Original Article

Basal energy expenditure, resting energy expenditure and one metabolic equivalent (1 MET) value for young Chinese adults with different body weight

Jinghuan Wu PhD[1], Deqian Mao MD[1], Ying Zhang PhD[1], Xiaorong Chen PhD[2], Ping Hong PhD[3], Jianhua Piao BSc[1], Qin Zhuo PhD[1], Xiaoguang Yang PhD[1]

[1]*Key Laboratory of Trace Element Nutrition of National Health Commission(NHC), National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention, Beijing, P.R. China*
[2]*National Center for Chronic and Noncommunicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, Beijing, P.R. China*
[3]*China Institute of Sport Science, Beijing, P.R. China*

Background and Objectives: Accurately assessing energy expenditure (EE) of people with different body weight is essential to facilitate weight management intervention. The aim of this study was to measure basal energy expenditure (BEE), resting energy expenditure (REE) and to explore the true 1 MET value for young Chinese adults with different body weight. **Methods and Study Design:** A total of 251 young Chinese adults were divided into three groups: the normal weight group, the overweight group and the obese group. Their BEE, REE and 1MET value were measured by Cortex Metamax 3B (MM3B). Multiple linear regressions and correlation analysis were used to examine factors that influence EE in Chinese population. **Results:** The mean measured BEE and REE of young Chinese adults with normal weight, overweight and obesity was 1429, 1609, 1778 kcal/day and 1522, 1712, 1885 kcal/day, respectively. The EE per kilogram body weight decreased with the increasing body weight. The mean oxygen consumption in the three group was 3.78, 3.47, 3.21 mL/kg/min respectively. There was no significant difference in BEE and REE after adjustment for fat-free mass (FFM). The significant influencing factors were body mass index (BMI) and sex in BEE, FFM and BMI in REE in Chinese population. **Conclusions:** BEE and REE were significantly different in different body weight while these differences disappeared after adjustment for FFM, and people with different body weight maybe need different 1 MET value. Further studies should be conducted to obtain more accurate daily energy requirement and 1MET value for specific Chinese population.

Key Words: basal energy expenditure, resting energy expenditure, metabolic equivalent value, Chinese adults, body weight

INTRODUCTION

The rate of overweight and obesity in Chinese people more than 18 years was 30.1% and 11.9%, which increased by 7.3% and 4.8% since 2002 respectively, according to Chinese standard of BMI.[1] Overweight and obesity are major risk factors for a number of chronic diseases, including diabetes, cardiovascular diseases and cancer.[2,3] This rapidly increasing public health concern has prompted numerous interventions to facilitate healthy weight management. An accurate assessment of energy requirements is essential to complete individual nutrition assessments and to evaluate the effectiveness of planned nutrition interventions. The basal metabolic rate (BMR) and resting metabolic rate (RMR) are generally the basis for assessing energy requirements. BMR, or BEE, is a strict measurement obtained under total inactivity and controlled research conditions.[4] RMR, or REE, is measured when an individual is sitting quietly and slightly higher than BMR.[4]

There is now a considerable amount of BMR and RMR data from individuals living in western countries, using direct or indirect calorimeters. These studies have shown that there were distinct differences in BMR and RMR between men and women,[5] between obese and non-obese adults,[6] between old and young adults,[7] racial/ethnic differences and possibly physiological state.[8-11] However, there is still relatively little information on BMR and RMR from Chinese adults, especially for adults with overweight and obesity. The former studies focused on BEE or REE of Chinese young healthy adults with normal weight, and the results showed that some of the widely used prediction equations could not accurately estimate

Corresponding Author: Prof Qin Zhuo, the Key Laboratory of Trace Element Nutrition NHC, National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention, 29 Nanwei Road, Xicheng District, Beijing 100050, P.R. China.
Tel: +86-010-66237240; Fax: +86-010-67711813
Email: zhuoqin@ninh.chinacdc.cn
Manuscript received 04 January 2018. Initial review completed 09 August 2018. Revision accepted 12 October 2018.
doi:

the BEE and REE of southern Chinese healthy adults.[12,13] Even though a few studies tried to investigate the BEE or total energy expenditure of Chinese adults,[13-16] they were based, primarily, on relatively small sample sizes, or were not intended to be population based, such as overweight or obese groups.

