Applicability of different resting energy expenditure prediction equations to overweight and obese women of childbearing age with fertility problems

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ABSTRACT

Background and Objectives: This study compared the accuracy of current energy formulas in predicting resting energy expenditure (REE) in overweight and obese women with fertility problems. **Methods and Study Design:** This study evaluated REE prediction formulas in 82 overweight/obese women (18-49 years) with fertility problems. REE is accurately measured using indirect calorimetry, which is considered the gold standard for evaluating energy. Anthropometric data, including height, weight, and waist circumference. Body composition analysis was performed using bioelectrical impedance analysis to determine fat-free mass and other related indicators. Statistical analyses included Spearman correlation coefficients to assess the relationship between REE and various predictors. The accuracy and reliability of the existing prediction equations were evaluated by comparing their predicted values with resting energy expenditure values measured by Indirect Calorimetry using Bland-Altman analysis. **Results:** Among the prediction equations assessed, Mifflin's equation demonstrated superior performance in estimating REE in overweight/obese women experiencing fertility problems, exhibiting the least bias (-9.7 kcal/day) and a low standard deviation (240 kcal/day). Variables such as body weight, lean body weight, and central obesity indicators like waist circumference and waist-height ratio emerged as significant predictors of REE, with their impacts being age-dependent. The Mifflin-St. Jeor Equation, which integrates weight, height, and age variables, offers a reasonably accurate estimation of energy needs for this specific demographic. **Conclusions:** The Mifflin-St. Jeor Equation is an accurate tool for predicting REE in overweight and obese women with fertility problems, offering important insights for nutritional assessment and intervention strategies in fertility management.

Key Words: energy expenditure, prediction equations, overweight and obese, women, fertility problems

INTRODUCTION

Globally, the issues of overweight, obesity, and infertility are escalating in severity, increasingly recognized as significant determinants of human health. As of 2022, around 2.5 billion individuals aged 18 and above are categorized as overweight, including over 890 million who are obese, with a notably higher prevalence observed among women compared to men.[1] Overweight and obesity are established contributing factors to infertility.[2, 3] Compared to normal-weight women, the per-cycle conception probability is significantly reduced by 8% in overweight women and 18% in those with obesity.[4] There is a close connection between obesity and infertility. For women, obesity can disrupt the body's endocrine system,[5] resulting in reproductive complications such as ovulatory dysfunction and diminished oocyte quality, thereby elevating the risk of infertility.[6] A prospective study shows that optimizing body mass index (BMI) in women starting from the preconception period may represent a significant strategy for improving fertility outcomes.[7] Therefore, it is imperative to implement personalized weight management strategies for this population. From a nutritional perspective, it is crucial to utilize the resting energy expenditure (REE) to conduct individualized assessments of energy requirements.

The total energy consumption of the human body consists of three components: resting energy consumption, metabolic energy consumption, and physical activity energy consumption, of which resting energy consumption accounts for approximately 75.0% to 100.0%. Restricting caloric intake is among the most frequently utilized approaches in the management of obesity.[8] To reduce body weight, energy requirements were calculated using the REE prediction equation. To effectively reduce body weight, accurate calculation of energy requirements is crucial, and this is often achieved by measuring REE. Indirect Calorimetry (IC) is the recognized standard method for determining the resting metabolic rate [9, 10] However, in clinical practice, it is often infeasible to measure REE using IC due to various limitations such as high cost, complex equipment, and time-consuming procedures. As a result, prediction equations have become a commonly used method for estimating REE. Unfortunately, most equations overestimate or underestimate the REE in both overweight and obese populations,[11-14] and this inaccuracy has resulted in a lack of consensus on the most accurate REE prediction equation for obese individuals.

REE refers to the energy consumption of the body after fasting for more than 2 h and lying flat and resting for 30 min at the appropriate temperature, mainly used to maintain the normal function of the body’s cells and organs and the awakening state of the human body, being used for estimation of the calorie need.[15] REE is influenced by many factors, such as gender and age. In the population of overweight and obese individuals with infertility, there may be unique patterns of change in REE. Currently, there are energy prediction equations for overweight and obese people, but there are significant differences among different ethnic groups. No study has yet described an equation applicable to overweight and obese Chinese women with infertility. For overweight and obese women, we need to obtain their energy consumption quickly and accurately to provide them with reasonable nutritional guidance for subsequent weight loss. Therefore, we carried out the following research.

