18.5 kg/m^2.

In order to determine the most appropriate predictive equation for the Iranian underweight females, this study aimed to compare the accuracy of the commonly used RMR predictive equations with RMR measured by indirect calorimetry.

Materials and Methods

Subjects

In this cross-sectional study conducted in 2013, 104 volunteer female students were recruited from Tabriz universities via flyers and announcements. Inclusion criteria were included: being apparently healthy had no chronic disease (e.g. cancer, type 2 diabetes, etc.), age range of 18-30 years old and had BMI<18.5 kg/m^2. Exclusion criteria were included: pregnancy, lactation, being athlete and current using of medications known to affect RMR (e.g. diuretics, corticosteroids, anti-psychotic and thyroid drugs). The protocol of this study was approved by the Ethics Committee of Tabriz University of Medical Sciences and. Before study written informed consent document was obtained from all participants.

Anthropometric measurements

Weight was measured to the nearest 0.1 kg using the in-built BIA as a weight scale; participants were weighed in light clothing without shoes. Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer while subjects were standing without shoes with shoulders in a standard position. Body mass index (BMI) was calculated as the weight in kilograms divided by the height in square meters (kg/m^2). Waist circumference was measured between the inferior margin of the last rib and the iliac crest. The greatest circumference of hip was considered as the hip circumference and the waist to hip ratio (WHR) was calculated.

Body composition

Body composition was measured by bioelectrical impedance analysis (BIA). This method is widely used because it is relatively cheap, quick, and non-invasive and requires limited operator training (24). TANITA BC-418 MA eight electrode, hand to foot system (Tanita Co., Tokyo, Japan) was used for measurements of impedance (±1 Ω), estimation of body fat (±0.1%), FM (±0.1 kg) and FFM (±0.1 kg), at a frequency of 50 kHz. The subjects' age, gender, and height of each subject were entered in to the machine, and a standard 2 kg was entered as an adjustment for clothing weight in all participants. Subjects were then asked to stand barefoot on the metal foot-plates of the machine while holding the handles for ~30 sec.

Resting metabolic rate

RMR was determined by using of the Fitmate instrument. The Fitmate was developed by Cosmed (Roma, Italy) is a new portable metabolic analyzer designed to measure oxygen consumption and resting metabolic rate. This instrument uses a turbine flow meter that is located at the end of a disposable face mask for measuring minute volume and galvanic full cell oxygen sensor for analyzing the FeO2. Using a fixed RQ (Respiratory Quotient) of 0.85, calculation of RMR is allowed. In a previous study, FitMate™ gave reproducible and accurate oxygen consumption and RMR measurements when compared to the Douglas bag method and no significant differences were reported between two techniques for oxygen consumption and RMR in a wide range of BMI (25).

In this study, participants underwent to evaluation between 8:00 to 10 am in the morning after 10-12 h fasting and were advised to avoid strenuous exercise from 24h before RMR measurement and refrain from caffeinated beverages and medications. Subjects sat quietly for 20 minutes prior to RMR measurement, then they were asked to put Fitmate mask on their nose and mouth at sitting and supine position in a quiet room with temperature around 25 °C. Using the Fit Mate™ metabolic system for 15 minutes, the resting energy expenditure was measured. Calibration was done automatically for every measurement (25)

For each subject, RMR was estimated using the selected equations, as listed in Table 1 and compared to measure RMR.

Table 1: Equations used to predict resting metabolic rate (kcal/day)

Mifflin	9.99 ×weight + 6.25× height - 4.92 × age - 161
Muller	(0.08961 × FFM + 0.05662 × FM + 0.667) × 238.84
Owen	795 + 7.18 × weight
Schofield*	14.8 × weight + 487
Schofield**	13.6 × weight + 283 × hight2 + 98
Harris-Benedict	665 + 9.56 × weight + 1.84 × height - 4.67 × age
Abbreviation	0.95×24×weight
WHO*	8.7 × weight + 829
WHO**	8.7 × weight + (25 × hight2) + 865
Liu	(13.88 × weight) + (4.16× height) - (3.43 × age) + 54.34

