Predictive equations for the estimation of basal metabolic rate in Malaysian adults.

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ABSTRACT

In the field of human energy expenditure, the measurement of basal metabolic rate (BMR) is an essential element to derive energy requirement estimates for any given population. Besides basic anthropometrics data, this paper reports the generation of predictive equation for basal metabolic rates of healthy Malaysian adult from prospective measurements on 307 male and 349 females aged 18-60 years, using the Douglas bag technique. These new equations based on body-weight reveal that the current FAO/WHO/UNU (1985) predictive equations overestimate BMR of adult Malaysian by an average of 13% in males and 9% in female subjects while differences of between 4-5% were observed when compared to Henry & Rees (1991) equations for tropical people. There is a good reason to believe that the capacity to slow down metabolism amidst the hot and humid climate experience throughout the year as a genuine phenomenon for Malaysians. Similarly, these findings suggest that at equal energy intake recommendation for similar body weight, the lower energy needs of Malaysian could put them at greater risk for developing obesity. These observed deviations must be taken into account in formulating energy requirements of the population.

INTRODUCTION

The need to estimate energy expenditure of individual or population is important because it is a major determinant of food energy requirements. Since basal metabolic rate (BMR) constitute about 60% to 70% of the total energy expenditure, it has been widely used as the basis of the factorial method for deriving energy requirement of any given population.

Predictions of BMR have gained attention since the publication of the FAO/WHO/UNU (1985) expert consultation report which adopted the principle of relying on estimates of energy expenditure rather than energy intake to estimate the energy requirement of adults.

The BMR of an individual can simply be defined as the minimum metabolic activity required to maintain life and is a major component of total energy expenditure, whether the individuals are sleeping, resting or working (Payne & Waterlow, 1971). BMR is measured under standardised resting conditions : bodily and mentally at rest, 12-14 hours after a meal and in a neutral thermal environment. However in practice it is for more difficult to achieve the conditions of 'basal metabolism' than it is to define them (Garrow, 1978).

In practice, BMR is not commonly measured instead, prediction equations based on age, sex and weight are used (Dubois & Dubois, 1916; Harris & Benedict, 1919).The largest and most comprehensive analysis of BMR to date, Schofield *et al* (1985) reviewed some 11,000 BMR measurements in the literature and developed predictive equations for males and females which were later adopted for use in the FAO/WHO/UNU (1985) report. While the Schofield equations predict BMR accurately in many individual from temperate climate, they are said to be less accurate in predicting BMR in populations living in the tropics. It must be mentioned that most values were derived from North American and European subjects and that their analysis revealed an overestimation of BMR of 10-11% in Asiatic Indians (Henry & Rees, 1991; Piers and Shetty, 1993; Soares *et al*, 1993).

The difference in BMR for peoples living in the tropics was first reported by De Almedia (1921) who showed that the BMR in Brazilians was approximately 24% lower than the Aub-Dubois standards. There is now a substantial body of evidence indicating that people living in the tropics have lower BMR than their counterparts in the temperate regions. The present study was aimed at deriving predictive equations of BMR for adult Malaysians and to compare with the current FAO/WHO/UNU (1985) and Henry and Rees (1991) predictive equations.

METHODS

Study area

The study was carried out in the northern, central, southern and eastern regions in Peninsular Malaysia, Sabah and Sarawak in East Malaysia. Although true randomization of the study area was difficult to achieve, we have the assistance of the Social Economic Research Unit (SERU), the Economic Planning Unit (EPU) and the District offices in each region to select the study areas. The study covered at least one urban and one rural area in our attempt to make it as representative as possible of the local population. The local town halls and health centers were used to screen the population and only those who conform to the study criteria were selected and consents obtained on a voluntary basis.

Subjects

A total of 5623 adults aged 18-60 years (3016 males and 2607 females) from the six regions were screened (Ismail *et al*, 1995). A sub sample of 656 apparently healthy subjects (males=307, females=349) showing no signs or symptoms of disease with

acceptable range of BMI 20.5 – 25.0 kg/m^2 for males and 18.7 – 23.8 kg/m^2 for females (FAO/WHO/UNU, 1985) were selected for the study. Subjects were from the main ethnic groups in the regions, namely Malay, Chinese, Indian and Dayak residing in either urban or rural areas.

Anthropometry

Body weight was measured in light clothing, without shoes to the nearest 0.1 kg using a digital SECA balance (model 713 Germany) Height was measured to the nearest 0.1cm using the SECA balance with height attachment. Body mass index (Wt/H^2) was calculated for each individual.