The MET value is a commonly used physiological term that is used to express the energy cost of physical activities as a multiple of RMR.[17-19] The conventional definition of 1 MET is 3.5 mL/kg/min and is assumed to be approximately equal to 1 kcal/kg/h or 4.184 kJ/kg/h for a man who weighs 70 kg aged 40 years old.[17] The MET system is widely used by researchers, clinicians and practitioners to estimate and classify the energy cost of human physical activity and has attained widespread acceptance. However, the standard expression of 1 MET has been criticized and questioned during the past decade by many in the scientific community.[9-11] This is because basal and resting metabolism varies according to various factors as those described above.[5-11] Some studies indicated that using a single estimate of RMR, 3.5 mL/kg/min, to denote 1 MET for an entire population subgroup is likely to misrepresent expected energy costs of physical activity.[20-23]

As indicated in a recent study by Frankenfield DC and McMurray RG, there may be differences in RMR and the 1 MET value assessment based on obesity status.[22,23] Therefore, our study was initiated to obtain information on BEE, REE and explored the proper value of 1 MET of young Chinese adults with overweight and obesity, which could help determine more individualized and accurate calorie needs and weight management recommendations for this population.

METHODS

Participants

The study was conducted at the Peking University Health Science Center, West China School of Public Health Sichuan University and XiangYa School of Medicine, Central South University. All study volunteers were recruited from these colleges. Two hundreds and fifty-one healthy individuals were recruited for this study, including 133 men and 118 women. Participant's ages ranged from 20 to 32 years old and with light-activity lifestyles. Anthropometric measurements including weight, height, waist circumference (WC) were conducted for all the participants. Subjects with hepatic diseases, thyroid diseases, insulin-dependent diabetes mellitus, renal diseases or any other metabolic disorder were excluded. Women participants were evaluated when not in their menstrual period. Subjects were divided into three groups (the normal weight group (BMI=18.5-23.9); the overweight group (BMI=24.0-27.9) and the obese group (BMI ≥28.0)) according to their BMI.

All procedures involving human subjects of this study were approved by the Ethics Review Board of the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention (Ethical approval number: 2014-018). Written informed consent was obtained from all subjects.

The determination of BEE and REE

BEE and REE of participants were measured by indirect calorimetry via a breath-by-breath system, named MM3B gas analyzer (Cortex, Leipzig, Germany) as detailed elsewhere.[24]

In this procedure, subjects had been asked to stay in a hotel with a stable temperature of 20-25℃ and get accustomed to the apparatus, face mask and the surrounding environment on the day before the experiment. After an overnight fast of 10-12 hours, subjects were awakened gently from sleeping and asked to lie down quietly. They were told to relax and avoid nervous movements, sleeping and hyperventilation during measurements. Oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured for 15 minutes using the Cortex equipment. After that, participants were allowed to get up, wash, and move lightly. Half an hour later, subjects were instructed to sit on the bed again. When they became quiet and their breathing became steady, the REE was then tested for 15 minutes. Data generated during the first 5 minutes were excluded and the remaining data were averaged. Values for EE were calculated from VO_2 and VCO_2 using Weir's equation.[18] Ten percent of these subjects had their BEE and REE measured once again.

The MM3B is a portable metabolic system with a total weight of 1.40 kg. It is comprised of a measurement module and a battery module. These two parts are the same size (120×110×45 mm) and designed to be worn on the chest with a harness. The MM3B measures volume using a bidirectional digital turbine. A 60 cm length of Nafion/Permapure sampling tube is attached to the turbine to permit analysis of the O_2 and CO_2 concentrations using an electrochemical cell and an infrared analyzer, respectively. Prior to use, the system was turned on for at least 20 minutes, and then calibrated prior to every test according to the manufacturer's instructions.

Measurement of body surface area (BSA) and body composition

A subsample of the population (n=102) was studied to validate the relationship between body composition and EE. BSA was calculated using the following formula proposed by Zhao et al.[25,26] For men, BSA (m^2) = 0.00607 height (cm) + 0.0127 weight (kg) – 0.0698; for women, BSA (m^2) = 0.00586 height (cm) + 0.0126weight (kg) – 0.0461. Body composition including fat mass (FM) and FFM was assessed by means of dual energy x-ray absorptiometry (LUNAR DPX, GE).

Statistical analyses

The statistical analysis was performed using the SPSS software (version 19.0; SPSS, Inc., Chicago, IL, USA). Descriptive data were presented as mean ± standard deviation (SD) and analyzed using analysis of variance. The Kruskal–Wallis test was used and followed by a Dunnett-type method when appropriate. The relationship between measured BEE, REE and the related variables such as FFM, FM, BSA, weight, height and so on, was assessed using Pearson's correlation. Multiple linear regressions were used to assess factors that influence EE in Chinese population. Significance for all analyses was set at $p<0.05$.

RESULTS

Anthropometric measurements

Characteristics of the participants were summarized in Table 1. There was no significant difference in age and height among the normal weight group, the overweight group and the obese group, neither in men nor in women. Significant differences were observed in weight, BMI and WC among the three groups, both in men and women. The obese group had the highest weight, BMI and WC.