* Weight based formula.
**Weight and height based formula

Statistical analysis

All data were reported as means ± standard deviation. Paired t-test was used to evaluate the difference between the measured RMR values and those estimated by predictive equations. Accuracy of predictive formulas at the individual level was defined as percentage of the subjects who's predicted RMR was within ±10% of measured RMR (12, 26). A prediction <90% of measured RMR was considered as under-prediction, and a prediction > 110% of measured RMR was considered as over-prediction. Group level accuracy was considered as the mean percentage difference (bias) between measured and predicted RMR. The root mean squared prediction error (RMSE) was used to indicate how well the model predicted in our data set (12). Bland-Altman analysis was used to determine the extent of error for predictive equations compared to measure RMR (27, 28). Data were analyzed using SPSS statistical package, version 16 (SPSS Inc., Chicago, IL). *P*-value <0.05 was considered as statistically significant.

Results

Physical characteristics of 104 underweight female students have been shown in Table 2. All subjects were between 18 and 30 years old. The mean body mass index (BMI) was 17.3±1.3 kg/m^2 (13.4-19.2). Comparison of measured RMR with predicted RMR are presented in Table 3, the mean measured RMR derived from the FitMate™ was 1084.7±175 kcal/day (736-1490). There were no significant differences between measured RMR and RMR calculated by Muller and Abbreviation equations.

Table 2: Baseline Characteristics of underweight female subjects (n=104)

Variable	Mean ± SD
Age(yr)	21.9±2.2
Weight(kg)	46.3±4.6
Height(cm)	163.6±4.8
BMI(kg/m2)*	17.3±1.3
Wrist circumference (cm)	14.6±0.6
Waist circumference (cm)	66.3±7.5
Hip circumference (cm)	89.7±5.2
WHR¶	0.7±0.1
FFM§ (kg)	38.1±3.8
FM £ (kg)	8.0±2.9
FM (%)	16.8±4.9
RMR† (kcal/day)	1084.7±175

* BMI, body mass index
¶ WHR, Waist to hip ratio
§ FFM, fat free mass
£ FM, fat mass
† RMR, Resting metabolic rate

Table 3: Comparison of measured RMR with predicted RMR in underweight females

Variable	Meas±SD (kcal/day)	Mean difference±SD (kcal/day)	95% Confidence Interval	*P* value¶
Measured RMR	1084.7±175.0	-	-	-
Predicted RMR				
Mifflin	1216.5±70.9	131.8±165.9	99.6 to 164.1	<0.001
Muller	1082.0±97.3	-2.8±163.1	-34.5 to 29.0	.863
Owen	1126.9±33.2	42.2±166.7	9.8 to 74.6	.011
Schofield*	1172.3±68.5	87.5±164.9	55.5 to 119.6	<0.001
Schofield**	1190.7±73.0	105.9±165.3	73.8 to 138.1	<0.001
Abbreviation	1055.7±105.6	-29.0±171.0	-62.3 to 4.2	.087
Harris-Benedict	1306.6±51.3	221.9±164.9	189.8 to 254.0	<0.001
WHO*	1231.9±40.3	147.1±165.8	114.9 to 179.4	<0.001
WHO**	1308.7±41.1	224.0±165.7	191.7 to 256.2	<0.001
liu	1302.6±79.4	217.9±166.0	185.6 to 250.2	<0.001

* Weight based formula/ ** Weight and height based formula
¶ *P* values are obtained by paired t-test analysis.

Bland-Altman plots displaying bias and agreement of 3 selected predicted equations are presented in Fig. 1. The lowest mean difference between measured RMR and estimated RMR was found in the Muller prediction equation with mean difference of -2.8 kcal/day and the 95% limits of agreement from 316.9 to -322.5 kcal/day.