MATERIALS AND METHODS

Subjects and methods

This study utilized data from participants enrolled in the Nutritional Survey and Nutritional Intervention for the Overweight and Obese Population with Menstrual Disorders or Infertility.

Baseline data were collected from all subjects, and the 147 subjects who successfully completed REE measurements were included in the analysis. The inclusion criteria for this study were as follows: 1) aged 18 - 45 years; 2) BMI > 24 kg/m²; 3) Menstrual irregularities, abnormal hormone levels, and other fertility problems; 4) no other metabolic diseases. A total of 82 participants were finally included in the study analysis. Informed consent was obtained from each participant at the beginning of the study, which was conducted in accordance with the ethical standards outlined and approved by the Ethics Committee of the First Hospital of Hebei Medical University (Approval No. 2024-088).

Indirect calorimetry

The primary dependent variable in this study was REE (kcal/day), measured using IC with the Vmax Encore 29 automated pulmonary function diagnosis and metabolic examination system (SensorMedics, USA). Trained nutritionists performed all measurements following a standardized protocol. Participants were instructed to fast and discontinue enteral nutrition for at least 2 h prior to testing, refrain from exercise, and rest in a supine position at a comfortable temperature for 30 min. During the test, subjects lay flat on the examination bed in a relaxed supine position. Measurements were repeated until a stable state lasting 3 minutes was achieved. The entire procedure took approximately 20 min per subject. REE was calculated using standard computer software, which determined oxygen consumption and carbon dioxide production per unit time, based on the principles of energy conservation and chemical reactions in IC.

Body composition analysis

Body composition was assessed using bioelectrical impedance analysis (BIA) with the InBody S10 body composition analyzer (South Korea). This method provided direct measurements of body weight, FFM, visceral fat, total body water, muscle mass, phase angle, and other relevant indicators. Measurements were conducted in a controlled environment with room temperature maintained at 20-25°C, and the instrument was preheated prior to use. Participants were required to fast for at least 4 h, empty their bladder and bowels, avoid wearing heavy clothing, and remove metal objects such as phones, watches, accessories, and belts. Socks and gloves were also removed to expose electrode contact areas. After resting for 30 min, measurements were taken following the manufacturer's guidelines.

Statistical analysis

The statistical analysis included the use of Spearman correlation coefficients to assess the relationships between REE and predictive variables (weight, height, waist circumference (WC), fat-free mass (FFM), and age). The agreement between existing predictive equations (as shown in Table 1.) and IC-measured REE was evaluated using Bland-Altman analysis to assess their accuracy. The analysis was performed using SPSS 26.0, with the significance level set at α=0.05, ensuring a robust evaluation of REE predictive variables and the accuracy of the equations.

RESULTS

Characteristics of study population.

This study enrolled a total of 82 participants, who were divided into three distinct age groups: 18–25 years (37.8% of the total participants), 25–30 years (30.5%), and ≥30 years (31.7%). The mean age of the participants was 27.4 years (± 5.82), with an average height of 161cm (± 5.48) and a mean weight of 83.07 kg (interquartile range (IQR): 75.1, 89.0). The median BMI was 32.10 kg/m² (IQR: 28.3,34.1). WC varied across different age groups. FFM was 47.98 ± 5.87 kg, and body fat was 35.04% (IQR: 29.8, 38.7); both remained consistent across groups. The median REE was 1476 kcal/day (IQR: (1367, 1658)), with minor variations by age. These results are presented in Table 2.

Correlation of body composition indicators

The Spearman correlation coefficients between REE and various predictive variables are presented in Table 3 for the total sample and stratified by age groups (18-25 years, 25-30 years, and ≥ 30 years). In the total sample (n = 82), REE showed significant positive correlations with all predictive variables, including height (r = 0.260, p <0.05), weight (r = 0.628, p <0.01), BMI (r = 0.541, p <0.01), FFM (r = 0.627, p<0.01), body fat (r = 0.436, p<0.01), WC (r = 0.504, p <0.01), waist-to-hip ratio (WHR) (r = 0.348, p <0.01), and waist-height ratio (WHtR) (r = 0.441, p <0.01). Among these, weight and FFM exhibited the strongest correlations with REE. Additionally, significant intercorrelations were observed among predictive variables, such as weight and BMI (r = 0.832, p <0.01), weight and FFM (r = 0.816, p <0.01).