EE in basal metabolism and resting metabolism for participants

Measured EE in basal metabolism and resting metabolism were described in Table 2. The expended energy was significantly different among different body weight groups in basal and resting metabolism. It was quite clear that the overweight group and the obese group expended much more energy than that in the normal weight group. Furthermore, the obese group used much more energy than that in the overweight group. In the same BMI group, it was obvious that men consumed much more energy than women in basal or resting metabolism. The data also showed that the EE consumed in resting metabolism was about 10% higher than that of their relevant BEE.

As for the EE per kilogram body weight, it decreased with the increasing BMI. It was obvious that the overweight group and the obese group expended much less energy per kilogram body weight than that in the normal weight group, both in the basal metabolism and resting metabolism. Furthermore, the obese group consumed much less energy per kilogram body weight than that in the overweight group in men.

BMR, RMR and the oxygen consumption

The BMR, RMR and the oxygen consumption were presented in Table 3. Both of the two rates (kcal/kg/h) were obviously different among the different BMI groups in men, women and total subjects. As for the BMR, the overweight and obese group was obviously lower than that of the normal weight group, while there was no significant difference between the overweight and the obese group. The RMR of the normal weight group was significantly higher than that of the overweight and obese groups in men, women and total subjects. Furthermore, the RMR of the overweight group was higher than that of the obese group in men and total subjects, this observation did not hold true for women subjects. In total, the value of the BMR and the RMR in the normal weight, overweight and obese group were 1.00, 0.89, 0.85 kcal/kg/h and 1.09, 1.00, 0.90 kcal/kg/h, respectively. As for the same BMI group, there was no significant difference in BMR or RMR between men and women.

There were significant differences in oxygen consumption in resting metabolism among different BMI group in men, women and total subjects. The overweight group and the obese group consumed less oxygen than that in the normal weight group. In addition, the obese group expended less oxygen than that in the overweight group in men and total subjects.

Table 1. Anthropometric characteristic of participants

Variables	Men			Women		
	Normal	Overweight	Obesity	Normal	Overweight	Obesity
Number	43	49	41	50	45	23
Age (years)	23.7±2.5	24.0±2.1	24.9±3.0	23.4±2.1	23.6±2.8	23.3±2.3
Weight (kg)	62.4±5.4	75.9±6.7†	90.9±7.8†‡	54.4±5.4	66.7±4.5†	78.1±9.2†‡
Height (cm)	172±4.4	172±5.2	173±5.0	160±4.5	161±4.6	160±6.1
BMI (kg/m^2)	21.2±1.5	25.7±1.2†	30.2±2.0†‡	21.4±1.5	25.9±1.1†	30.6±2.7†‡
WC (cm)	75.5±6.1	85.4±5.7†	98.8±6.9†‡	71.7±5.2	82.2±5.1†	92.6±6.5†‡

BMI: body mass index; WC: waist circumference.
†Significantly different from values in normal group (*p*<0.05).
‡Significantly different from values in overweight group (*p*<0.05).

Table 2. Measured EE in basal metabolism and resting metabolism for participants

Sex	Group	EE (kcal/day)		EE/kg (kcal/kg)	
		Basal metabolism	Resting metabolism	Basal metabolism	Resting metabolism
Men	Normal	1566±142	1678±140¶	24.9±2.5	26.8±2.8¶
	Overweight	1767±134†	1860±96†¶	23.3±2.5†	24.8±2.1†¶
	Obesity	1871±116†‡	1981±134†‡¶	20.3±2.3†‡	22.1±2.3†‡¶
Women	Normal	1317±151§	1398±154§¶	24.1±3.3	25.7±3.6
	Overweight	1454±182†§	1557±215†§¶	21.6±2.3†§	23.4±3.0†§¶
	Obesity	1609±185†‡§	1717±208†‡§¶	20.6±2.5†	22.1±2.2†¶
Total	Normal	1429±192	1522±203¶	24.5±2.9	26.2±3.3¶
	Overweight	1609±224†	1712±224†¶	22. 5±2.5†	24.1±2.6†¶
	Obesity	1778±191†‡	1885±208†‡¶	20.4±2.3†‡	22.1±2.2†‡¶

EE: energy expenditure.
†Significantly different from values in the normal group (*p*<0.05).
‡Significantly different from values in the overweight group (*p*<0.05).
§Significantly different from values in men (*p*<0.05).
¶Significantly different from values in basal metabolism (*p*<0.05)

Table 3. The BMR, RMR and oxygen consumption for participants

Sex	Group	BMR (kcal/kg/h)	RMR (kcal/kg/h)	Oxygen consumption (mL/kg/min)
Men	Normal	0.99±0.24	1.12±0.12	3.87±0.4
	Overweight	0.87±0.31†	1.03±0.09†	3.58±0.33†
	Obesity	0.84±0.16†	0.90±0.18†‡	3.21±0.30†‡
Women	Normal	1.01±0.13	1.07±0.15	3.72±0.52
	Overweight	0.91±0.10†	0.97±0.12†	3.36±0.44†
	Obesity	0.87±0.10†	0.92±0.09†	3.21±0.44†
Total	Normal	1.00±0.19	1.09±0.14	3.78±0.48
	Overweight	0.89±0.24†	1.00±0.11†	3.47±0.40†
	Obesity	0.85±0.14†	0.90±0.15†‡	3.21±0.36†‡

BMR: basal metabolic rate; RMR: resting metabolic rate.
†Compared with normal group, $p<0.05$.
‡Compared with overweight group, $p<0.05$.