Compared to measured RMR values, the Abbreviation and Muller equations slightly under-predicted RMR, while other equations significantly over-predicted it. Maximum over-prediction was provided by Harris-Benedict equation (76.9%). Table 4 shows the accuracy rates, percentage bias and the RMSE values (in kcal/d) of different predicted equations in studied subjects. As indicated in Table 4, the range of accuracy varied between equations from 23.1% to 54.8%. The percentage bias for equations varied from -0.63% to 24.6%, and the RMSE varied from 162 to 278 kcal/d. Among ten equations, the highest accuracy rate was produced by the Muller equation, with 54.8% accurate prediction (22.1% under-prediction and 23.1% over prediction) and a small percentage bias of 1.8% and RMSE of 162 kcal/d. The lowest percentage bias was found in the abbreviation equation (-0.63); however the accuracy rate was 43.3% and RMSE was 173 kcal/d. The Owen equation provided 47.1% accurate prediction (with 16.3% under-prediction and 36.5% over-prediction), with a bias of 6.8% and RMSE of 171 kcal/d.

Table 4: The accuracy rates of RMR predicted by different equations in underweight female subjects (n=104)

RMR predictive equations	Accurate predictions¶ (%)	Under-predictions§ (%)	Over-predictions£ (%)	Bias† (%)	Maximum negative error‡(%)	Maximum positive errorϛ (%)	RMSE (kcal/d)
Mifflin	40.1	7.7	51.9	15.4	-13.6	60.01	211
Muller	54.8	22.1	23.1	1.8	-36	38	162
Owen	47.1	16.3	36.5	6.8	-22	47	171
Schofield*	39.4	12.5	48.1	11	-16	53	186
Schofield**	37.5	11.6	50.9	12.8	-14	56	195
Harris-Benedict	23.1	0	76.9	24.3	-8	68	276
Abbreviation	43.3	31.7	25	-0.63	-27	45	173
WHO*	35.6	6.7	57.7	17.02	-14	60	221
WHO**	25	0	75	24.6	-9	70	278
Liu	26.9	0	73.1	23.8	-6	72	273

* Weight based formula

**Weight and height based formula

¶ The percentage of subjects predicted by this predictive equation within ±10% of the measured value.

§ The percentage of subjects predicted by this predictive equation within <10% of the measured value.

£ The percentage of subjects predicted by this predictive equation within>10% of the measured value.

†Mean percentage error between predictive equation and measured value.

‡ The largest under-prediction that was found with this predictive equation as a percentage of the measured value.

ϛ The largest over-prediction that was found with this predictive equation as a percentage of the measured value.

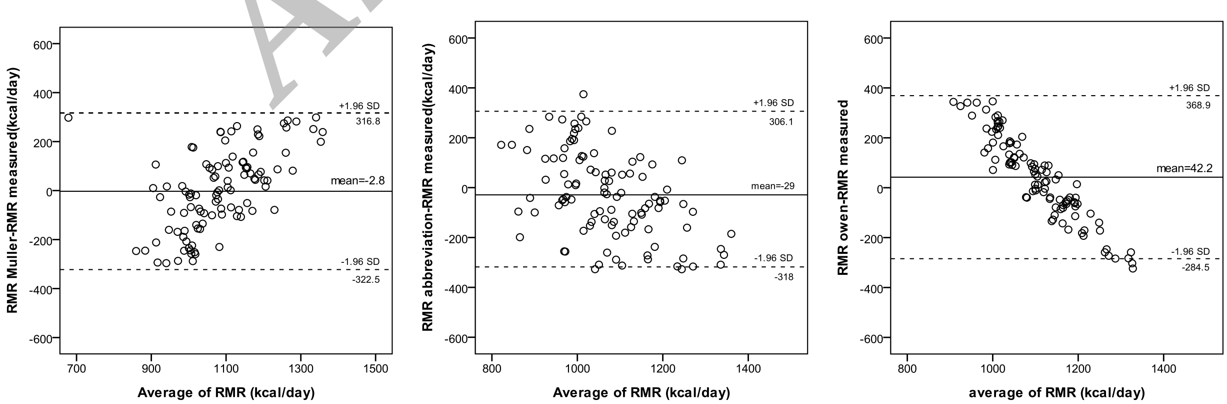

Fig. 1: Bland-Altman plots for 3 selected BMR predictive equations. Solid lines indicate the mean difference between predicted and measured RMR values. Dashed lines indicate the limit of agreement