After age-stratified analysis, in 18-25 age group, REE was significantly correlated with weight ($r = 0.520$, $p < 0.01$), BMI ($r = 0.422$, $p < 0.05$), FFM ($r = 0.508$, $p < 0.01$), WC ($r = 0.557$, $p < 0.01$), and WHtR ($r = 0.410$, $p < 0.05$). However, no significant correlation was observed between REE and body fat ($r = 0.328$, $p > 0.05$) or WHR ($r=0.268$, $p > 0.05$). For 25–30 years: REE showed significant correlations with weight ($r = 0.614$, $p < 0.01$), BMI ($r = 0.640$, $p < 0.01$), FFM ($r = 0.587$, $p < 0.01$), body fat ($r = 0.535$, $p < 0.01$), WC ($r = 0.516$, $p < 0.05$), WHR ($r = 0.469$, $p < 0.05$), and WHtR ($r = 0.548$, $p < 0.01$). The strongest correlations were observed between weight and BMI ($r = 0.898$, $p < 0.01$) and WC and WHtR ($r = 0.984$, $p < 0.01$). In the age group of ≥30 years, REE was significantly correlated with height ($r = 0.582$, $p < 0.01$), weight ($r = 0.736$, $p < 0.01$), BMI ($r = 0.598$, $p < 0.01$), FFM ($r = 0.796$, $p < 0.01$), body fat ($r = 0.504$, $p < 0.01$), and WC ($r = 0.554$, $p < 0.01$).

The consistency between the results measured by IC and the predictions of various equations

Across all age groups, weight and FFM consistently demonstrated the strongest correlations with REE, highlighting their importance as key predictors of energy expenditure. Additionally, WC and WHtR showed strong correlations with REE in younger age groups (18-30 years), whereas their significance diminished in the ≥30 years group. These findings suggest that age-specific factors may influence the relationship between anthropometric variables and REE, emphasizing the need for age-stratified approaches in predictive modeling.

Table 4 shows the REE from different prediction formulas. According to the comparison in Table 4, the Mifflin-St. Harris B and Henry formulas showed no significant difference from the measured energy levels, and there were no significant differences between the stratified age groups ($p > 0.05$). All other formulas showed differences in energy intake compared to measured values ($p < 0.05$, $p < 0.01$), except for the Liu formula, which showed no difference in the 25–30 age group. The Owen and WHO/FAO/UNU formulas also showed no differences in energy intake for populations aged 30 and above compared to measured values.

Mean differences between each calculation and measured resting metabolic rate are shown in Table 5. Eight formulas were used for Bland-Altman analysis, the abscissa is the mean of the calculated value and the measured value, and the ordinate is the difference between the calculated value of the formula and the measured value. The Mifflin-St Jeor Equation demonstrated the best performance among all tested equations, with the smallest bias (-9.73 kcal/day), indicating that its predicted values were closest to the IC-measured REE.

Additionally, the Mifflin-St Jeor Equation showed a relatively low standard deviation (SD) of bias (240kcal/day) and a narrow 95% limits of agreement range (-460, 479kcal/day), further confirming its stability and consistency in prediction. In contrast, other equations performed less favorably. For example, the Yang equation exhibited significant bias (-426kcal/day), indicating a systematic underestimation of REE, and its 95% limits of agreement range was wide (- 946, 94.2 kcal/day), reflecting poor predictive consistency. Furthermore, the Jiahong and WHO/FAO/UNU equations showed significant overestimation, with biases of 272kcal/day and 269 kcal/day, respectively. Both equations also demonstrated large predictive variability, with 95% limits of agreement ranging from -209 to 753 kcal/day and -304 to 865 kcal/day, respectively, indicating lower reliability.

DISCUSSION

Our results found that mean WC was greatest in women aged 25 to 30 years and that actual measured resting consumption and WC were highly correlated. We analysed by age group and paid close attention to the role of WC in predicting the energy equation. WC, as an easily measurable anthropometric indicator, could potentially serve as a valuable tool in estimating an individual's energy-related parameters. Siervo et al.calculated changes in REE for each decade, stratified by BMI and sex, relative to the youngest age group.[16] They have recently demonstrated that the energy gap was age-dependent as it became progressively larger in older subjects and it was, again, greater in obese women (-277 kcal/day). This finding not only highlights the impact of age on energy metabolism but also emphasizes the unique metabolic challenges faced by obese women.