The correlation between measured BEE, REE and body composition

The number of participants measuring their body surface and body composition in the normal weight, overweight and obese group was 18, 19 and 15 for men and 16, 23 and 11 for women. As shown in the Table 4, the obese group had the highest BSA, FM and FFM, both in men and women. The obesity had twice more FM than people with normal body weight. After adjustment for body weight, there were still significant differences in BEE in women and in REE in both genders among different BMI groups. While after controlling for FFM, BEE and REE did not differ significantly among different BMI groups.

As presented in Table 5, significant relationship was found between BEE, REE and FFM, BSA, sex, height, weight and WC in the normal weight group. In the overweight group, obvious relationship was found between BEE, REE and FFM, BSA, sex, height, weight and FM. Remarkable relationship was found between BEE, REE and FFM, BSA, sex, height and weight in the obese group. In total, strong relationships were found between BEE, REE and BSA, FFM, weight, WC, height, BMI, sex and FM, except age.

The multiple linear regression analysis between measured BEE, REE and body composition

In order to examine factors that influence EE in basal and resting metabolism in Chinese population, multiple linear regression analysis was therefore used. Independent variables were BSA, FFM, weight, WC, height, BMI, sex and FM. When the best goodness of fit obtained in BEE, the significant factors were BMI (p=0.001) and sex (p<0.000), and the regression equation was BEE (kcal/day) = 278 + 24.4 BMI + 215.0 Sex (male=1 and female=0; r^2=0.689, residual standard deviation (RD)=137). When the best goodness of fit obtained in REE, the significant factors were FFM (p<0.000) and BMI (p<0.000), and the regression equation was REE (kcal/day) = 341 + 17.1 FFM + 21.1 BMI (r^2=0.684, RD=138).

DISCUSSION

The purpose of this study was to determine the BEE and REE of young Chinese adults with different body weight and explore the actual value of 1 MET for these Chinese adults. Measuring human EE directly remains very difficult; however, some portable devices which demonstrated

Table 4. Anthropometric characteristic of subsamples

Variables	Men			Women		
	Normal	Overweight	Obesity	Normal	Overweight	Obesity
Number	18	19	15	16	23	11
Age (years)	24.8±2.8	24.9±2.1	26.0±2.8	24.9±0.9	24.9±2.7	24.5±2.3
Weight (kg)	64.4±6.0	75.6±6.1†	88.4±6.8†‡	52.7±4.2	67.1±5.3†	81.3±12.6†‡
Height (cm)	172±4.8	171±5.3	172±4.8	158±4.8	161±4.6	161±7.0
BMI (kg/m²)	21.7±1.5	25.7±1.2†	29.9±1.6†‡	21.1±1.4	26.0±1.2†	31.4±3.9†‡
WC (cm)	77.0±5.2	86.2±4.4†	96.8±6.0†‡	71.1±2.3	83.6±5.2	95.1±8.2†‡
BSA (m²)	1.8±0.1	1.9±0.1†	2.1±0.1†‡	1.5±0.1	1.7±0.1†	1.9±0.2†‡
FM (kg)	11.3±4.2	17.9±4.4†	28.8±6.2†‡	14.8±1.9	24.7±3.9†	33.9±6.4†‡
FFM (kg)	52.2±3.9	56.3±5.3†	58.0±3.9†	36.3±3.5	39.8±3.4†	45.6±6.7†‡
BEE (kcal/day)	1554±105	1741±113†	1896±131†‡	1292±158	1463±194†	1613±193†‡
REE (kcal/day)	1664±124	1840±70†	2007±137†‡	1409±164	1579±187†	1725±254†‡
BEE (kcal/kg)	24.2±2.0	22.0±5.7	21.6±2.2	24.6±3.1	21.8±2.7	20.0±1.9†
REE (kcal/kg)	26.2±2.2	24.7±2.0†	22.9±2.3†‡	26.8±3.0	23.6±2.3†	21.3±2.1†‡
BEE (kcal/FFM)	29.8±2.2	29.7±7.8	32.9±3.5	35.8±4.8	36.9±5.6	35.6±2.9
REE (kcal/FFM)	32.2±2.1	33.2±3.6	34.9±3.3	38.9±4.2	39.7±4.2	37.9±2.7

BMI: body mass index; WC: Waist circumference; BSA: body surface area; FM: fat mass; FFM: fat-free mass; BEE: basal energy expenditure; REE: resting energy expenditure.
†Compared with normal group, $p<0.05$.
‡Compared with overweight group, $p<0.05$.