Measurement of BMR

Subjects were introduced to the equipment and given a briefing on the experimental protocol before the day of the measurement. They were advised to abstain from coffee and other nicotine containing food or beverage, heavy meals, alcohol and strenuous exercise in the evening prior to measurement. They were required to under go a 12 hours overnight fast and to reach the study center without undue exertion. Subjects were than allowed to lie down quietly and relaxed for half an hour before measurement commenced. Female subjects were measured within the first ten days of menstrual cycle(the first day of menstruation taken as day 1). All measurements were carried out between 6am – 8.30am, in a room, with temperatures and humidity ranging from 23^0 – 26^0C and 758 – 770mmHg, respectively. A triplicate samples of expired air (10 minute each) were collected from each subject.

BMR was measured using the Douglas bag technique. Douglas bag (Harvard, UK) outlet were fitted with accessories (e.g tube, air-valves and mouthpieces) purchased from Hans Rudolfh, USA which are smaller and more comfortable to use. Samples of air were analyzed soon upon collection using Oxygen analyser (Model 570A, Servomex Ltd., England), which was calibrated frequently using oxygen free nitrogen. Volume of expired air (corrected to STP) was determined using a digital dry gas meter (Harvard Ltd, UK). Barometric pressure was measured daily using an aneroid barometer. The energy expenditure of subjects were derived using the Wier (1949) formula. The pulse rate and respiration rate of subjects were recorded while BMR was being measured. The BMR values was considered to be technically valid when the intra-subject coefficient of variation (cv) is < 2.5% or less. Measured BMR of each subject was compared to the following predictive equations :

1. FAO/WHO/UNU (1985)
   Males

   18-30 years (MJ/day) = 0.0640 W + 2.84
   30-60 years (MJ/day) = 0.0485 W + 3.67
   Females
   18-30 years (MJ/day) = 0.0615 W + 2.08
   30-60 years (MJ/day) = 0.0364 W + 3.47
2. Henry & Rees (1991)
   Males
   18-30 years (MJ/day) = 0.0560 W   +   2.800

30-60 years (MJ/day) = 0.0460 W + 3.160
Females
18-30 years (MJ/day) = 0.0480 W + 2.562
30-60 years (MJ/day) = 0.0480 W + 2.448

Statistical analysis

All data were analyzed using SPSS/PC package version 9.0. Correlation and regression analysis were done to determine relationship between variables. Results were considered
significant at 5% level.

RESULTS AND DISCUSSION

The mean age, weight, height and Body Mass Index (BMI) of the subjects by age-group and sex are shown in Table 1 for males and Table 2 for females. There were significant differences (P<0.01) in age, height and BMI between age-groups in both male and female subjects. Younger subjects have lower BMI due to their height. The were also significant differences in weight, height and BMI between males and female subjects.

A regression equation of BMR for the entire data which included both weight (WT) and age (AGE) was established as shown below :

Male

BMR(MJ/d)= 0.047(WT) – 0.035 (AGE) + 3.083
    * p<0.05, r=0.539; n =307

Female

BMR (MJ/d) =0.054(WT) – 0.027 (AGE) + 1.985
    * p<0.05, r=0.512; n = 349

The ANOVA analysis, however, indicated that only the weight predictor variables contribute significantly to the dependent variable (BMR) both male and female subjects (P<0.05). Height and age did not contribute significantly to BMR thus the inclusion of age and height contribute little to the predictive equations for BMR in this study. Body weight, an easily and accurately measurable variable, is usually retained in a stepwise regression as

Table 1 : Physical characteristics of subjects

Age-group	n	Age	Weight	Height	BMI
Male					
18-30	84	24.29 ± 2.97^a	58.61 ± 6.26^b	$1.64 \pm 0.06^{a,b}$	$21.57 \pm 1.78^{a,b}$
30-60	223	42.14 ± 8.57	58.20 ± 6.69^b	1.61 ± 0.05^b	22.42 ± 2.04^b
Female					
18-30	131	23.65 ± 2.90^a	49.81 ± 6.29	1.54 ± 0.07^a	20.91 ± 2.22^a
30-60	218	41.25 ± 7.72	49.05 ± 5.73	1.50 ± 0.06	21.84 ± 2.26

[a] P<0.01 when compared between age-groups in the same sex
[b] P<0.01 when compared between difference sex

Table 2: BMR-predictive formula for male and female subjects

Age Group	n	Formula	r	SE Mean	%Difference
Male					
18-30	84	0.0550(W) + 2.480	0.644	0.0363	13%WHO 6%HR
30-60	223	0.0432(W) + 3.112	0.501	0.0189	13%WHO 4%HR
Female					
18-30	131	0.0535(W) + 1.994	0.511	0.0263	9%WHO 6%HR
30-60	218	0.0539(W) + 2.147	0.519	0.0200	9%WHO 2%HR

the best single predictor of BMR (Schofield et al 1985; Henry & Rees, 1991).