Discussion

The commonly used predictive equations were not appropriate for underweight subjects and created a new predictive equation for this specific population (17). In this study, we evaluated accuracy of Muller and different previously developed RMR predictive equations against measured RMR in 104 Iranian healthy underweight female students. We found that among 10 RMR predictive equations that were used in this study, Muller et al. equation gave a fairly acceptable RMR prediction, while most of the commonly used RMR predictive equations did not accurately predict RMR at both group and individual levels. Our data also showed that all of the equations except Muller and Abbreviation equations significantly overestimated RMR in underweight young females, with mean differences ranging from 42.2 to 224kcal/day. Overestimations may be due to: first, it has been reported that energy requirements of people from developing countries are low and using standard equations might lead to greater bias and overestimation of energy requirements (29). Second, in underweight people adaptation to under-eating and underweight may result in hypometabolic status (30). Third, underweight subjects such as anorexia nervosa patients who are considered to be physically healthy, seem to be characterized by elevated RQ larger than 0.8. Since FitMate calculates RMR from oxygen consumption using a fixed RQ of 0.85, if RQ is between 0.85 and 1, underestimation is possible (31-33).

Since WHO equations have been derived from researches in subjects with a wide range of BMI, they are often applied for estimating RMR in underweight subjects (10). However in our study there were significant differences in RMR predicted by WHO equations and measured RMR with accuracy rates of 35.6% for weight-base and 25% for weight-based and height-base equations. Since WHO equations have been developed from research in Europeans and considering the impact of ethnicity on RMR, the WHO equations may not be appropriate for Asians, especially for Iranian underweight females. In addition, WHO weight-base predictive equation overestimates RMR at low body mass index (10).

It was reputed that Owen equation can be used for all weight group classifications (18). In this study, in spite of 47.1% accuracy rate, Owen equation had statistically significant difference with those measured by indirect calorimetry in group means. Although, Owen equation was developed from a sample of 44 women aged 18 to 65 years old, only one of them was underweight. Therefore, it appears that the Owen equation is not suitable for prediction of RMR in underweight individuals.

These discrepancies could be due in part to the differences in the body composition and physical activity level between subjects in the previous and current studies (34). It has been reported that the fat free mass play an important role in RMR value (7, 9) and the physical activity training also can influence RMR by increasing lean tissue mass and influencing residual metabolism rate (35). Furthermore, most of the equations have been developed from researches in western Caucasian people; it is likely that a greater proportion of body weight in western women is made up of muscle and viscera with higher energy expenditure, as compared to their Asian counterparts (34, 36). Harris-Benedict and WHO equations overestimated the RMR in Asian women (22). They indicated that measured RMR was significantly lower than predictive RMR using Harris-Benedict and WHO equations by 8.5% ($P<.001$) and 5.4% ($P<.01$), respectively (22).

The differences between measured and predicted RMR values may be partially explained by methodological problems. Since there are no reference databases for methodological approaches, the accuracy of studies can be affected by the different criteria of measurements such as measurement condition, time and etc. (8).

Limitations of this study include: first, the research was restricted to women with narrow age range (18-30 years old). Secondly, the absence of control group which would have helped to clarify potential BMI differences. Thirdly, we measured each subject only once thereby we could not estimate the intra-individual variation in RMR.

Conclusion

Muller equation gave fairly acceptable prediction in underweight female population. However, for better management of nutritional plans in this specific range of BMI, further studies are needed to develop and validate more suitable new equations.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgements

The authors are grateful for the financial support of Nutrition Research Center of Tabriz University of Medical Sciences. The authors also would like to thank the participants for their enthusiastic support. This article was written based on a dataset of MSc thesis (Soghra Aliasgharzadeh) registered in Tabriz university of Medical Science. The authors declare that there is no conflict of interests.