Table 5. Pearson correlation coefficient for BEE, REE and body composition

Variables	BEE (kcal/day)				REE (kcal/day)			
	Normal	Overweight	Obesity	Total	Normal	Overweight	Obesity	Total
Age (years)	-0.046	0.083	0.037	0.076	0.312	0.076	0.001	0.103
Sex (0, 1)†	0.741**	0.654**	0.674**	0.601**	0.688**	0.668**	0.597**	0.581**
Height (cm)	0.739**	0.588**	0.526**	0.564**	0.720**	0.627**	0.540**	0.592**
Weight (kg)	0.718**	0.611**	0.607**	0.759**	0.713**	0.618**	0.638**	0.762**
BMI (kg/m^2)	0.276	0.225	0.264	0.576**	0.283	0.131	0.295	0.570**
WC (cm)	0.567**	0.235	0.309	0.618**	0.557**	0.183	0.374	0.616**
FM (kg)	-0.207	-0.313*	-0.002	0.346**	-0.264	-0.355*	0.002	0.326**
FFM (kg)	0.743**	0.659**	0.741**	0.734**	0.775**	0.687**	0.788**	0.765**
BSA (m^2)	0.754**	0.634**	0.648**	0.783**	0.745**	0.655**	0.670**	0.791**

BEE: basal energy expenditure; REE: resting energy expenditure; BMI: body mass index; WC: waist circumference; FM: fat mass; FFM: fat-free mass; BSA: body surface area.
†Women=0 and men=1.
*p<0.05; **p<0.001.

good correlation with the metabolic cart have been used in office/clinical setting.[27-29] In the present study, BEE and REE of adults was measured by a portable indirect calorimetry machine via a breath-by-breath system called MM3B gas analyzer, which has demonstrated reliable and reproducible results and has been widely used in field studies.[24,30]

There is a few of information about the BMR or RMR of overweight and obese population. Considering that measurement of metabolic rate through indirect calorimetry is not feasible for frequent and timely individual use, many equations are commonly used to predict the BMR and RMR for specific population demographics. However, Ziegler JE et al and Henes ST et al demonstrated that predictive equations lack reliability in estimating caloric requirements in overweight and obese adults compared with indirect calorimetry, and they suggested that it was necessary to provide a simple and accurate calculation of energy needs for use in the overweight and obese population.[31,32] The current study showed that the BEE and REE of young Chinese adults significantly increased with the increasing BMI, while the EE per kilogram, BMR, RMR and oxygen consumption decreased with the body weight. However, BEE and REE did not differ significantly among different BMI groups after controlling for FFM.

Lazzer S et al measured the BMR of obese adults aged from 18 to 74 years old with BMI >30 kg/m^2, and found that the averaged BMR for men and women was 9409 kJ/day (2249 kcal/day) and 7418 kJ/day (1773 kcal/day), respectively.[33] McMurray RG et al reviewed the literature on RMR and found that the mean value for RMR was higher for men than women, decreasing with increasing age, less in overweight than normal weight adults, and adults with BMI ≥30 kg/m^2 had the lowest RMR regardless of sex, which were consistent with our study.[23] Liu HY et al measured BMR of 223 healthy Taiwanese adults aged 20–78 years old by indirect calorimetry, using a metabolic measurement cart with a canopy system.[34] The study showed that the mean measured BEE of Taiwanese adults was 1202 kcal/day in total, 1372 kcal/day in men and 1058 kcal/day in women.[34] Yang X et al used the Cosmed K4b^2 portable metabolic system to measure the BEE of 165 southern Chinese healthy adults aged 18–45 years old with normal body weight.[12] The results showed that the mean measured BEE for this group was 5513 kJ/day (1318 kcal/day) in total, 6213 kJ/day (1485 kcal/day) in men and 4870 kJ/day (1164 kcal/day) in women.[12] These results indicated that there weren't the same BMR or RMR values among all the studies, neither in Westerners nor in Chinese.

The present study showed that the 1 MET values were different among the different BMI groups, which were inconsistent with the conventional definition of 1 MET.[19] Work by Byrne NM et al suggested that the use of the conventionally defined MET value often reflects an overestimate that does not apply well to all individuals or to population subgroups.[9] Studies by Kwan M et al suggested that the assumption of 1 MET=3.5 mL/kg/min VO_2 resting may over-estimate EE when applied to elderly people.[20] Wilms B et al confirmed that the commonly used 1 MET value largely overestimated EE in overweight and obese individuals.[11] These studies demonstrated that using a single estimate of RMR (3.5 mL/kg/min) to denote 1 MET to the entire population is likely to overestimate or underestimate the true "ratio" (activity/rest) in certain populations.