Overweight and obesity are increasingly recognized as significant factors affecting female fertility. Excess body weight can disrupt the delicate hormonal balance necessary for regular menstrual cycles and ovulation. A substantial proportion of women experienced infertility, likely due to ovulatory dysfunction caused by hormonal imbalances such as elevated insulin levels and increased secretion of hormones like leptin and adiponectin. These metabolic alterations highlight the unique physiological characteristics of overweight/obese women with fertility problems, necessitating a tailored approach to their nutritional and fertility assessment.

Lifestyle interventions to reduce body weight in overweight or obese and have polycystic ovary syndrome have been suggested as effective interventions to restore ovarian function and combat comorbidities associated with overweight and adipose tissue.[17] Overweight and obese women with fertility problems are a particular group; they will likely show a high degree of variability in factors that may influence REE. No equations have been specifically designed to predict REE in overweight and obese women with fertility problems. However, our findings suggest that several existing equations are well-suited for this purpose.

Compared with the other equations tested, the Mifflin-St. Jeor Equation had the best agreement for energy prediction in overweight and obese women with fertility problems. This is consistent with the findings of Marcos Martin-Rincon et al.,[18] who also analyzed overweight individuals. This suggests that overweight and obesity are major factors affecting metabolism. In addition, the Mifflin-St. Jeor Equation was developed with obese individuals in mind, which may explain its better performance in this context.

This study has several strengths, including its focus on a specific and understudied population and the use of both measured and predicted REE values. The main limitations of this study include a small sample size and limited sample sizes across age subgroups. Additionally, the recruitment of a specific BMI population from a single center limits the generalizability of the results, and confounding factors such as diet and physical activity were not controlled for. Future studies should validate these findings through large-scale, multicenter cohort studies and include a broader population to enhance generalizability.

Conclusion

The Mifflin-St Jeor Equation proves to be a precise method for estimating REE in overweight and obese women experiencing fertility problems, providing valuable implications for nutritional evaluation and intervention approaches in fertility care. These results underscore the significance of employing equations tailored to specific populations for accurate assessment of energy needs in clinical settings.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

The authors declare that there are no conflicts of interest.

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Table 1. Different predictive equations

	equation
Mifflin-St[19]	REE=9.99W+6.25H-4.92A-161
HarrisB[20]	REE=655+9.56W+1.85H-4.68A
Henry[21]	18~30years: REE=(47W+2 88)/4.18 31~60years: REE=(39W+3 07)/4.18
Liu[22]	REE=13.9W+4.16H-3.43A-112×1+54.3
Yang[23]	REE=(277+89W+600S)/4.18;
Jiahong[24]	REE=REE=714+6.8W
Owen[25]	REE=795+7.18W
WHO/FAO/UNU[26]	18~30years: REE=13.3W+33.4H+35 31~60years: REE=(34W+3 54)/4.18 >60years: REE=9.2W+637H-302

A: age, W: weight, H: height, S: Sex (male=0, female=1).

Table 2. Characteristic of the study population

Characteristic	Total	18-25 years	25-30 years	≥30 years
n (%)	82 (100)	31 (37.8)	25 (30.5)	26 (31.7)
Age (yrs)	27.4±5.82	21.7±2.13	27.6±1.26	33.9±4.43
Height (cm)	161±5.48	162±6.19	160±5.57	161±4.39
Weight (kg)	83.1 (75.1, 89.0)	83.8 (76.5, 90.1)	83.5 (73.3, 90.0)	81.7 (72.8, 88.1)
Body mass index (kg/m^2)	32.1 (28.3, 34.1)	31.9 (30.1, 33.3)	33.0 (28.2, 37.0)	31.4 (28.0, 33.1)
Ideal body weight (kg)	55.0±4.93	55.9±5.57	54.0±5.01	54.9±3.95
WC (cm)	108 (87.0, 10)	93.7 (87.0, 102)	136 (86.8, 107.8)	97.3 (89.0, 105.3)
Waist to hip ratio	0.986 (0.825, 0.933)	0.855 (0.805, 0.906)	1.243 (0.826, 0.954)	0.884 (0.848, 0.954)
Waist to height ratio	0.672 (0.533, 0.645)	0.579 (0.535, 0.598)	0.857 (0.524,0.690)	0.605 (0.563, 0.650)
Fat free mass	48.0±5.87	48.2±4.90	47.2±6.58	48.5±6.35
Body fat	35.0 (29.9, 38.7)	35.6 (31.3, 39.7)	36.2 (27.2, 39.4)	33.2 (28.5, 35.9)
Fertility problems				
Irregular menstruation	82 (100)	31 (37.8)	25 (30.5)	26 (31.7)
Infertility	22	2	6	14
REE (kcal/day)	1476 (1367, 1658)	1561 (1369, 1667)	1505 (1362, 1670)	1411 (1333, 1606)