The age-specific equations for Malaysian males and females that relate BMR to body weight for two age groups (18-30 years and 30-60 years) were then compared to FAO/WHO/UNU (1985) and Henry & Rees (1991) equations as shown in Table 2.

The predictive equations generated by this study showed a significantly lower BMR (P<0.01) compared to the BMR predicted by FAO/WHO/UNU (1985) and Henry & Rees (1991) for both male and female subjects. Although the coefficient of determination (r^2) (range 0.25-0.42) for the equations derive in this study were small, they were close to values obtained by Schofield et al (1985) (r^2 between 0.36 and 0.44) and to those of Henry & Rees 1991 (r^2 between 0.35 and 0.42) for the 18-60 year age span.

Linear regression equation of BMR on body weight derived from this study were compared with the equations recommended by FAO/WHO/UNU (1985) and Henry and Rees (1991) for different age groups (Figure 1,2,3 and 4). For males subjects (Figure 1 and 2) the differences were between 4% to 13% while for females, smaller differences were observed (2%-9%). Figure 4 also revealed that the equation for older females in the study intersects the Henry and Rees (1991) equation between 45-55kg and at 80 kg (FAO/WHO/UNU, 1985) indicating that there are no differences between predicted and measured BMR at these body weights.

The lower BMR values of people in the tropics as compared to the Schofield et al 1985, is due to the bias introduce by the dominance of the Italian data which constitute over 3000(50%) of the 6000 BMR values for males between 10-60 years. Recent BMR studies (Hayter 1992, Soares et al 1993, Piers and Shetty 1993) however suggested that there are no differences between the temperate regions and the tropics provided the subjects are well
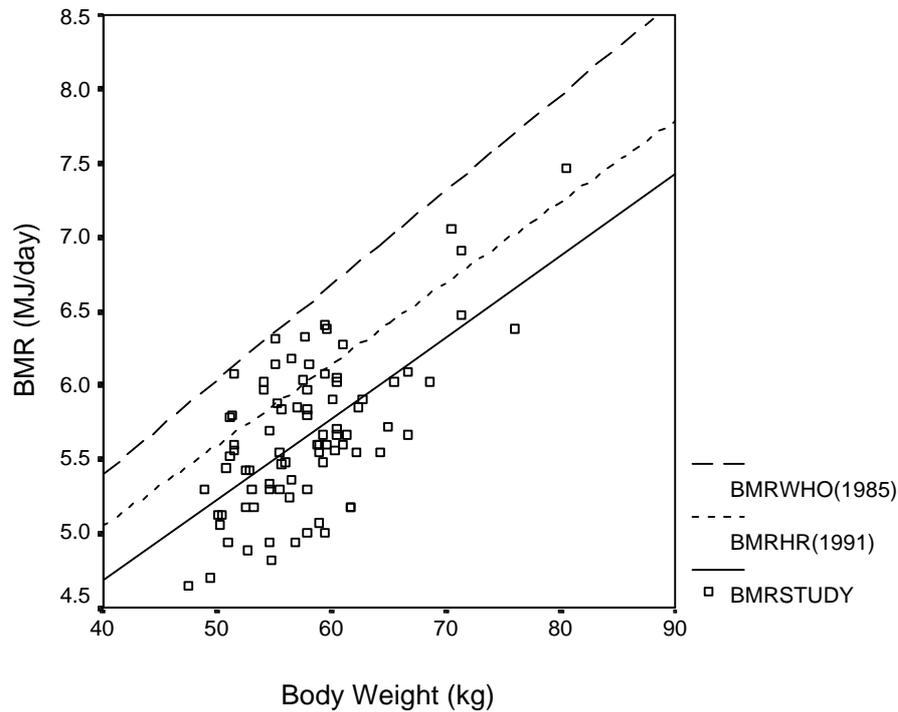
Figure 1 : Comparison between BMR study (Male aged 18-30 years old) and predicted BMR by FAO/WHO/UNU (1985) and Henry and Rees (1991).
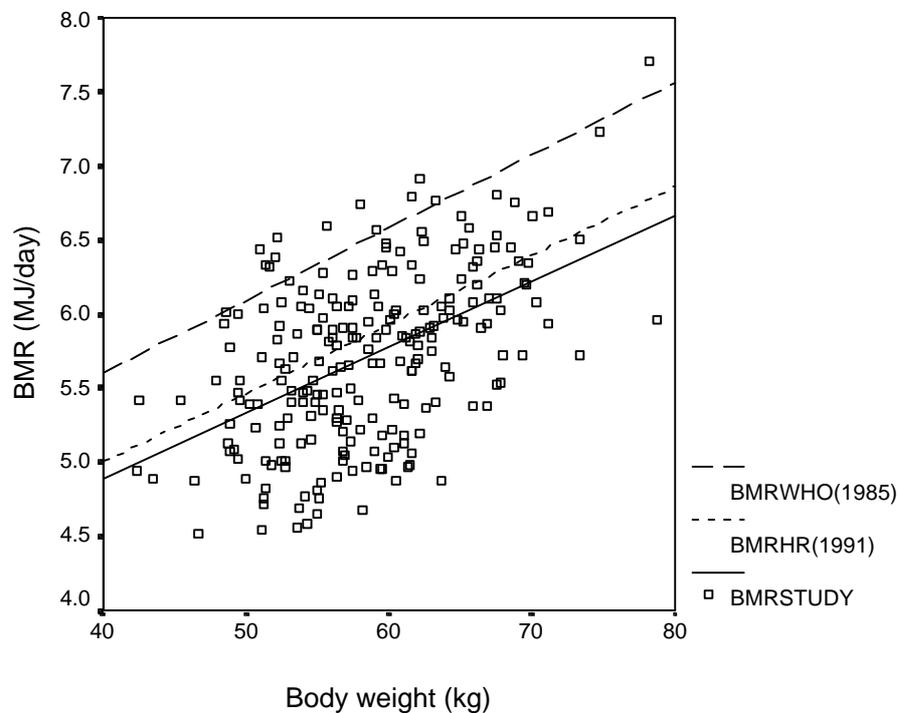