The present study indicated that BSA, FFM, weight, WC, height, BMI, sex and FM are strongly correlated with BEE and REE of young Chinese adults, which was accordance with other former studies.[35-37] FFM and FM were confirmed to be significant contributors to BMR or RMR, and also was suggested to be utilized to assess REE for men athletes of different body size.[35-37] The multiple linear regression analysis in this study showed that the significant influencing factors were BMI and sex in BEE, FFM and BMI in REE. Although there were still significant differences in BEE and REE among different body weight, BEE and REE did not differ significantly among different BMI groups after controlling for FFM in our study. This was accordance with the study of Wouters-Adriaens MP et al, which found that the absolute REE was lower in Asians (5.87±0.91 MJ/day) than in whites (7.00±1.11 MJ/day) while there was no significant difference in REE between the two races after adjustment for FFM.[38]

The values of BMR, RMR and the actual 1 MET of young Chinese adults in our study are not identical with that of the previous studies. As BMR and RMR vary according to body composition as expressed by FFM and FM, gender and age groups, it is possible that the EE equivalent to 1 MET is likely to vary with different BMR or RMR. Therefore, it is hard to get a standard BMR and RMR, which implies that people with different body weight maybe need different BMR and RMR. A correction factor has been recommended to adjust the MET level on the basis of an estimate of one's RMR, which accounts for age, height, weight, and sex. For example, Byrne NM et al and Kozey S et al recommended dividing the fixed RMR (3.5 mL/kg/min) by an RMR (mL/kg/min) predicted using the Harris–Benedict equation.[9,10] This quotient is then multiplied by the Compendium MET value.[21,22] While Wilms B et al produced BMI-specific MET correction factors.[11] Another reason for the discrepant values may be explained by the different methodologies and equipment employed including K4b[2], MM3B, Cosmed Quark CPET, the VH_MC (a metabolic cart), RMR_WRIC (a new whole room indirect calorimeter), and so on.[6,12,39,40] Henes ST et al and Rising R et al found that there were some significant differences between different indirect calorimeters.[39,40] The consistency and application range of these indirect calorimeters deserves further study.[6]

The present research used a relatively inexpensive, quick, and user-friendly portable calorimeter, MM3B, to measure the BEE, REE and the actual 1 MET for young Chinese adults with overweight and obese. To the best of our knowledge, there are very few similar studies on overweight and obese Chinese people. The obtained values could be an important resource for assessing energy requirements and the corresponding EE of 1 MET for Chinese people. Nonetheless, there were also several limitations in the present study. Most subjects in this study were college students who were younger than participants in other studies.[12] Further studies on the measurement of Chinese BEE, REE and 1 MET value may be necessary to correct for the young age profile of this cohort or to cover a wider age range. In addition, the BEE and REE was measured once for many individuals at one location. In order to attain more accurate data for establishing 1 MET standard, more researches should make as many measurements as possible at just one location with the same equipment, which might eliminate inter location/investigator/equipment errors.

In conclusion, the present study showed that BMR and RMR were significantly different in different body weight while these differences disappeared after adjustment for FFM, and people with different body weight maybe need different 1 MET values. More researches are necessary to explore the proper BMR, RMR and 1 MET value for specific Chinese population, and make more accurate nutrition recommendation and weight management intervention on individuals and possibly more successful outcomes when working with overweight and obese adults.

ACKNOWLEDGEMENTS

The authors wish to thank the staff of Peking University Health Science Center, West China School of Public Health Sichuan University and XiangYa School of Medicine, Central South University for their assistance of this study. We are also very appreciative of all of the volunteers that participated in the study.

AUTHOR DISCLOSURES

The authors declare no conflict of interest. This work was supported by a project of the Ministry of Science and Technology of the People's Republic of China (grant number 2013FY114700).