Mean (±SD), Median (IQR).

Table 3. Spearman correlation coefficients for REE and other predictive variables (n=82)

Predictive variables	REE	Height	Weight	BMI	FFM	Body fat	WC	WHR
Total sample								
Height	0.260*							
Weight	0.628**	0.468**						
BMI	0.541**	-0.023	0.832**					
FFM	0.627**	0.672**	0.816**	0.514**				
Body fat	0.436**	0.217	0.882**	0.877**	0.482**			
WC	0.504**	0.206	0.755**	0.739**	0.581**	0.708**		
WHR	0.348**	0.064	0.448**	0.532**	0.358**	0.417**	0.842**	
WHtR	0.441**	-0.030	0.652**	0.774**	0.410**	0.684**	0.959**	0.843**
18-25 years								
Height	0.192							
Weight	0.520**	0.362*						
BMI	0.422*	-0.281	0.743**					
FFM	0.508**	0.709**	0.700**	0.248				
Body fat	0.328	0.003	0.855**	0.854**	0.28			
WC	0.557**	0.130	0.758**	0.638**	0.584**	0.645**		
WHR	0.268	-0.265	0.196	0.338	0.215	0.133	0.660**	
WHtR	0.410*	-0.228	0.540**	0.683**	0.254	0.609**	0.897**	0.730**
25-30 years								
Height	0.005							
Weight	0.614**	0.455*						
BMI	0.640**	0.124	0.898**					
FFM	0.587**	0.596**	0.818**	0.656**				
Body fat	0.535**	0.332	0.918**	0.903**	0.584**			
WC	0.516*	0.173	0.827**	0.817**	0.584**	0.805**		
WHR	0.469*	0.108	0.705**	0.727**	0.502*	0.643**	0.925**	
WHtR	0.548**	0.076	0.791**	0.830**	0.518*	0.795**	0.984**	0.929**
≥30 years								
Height	0.582**							
Weight	0.736**	0.572**						
BMI	0.598**	0.194	0.881**					
FFM	0.796**	0.677**	0.902**	0.701**				
Body fat	0.504**	0.31	0.845**	0.884**	0.598**			
WC	0.554**	0.445*	0.779**	0.765**	0.663**	0.741**		
WHR	0.416	0.377	0.467*	0.469*	0.374	0.474*	0.842**	
WHtR	0.414	0.201	0.682**	0.778**	0.511*	0.744**	0.948**	0.769**

*p <0.05 ** p <0.01.

Table 4. Comparisons of measured REE and REE estimated by different predictive equations (n=82, kcal/day)

	Measured REE	Mifflin-St	HarrisB	Henry	Liu
Total sample	1476 (1367, 1658)	1528$^{\#}$ (1432, 1615)	1606$^{\#}$ (1533, 1675)	1580$^{\#}$ (1496, 1658)	1657** (1565, 1748)
18-25 years	1561 (1369, 1667)	1567$^{\#}$ (1503, 1693)	1647$^{\#}$ (1590, 1742)	1623$^{\#}$ (1548, 1700)	1689** (1616, 1842)
25-30 years	1505 (1362, 1670)	1500$^{\#}$ (1424, 1619)	1594$^{\#}$ (1520, 1693)	1590$^{\#}$ (1512, 1700)	1631$^{\#}$ (1524, 1781)
≥30 years	1411 (1333, 1606)	1491$^{\#}$ (1390, 1584)	1573$^{\#}$ (1489, 1635)	1497$^{\#}$ (1440, 1610)	1623* (1490, 1731)