Figure 2 : Comparison between BMR study (Male aged 30-60 years old) and predicted BMR by FAO/WHO/UNU (1985) and Henry and Rees (1991).
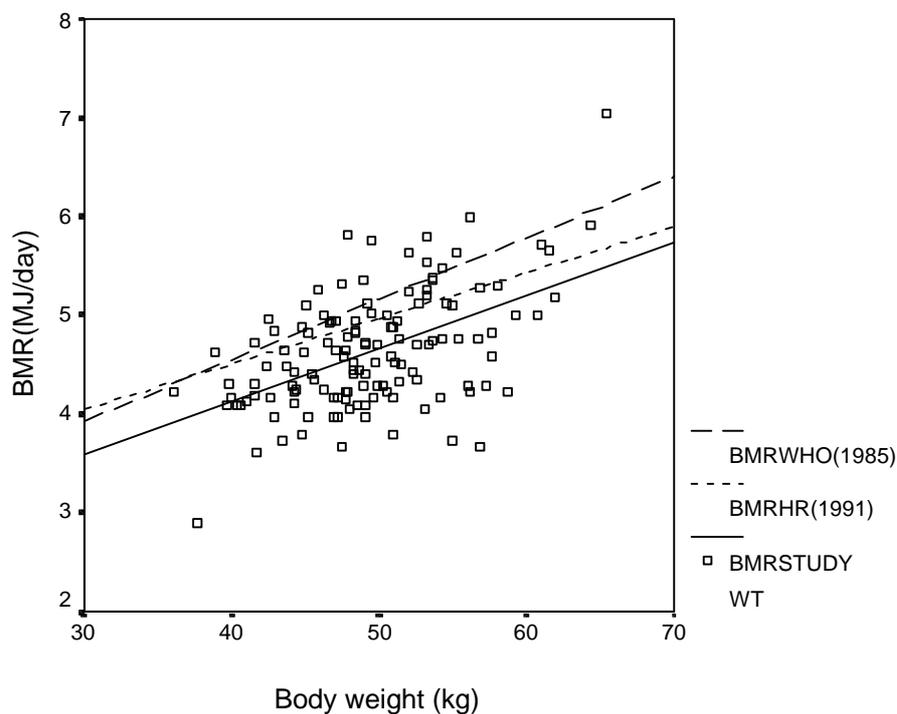
Figure 3 : Comparison between BMR study (Female aged 18-30 years old) and predicted BMR by FAO/WHO/UNU (1985) and Henry and Rees (1991).
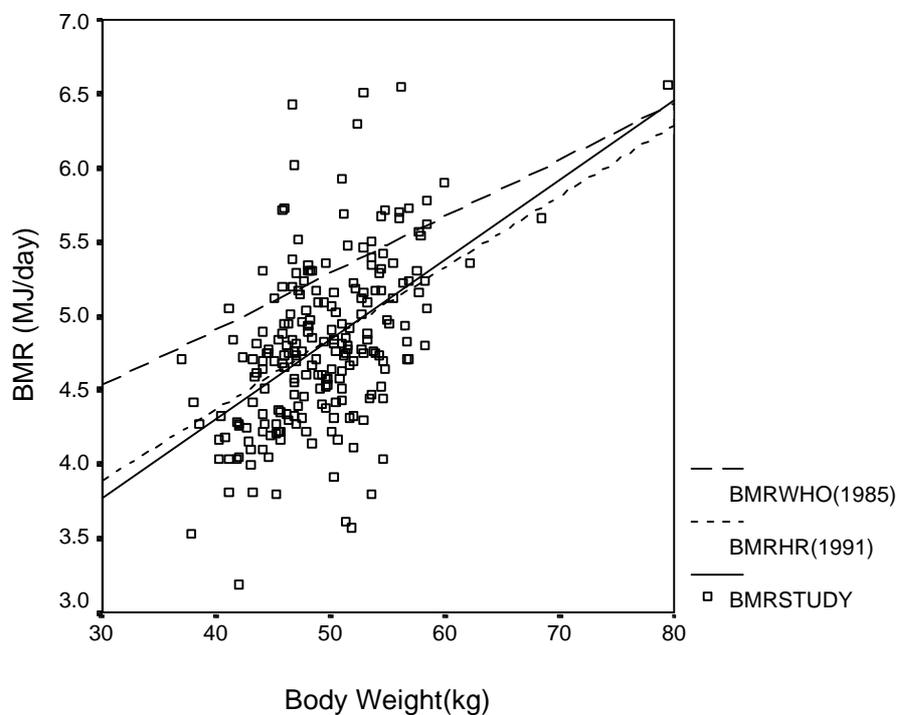