REFERENCES

1. Disease Control and Prevention Bureau of National Health and Family Planning Commission. Report on Chinese residents' chronic diseases and nutrition. Beijing: Peoples's Medical Publishing House; 2016.
2. He YH, Jiang GX, Yang Y, Huang HE, Li R, Li XY, Ning G, Cheng Q. Obesity and its associations with hypertension and type 2 diabetes among Chinese adults age 40 years and over. Nutrition. 2003;25:1143-9. doi: 10.1016/j.nut.2009.04.003.
3. Speakman JR. Obesity: The integrated roles of environment and genetics. J Nutr. 2004;134:2090S-105S. doi: 10.1093/jn/134.8.2090S.
4. Dionne I, Després JP, Bouchard C, Tremblay A. Gender difference in the effect of body composition on energy metabolism. Int J Obes Relat Metab Disord. 1999;23:312-9.
5. Geisler C, Braun W, Pourhassan M, Schweitzer L, Glüer CC, Bosy-Westphal A, Müller MJ. Gender-specific associations in age-related changes in resting energy expenditure (REE) and MRI measured body composition in healthy Caucasians. J Gerontol A Biol Sci Med Sci. 2016;71:941-6. doi: 10. 1093/gerona/glv211.
6. Woo P, Murthy G, Wong C, Hursh B, Chanoine JP, Elango R. Assessing resting energy expenditure in overweight and obese adolescents in a clinical setting: validity of a handheld indirect calorimeter. Pediatr Res. 2017;81:51-6. doi: 10.1038/pr.2016.182.
7. Geisler C, Braun W, Pourhassan M, Schweitzer L, Glüer CC, Bosy-Westphal A, Müller MJ. Age-dependent changes in resting energy expenditure (REE): insights from detailed body composition analysis in normal and overweight healthy Caucasians. Nutrients. 2016;8. doi: 10.3390/nu8060322.
8. Adzika Nsatimba PA, Pathak K, Soares MJ. Ethnic differences in resting metabolic rate, respiratory quotient and body temperature: a comparison of Africans and European Australians. Eur J Nutr. 2016; 55:1831-8. doi: 10.1007/s00394-015-1000-4.
9. Byrne NM, Hills AP, Hunter GR, Weinsier RL, Schutz Y. Metabolic equivalent: one size does not fit all. J Appl Physiol. 2005;99:1112-9. doi: 10.1152/japplphysiol.00023. 2004.
10. Kozey S, Lyden K, Staudenmayer J, Freedson P. Errors in MET estimates of physical activities using 3.5 mL × kg (−1) × min (−1) as the baseline oxygen consumption. J Phys Act Health. 2010;7:508-16.
11. Wilms B, Ernst B, Thurnheel M, Weisser B, Schultes B. Correction factors for the calculation of metabolic equivalents (MET) in overweight to extremely obese subjects. Int J Obes (Lond). 2014;38:1383-7. doi: 10.1038/ ijo.2014.22.
12. Yang X, Li M, Mao D, Zeng G, Zhuo Q, Hu W, Piao J, Yang X, Huang C. Basal energy expenditure in southern Chinese healthy adults: measurement and development of a new equation. Br J Nutr. 2010;104:1817-23. doi: 10.1017/S0007114510002795.
13. Rao ZY, Wu XT, Liang BM, Wang MY, Hu W. Comparison of five equations for estimating resting energy expenditure in Chinese young, normal weight healthy adults. Eur J Med Res. 2012;17:26. doi: 10.1186/2047-783X-17-26.
14. Liu JM, Yang XG, Piao J, Sun R, Tian Y. Dietary energy requirements of young adult women in China by the doubly labeled water method. Asia Pac J Clin Nutr. 2010;19:520-5.