Reference

1. Bovet P, Kizirian N, Madeleine G, Blössner M, Chiolero A (2011). Prevalence of thinness in children and adolescents in the Seychelles: comparison of two international growth references. *Nutr J*, 10(1): 65.
2. Marques-Vidal P, Ferreira R, Oliveira J M, Paccaud F (2008). Is thinness more prevalent than obesity in Portuguese adolescents? *Clin Nutr*, 27(4): 531-36.
3. Ezzati M, Lopez AD, Rodgers A, Vander Hoorn S, Murray CJ (2002). Selected major risk factors and global and regional burden of disease. *Lancet*, 360:1347-60.
4. Luder E, Alton I (2005). The underweight adolescent. In Guidelines for Adolescent Nutritional Services. In: Strang J, Story M. Minnesota: University of Minnesota, 93-100.
5. Malina RM (1986). Motor development and performance of children and youth in undernourished populations. In: Katch, F.I, ed. Sport, Health and Nutrition. Human Kinetics, Champaign, 213-226.
6. Ember R.C, Ember M, Korotayev A, de Munck V (2005). Valuing thinness or fatness in women Reevaluating the effect of resource scarcity. *Evol Hum Behav*, 26: 257-70.
7. Wang Z, Heshka S, Gallagher D, Boozer C.N, Kotler PD, Heymsfield SB (2000). Resting energy expenditure-fat-free mass relationship: new insights provided by body composition modeling. *Am J Physiol Endocrinol Metab*, 279:539-45.
8. Marra M, Pasanisi F, Montagnese C, De Filipo E, De Caprio C, De Magistris L, Contaldo F (2007). BMR variability in women of different weight. *Clin Nutr*, 26:567-72.
9. Leibel R, Rosenbaum M, Hirsch J (1995). Changes in energy expenditure resulting from altered body weight. *N Engl J Med*, 332(10):621-28.
10. Frankfield D, Roth-Yousey L, Compher Ch (2005). Comparison of Predictive Equations for Resting Metabolic Rate in Healthy Nonobese and Obese Adults: A Systematic Review. *Am Diet Assoc*, 105:775-89.
11. Dellava JE, Hoffman DJ (2009). Validity of resting energy expenditure estimated by an activity monitor compared to indirect calorimetry. *Br J Nutr*, 102:155-59.
12. Weijs PJM, Vansant GA (2010). Validity of predictive equations for resting energy expenditure in Belgian normal weight to morbid obese women. *Clin Nutr*, 29:347-351.
13. Siervo M, Boschi V, Falconi C (2003). Which REE prediction equation should we use in normal-weight, overweight and obese women?. *Clin Nutr*, 22(2):193-204.
14. Harris JA, Benedict FG (1918). A biometric study of human basal metabolism. *Proc Natl Acad Sci USA*, 4:370-3.
15. Mifflin MD, Stjeor ST, Hill LA, Scott BJ, Daugherty SA, Koh YO (1990). A new predictive equation for resting energy expenditure in healthy individuals. *Am J Clin Nutr,* 51:241-7.
16. FAO/WHO/UNU (1985). Energy and protein requirements. Report of a joint FAO/WHO/UNU expert consultation. Geneva: WHO, WHO technical report service no. 724.