Figure 4 : Comparison between BMR study (Female aged 30-60 years old) and predicted BMR by FAO/WHO/UNU (1985) and Henry and Rees (1991).

nourished. It is unlikely that the lower BMR observed in our analysis is due to the inclusion of malnourished subjects as they were all selected from a normal healthy population with BMI 18.7-25.0.

The differences in BMR between population of the world is equivocal. Earlier studies (Schofield et al 1985, Henry & Rees 1991) showed 8-10% lower in the tropics while (Haytar 1992, Soares *et al* 1993) suggested no difference in BMR between Indians and Europeans. Close examination of the database revealed no significant differences between the major ethnic groups in this study which is in agreement with several earlier reported energy expenditure studies in adult Malaysian (Ismail and Zawiah, 1989; Henry *et a*l 1991, Ismail *et al* 1993).

Difference in BMR, measured during the different phases of menstrual cycle, possibly play an important role since they can contribute as much as 8.5% of the variation in the same subject (Bisdee, James & Shaw 1989). In this study effort were made to measure female subjects during the same phase of menstrual cycle and the difference observed may well be due to the fact that no consideration was given to the period in the menstrual cycle from the earlier studies reported by Henry and Rees (1991). Furthermore, it is not unlikely that the Western women have a greater proportion of their body weight made up of muscle and viscera with their inherently higher energy expenditure, as compared to their Malaysian counterpart. Thus with lower fat free

mass(FFM) perhaps explain in part the current finding of a lower BMR. A greater degree of muscle relaxation during BMR measurements by Asians may also contribute to the lowered BMR and it is also likely that differences in body composition in the population groups in the tropics may also contribute to this difference.

Other evidence suggest that the relationship between BMR and standard independence variables (age, sex and body size) may vary among populations including of seasonal variations in BMR corresponding with diet and/or temperature changes (Ferro-Luzzi and Branca, 1993).

CONCLUSION

The present study shows that the BMR in adult Malaysian is lower than that predicted by the FAO/WHO/UNU(1985) and Henry and Rees (1991) equations and should not be dismissed as an artifact. There is a good reason to believe that the capacity to low down metabolism in a hot and humid climate experienced throughout the year as a genuine phenomenon in Malaysia besides body size and composition and metabolic economies in response to energy deficit. Similarly, these findings suggest that at equal energy intake recommendation for similar body weight, the lower energy needs of Malaysian would put them at greater risk for developing obesity. It is recommended that the predictive equations derived from this study be taken into account in formulating energy requirements of the adult population in Malaysia.

ACKNOWLEDGEMENTS

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