	Measured REE	Yang	Jiahong	Owen	WHO/FAO/UNU
Total sample	1476 (1367, 1658)	1946** (1807, 2103)	1269** (1225, 1319)	1381** (1334, 1434)	1227** (1135, 1429)
18-25 years	1561 (1369, 1667)	1979** (1837, 2126)	1280** (1234, 1327)	1392** (1344, 1442)	1195** (1105, 1290)
25-30 years	1505 (1362, 1670)	1918** (1769, 2124)	1260** (1213, 1326)	1372* (1322, 1441)	1158** (1065, 1287)
≥30 years	1411 (1333, 1606)	1938** (1759, 2086)	1267** (1209, 1313)	1379$^{\#}$ (1318, 1428)	1495$^{\#}$ (1392, 1558)

Median (IQR), * $p<0.05$, ** $p<0.001$, # $p>0.05$.

Table 5. Bland-Altman analysis of different predictive equations (n=82)

REE-predictive equations	Bias	SD of bias	95% limits of agreement
Mifflin-St	-9.7	240	-460, 479
HarrisB	-68.4	237	-532, 395
Henry	-44.1	234	-503, 414
Liu	-121	241	-592, 351
Yang	-426	265	-946, 94.2
Jiahong	272	245	-209, 753
Owen	159	244	-319, 638
WHO/FAO/UNU	269	304	-304, 865