17. Muller MJ, Bosy-Westphal A, Klaus S, Kreymann G, Luhrmann PM, Neuhauser- Berthold M, et al (2004). World Health Organization equations have shortcomings for predicting resting energy expenditure in persons from a modern, affluent population: generation of a new reference standard from a retrospective analysis of a German database of resting energy expenditure. *Am J Clin Nutr*, 80:1379-90.
18. Owen OE, Kavle E, Owen RS, Polansky M, Caprio S, Mozzoli MA, et al (1986). A reappraisal of caloric requirements in healthy women. *Am J Clin Nutr*, 44:1-19.
19. Schofield WN (1985). Predicting basal metabolic rate, new standards and review of previous work. *Hum Nutr Clin Nutr*, 39:5-41.
20. Liu HY, Lu YF, Chen WJ (1995). Predictive equations for basal metabolic rate in Chinese adults: a cross validation study. *J Am Diet Assoc*, 95:1403-8.
21. Vander Weg MW, Watson JM, Klesges RC, Eck Clemens LH, Slawson DL, McClanahan BS (2004). Development and cross-validation of a prediction equation for estimating resting energy expenditure in healthy African- American and European-American women. *Eur J Clin Nutr*, 58:474-80.
22. Case KO, Brahler CJ, Heiss C (1997). Resting energy expenditures in Asian women measured by indirect calorimetry are lower than expenditures calculated from prediction equations. *J Am Diet Assoc*, 97:1288-92.
23. Nhung BT, Khan NC, Hop LT, Lien DT, Le DS, Hien VT, Kunii D, Sakai T, Nakamori M, Yamamoto S (2005). FAO/WHO/UNU equations overestimate resting metabolic rate in Vietnamese adults. *Eur J Clin Nutr*, 59(10):1099–1104.
24. Jebb SA, Cole TJ, Doman D, Murgatroyd PR, Prentice AM (2000). Evaluation of the novel Tanita body-fat analyser to measure body composition by comparison with a four-compartment model. *Br J Nutr*, 83:115-122.
25. Nieman DC, Austin MD, Benezra L, Pearce S, McInnis T, Unick J, Gross SJ (2006). Validation of Cosmed's FitMate™ in measuring oxygen consumption and estimating resting metabolic rate. *Res Sports Med*, 14:89- 96.
26. Frankenfield DC, Rowe WA, Smith JS, Cooney RN (2003). Validation of several established equations for resting metabolic rate in obese and nonobese people. *J Am Diet Assoc*, 103:1152–9.
27. Altman DG, Bland JM (1983). Measurement in medicine: the analysis of method comparison studies. *Statistician*, 32:307–317.
28. Bland JM, Altman DG (2003). Applying the right statistics: analyses of measurement studies. *Ultrasound Obstet Gynecol*, 22:85–93.
29. Scagliusi FB, Ferriolli E, Lancha Jr AH (2006). Underreporting of energy intake in developing nations. *Nutr Rev*, 64:319-330.
30. De Zwaan M, Aslam Z, Mitchell JE (2002). Research on energy expenditure in individuals with eating disorders: a review. *Int J Eat Disord*, 32(Suppl. 2):127-134.
31. Hlynsky J, Birmingham C. L, Johnston M, Gritzner S (2005). The agreement between the MedGem indirect calorimeter and a standard indirect calorimeter in anorexia nervosa. *Eating and Weight Disorders*, 10(4):83-87.
32. Holdy KE (2004). Monitoring energy metabolism with indirect calorimetry: instruments, interpretation, and clinical application. *Nutr in Clin Prac*, 19(5):447-54.
33. El Ghoch M, Albert M, Carlo C, Calugi S, Dalle Grave R (2012). Resting Energy Expenditure in Anorexia Nervosa: Measured versus Estimated. *J Nutr Metab*, doi: 10.1155 /2012/652932.
34. Wang J, Thornton JC, Russell M, Burastero S, Heymsfield S, Pierson Jr RN (1994). Asians have lower body mass index (BMI) but higher percent body fat than do whites: comparisons of anthropometric measurements. *Am J Clin Nutr*, 60:23-8.
35. Speakman JR, Selman C (2003). Physical activity and resting metabolic rate. *Proc Nutr Soc*, 62: 621-34.
36. Wouters-Adriaens MP, Westerterp KR (2008). Low resting energy expenditure in Asians can be attributed to body composition. *Obesity (Silver Spring)*, 16:2212-6.