15. Xu J, Wang J, Guan Y, Mao D, Zhuo Q, Piao J, Xu J, Liu X. Basal metabolic rate of male young adults with normal BMI in North China. Acta Nutrimenta Sinica. 2007;29:13-5.
16. Zhuo Q, Sun R, Gou LY, Piao JH, Liu JM, Tian Y, Zhang YH, Yang XG. Total energy expenditure of 16 Chinese young men measured by the doubly labeled water method. Biomed Environ Sci. 2013;26:413-20. doi: 10.3967/0895-3988.2013.06.001.
17. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, O'Brien WL, Bassett DR Jr, Schmitz KH, Emplaincourt PO, Jacobs DR Jr, Leon AS. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc. 2000;32: S498-516.
18. Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. J Physiol. 1949; 109:1-9.
19. Jetté M, Sidney K, Blümchen G. Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. Clin Cardiol. 1990;13: 555-65.
20. Kwan M, Woo J, Kwok T. The standard oxygen consumption value equivalent to one metabolic equivalent (3.5 mL/min/kg) is not appropriate for elderly people. Int J Food Sci Nutr. 2004;55:179-82. doi: 10.1080/096374804 10001725201.
21. Melzer K, Heydenreich J, Schutz Y, Renaud A, Kayser B, Mäder U. Metabolic equivalent in adolescents, active adults and pregnant women. Nutrients. 2016;20:8. doi: 10.3390/ nu8070438.
22. Frankenfield DC, Coleman A. An evaluation of a handheld indirect calorimeter against a standard calorimeter in obese and non-obese adults. JPEN J Parenter Enteral Nutr. 2013; 37:652-8. doi: 10.1177/0148607112473340.
23. McMurray RG, Soares J, Caspersen CJ, McCurdy T. Examining variations of resting metabolic rate of adults: a public health perspective. Med Sci Sports Exerc. 2014;46: 1352-8. doi: 10.1249/MSS.0000000000000232.
24. Macfarlane DJ, Wong P. Validity, reliability and stability of the portable Cortex Metamax3B gas analysis system. Eur J Appl Physiol. 2012;112:2539-47. doi: 10.1007/s00421-011-2230-7.
25. Zhao SS, Liu YM, Yao JB, Gao SW, Zhang SJ. The estimation of body surface area of adult Chinese males. Acta Nutrimenta Sinica. 1984;6:87-95.
26. Zhao SS, Liu YM, Yao JB, Yang ZR, Liang YQ, Zhang SJ. The estimation of body surface area of adult Chinese females. Acta Nutrimenta Sinica. 1987;9:200-7.
27. Compher C, Hise M, Sternberg A, Kinosian BP. Comparison between Medgem and Deltatrac resting metabolic measurements. Eur J Clin Nutr. 2005;59:1136-41. doi: 10.1038/sj.ejcn.1602223.
28. Nieman DC, Austin MD, Chilcote SM, Benezra L. Validation of a new handheld device for measuring resting metabolic rate and oxygen consumption in children. Int J Sport Nutr Exerc Metab. 2005;15:186-94.
29. Hipskind P, Glass C, Charlton D, Nowak D, Dasarathy S. Do handheld calorimeters have a role in assessment of nutrition needs for hospitalized patients? A systematic review of the literature. Nurt Clin Practice. 2011;26:426-33. doi: 10.1177/0884533611411272.
30. Nathan D, Huynh du Q, Rubenson J, Nowak D, Dasarathy S. Estimating physical activity energy expenditure with the kinect sensor in an exergaming environment. PLoS One. 2011;10:e0127113. doi: 10.1371/journal.pone.0127113.
31. Ziegler JE, Rothpletzpuglia P, Tougerdecker R, Byhamgray L, O'Sullivanmaillet J, Denmark R. Resting energy expenditure in overweight and obese adults agreement between indirect calorimetry and prediction formulas. J Am Diet Assoc. 2008;108:A49. doi.org/10.1016/j.jada.2008. 06.105
32. Henes ST, Cummings DM, Hickner RC, Houmard JA, Kolasa KM, Lazorick S, Collier DN. Comparison of predictive equations and measured resting energy expenditure among obese youth attending a pediatric healthy weight clinic: one size does not fit all. Nutr Clin Pract. 2013;28:617-24. doi: 10.1177/0884533613497237.
33. Lazzer S, Bedogni G, Lafortuna CL, Marazzi N, Busti C, Galli R, De Col A, Agosti F, Sartorio A. Relationship between basal metabolic rate, gender, age, and body composition in 8,780 white obese subjects. Obesity (Silver Spring). 2010;18:71-8. doi: 10.1038/oby.2009.162.
34. Liu HY, Lu YF, Chen WJ. Predictive equations for basal metabolic rate in Chinese adults: a cross-validation study. J Am Diet Assoc. 1995;95:1403-8. doi: 10.1016/S0002-822 3(95)00369-X.
35. Johnstone AM, Murison SD, Duncan JS, Rance KA, Speakman JR. Factors influencing variation in basal metabolic rate include fat-free mass, fat mass, age, and circulating thyroxine but not sex, circulating leptin, or triiodothyronine. Am J Clin Nutr. 2005;82:941-8. doi: 10. 1093/ajcn/82.5.941.
36. Fett CA, Fett WC, Marchini JS. Resting energy expenditure measured vs. estimated and this relationship with body composition in women. Arq Bras Endocrinol Metabol. 2006; 50:1050-8.
37. Oshima S, Miyauchi S, Kawano H, Ishijima T, Asaka M, Taguchi M, Torii S, Higuchi M. Fat-free mass can be utilized to assess resting energy expenditure for male athletes of different body size. J Nutr Sci Vitaminol (Tokyo). 2011;57:394-400.
38. Wouters-Adriaens MP, Westerterp KR. Low resting energy expenditure in Asians can be attributed to body composition. Obesity (Silver Spring). 2008;16:2212-6.
39. Henes ST, Johnson A, Toner M, Mamaril K, Kelkar M, Xiao Y, Warren GL. Assessing resting metabolic rate in overweight and obese adolescents with a portable indirect calorimeter: a pilot study for validation and reliability. Nutr Clin Pract. 2016;31:355-61. doi: 10.1177/0884533615603 966.
40. Rising R, Whyte K, Albu J, Pi-Sunyer X. Evaluation of a new whole room indirect calorimeter specific for measurement of resting metabolic rate. Nutr Metab (Lond). 2015;12:46. doi: 10.1186/s12986-015-0043-0.