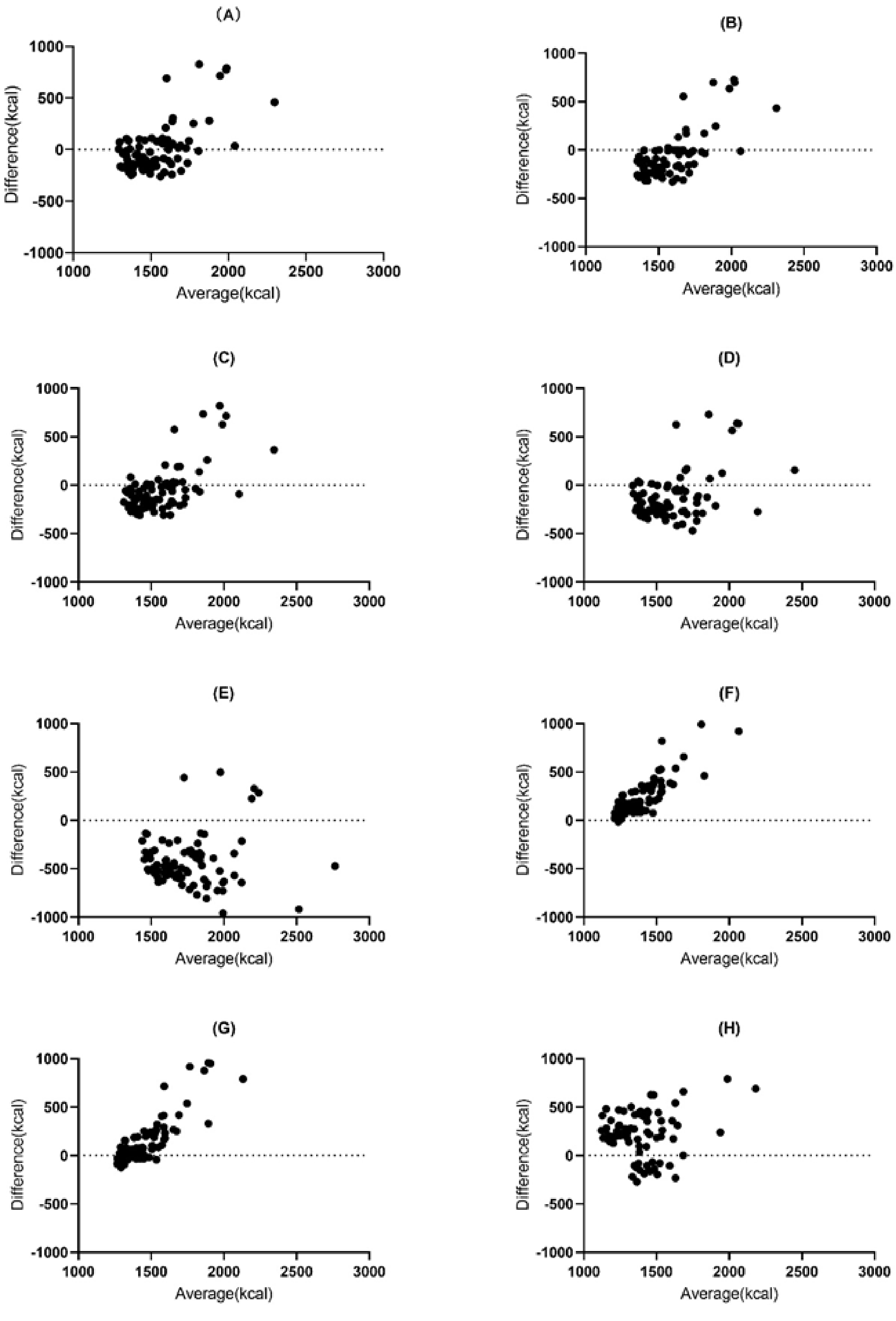

Figure 1. Bland Altman plot of measured REE and REE estimated by different predictive equations. (A) Bland-Altman of REE and Mifflin-St, (B) Bland-Altman of REE and HarrisB, (C) Bland-Altman of REE and Henry, (D) Bland-Altman of REE and Liu, (E) Bland-Altman of REE and Yang, (F) Bland-Altman of REE and Jiahong, (G) Bland-Altman of REE and Owen, (H) Bland-Altman of REE and WHO/FAO/UNU

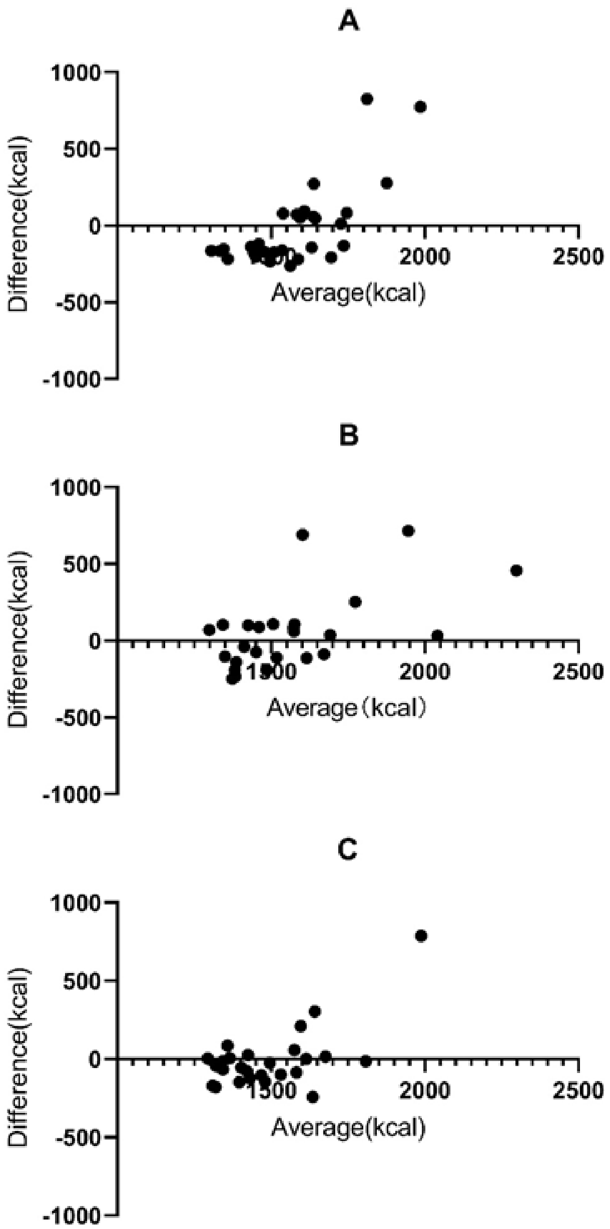

Figure 2. Bland-Altman analysis plot of comparing measured REE and REE estimated using the Mifflin-St. equation for different age groups. (A) 18-25years, (B) 25-30 years, (C) ⩾30 years