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Predictive equations for the estimation of basal metabolic rate of Malaysian adolescents

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ABSTRACT

A longitudinal study was conducted to relate basal metabolic rate (BMR) with growth during adolescence. Subjects comprise 70 boys and 69 girls aged between ten and thirteen years at the time of recruitment. Parameters studied include anthropometric measurements and BMR, which was measured by indirect calorimetry using the Deltatrac metabolic monitor. Measurements were carried out serially once every six months, with a total of 713 BMR data points collected over three years. Mean BMR of boys aged 11, 12, 13 and 14 years were 4.96 ± 0.63 MJ/day, 5.28 ± 0.71 MJ/day, 5.73 ± 0.68 MJ/day and 5.92 ± 0.63 MJ/day, respectively; while mean BMR of girls in the 10, 11, 12 and 13 year age groups were 4.96 ± 0.63 MJ/day, 4.85 ± 0.63 MJ/day, 5.05 ± 0.55 MJ/day and 4.94 ± 0.51 MJ/day, respectively. Comparison of measured BMR with BMR values predicted from the FAO/WHO/UNU (1985) equations shows that the predictive equations overestimated the BMR of Malaysian boys by 3% and that of girls by 5%. The Henry & Rees (1991) equations for populations in the tropics underestimated BMR of boys and girls by 1% and 2%, respectively. Linear regression equations to predict BMR based on body weight were derived according to sex and age groups. It is recommended that these predictive equations be used for the estimation of BMR of Malaysian adolescents.

INTRODUCTION

In 1985, a joint report of a FAO/WHO/UNU committee had recommended the use of basal metabolic rate (BMR) as the basis for calculating energy requirements of people above the age of 10 years. This approach emphasised the importance of accurately estimating BMR as over- or underestimation would affect the overall estimation of energy requirements.

BMR may be obtained from the actual measurement of BMR under thermoneutral, resting and fasting conditions or derived from predictive equations relating BMR with certain parameters. The FAO/WHO/UNU (1985) technical report presented a series of equations for calculating BMR according to age, sex and body weight. However, the data used to develop the predictive equations mainly comprise data from European and North American subjects. Data of subjects from other parts of the world is limited, that is, 5.2% only. Moreover, BMR data of young adolescents between the ages of ten and fifteen were very few compared with the data of adults (Schofield, 1985).

Henry & Rees (1991) developed a new series of predictive equations to calculate the BMR of tropical peoples by reanalysing data from BMR studies carried out in the tropics. They found that the BMR of tropical peoples was on average 8% below that predicted by the FAO/WHO/UNU equations. The actual BMR of boys and girls aged between 10 and 18 years were on average 7.1% and 7.6%, respectively, lower compared to the BMR predicted from the FAO/WHO/UNU equations.

Kaplan *et al.* (1996) found that resting energy expenditure was 14% lower in African-American children than in Caucasian children after adjusting for age, gender, body weight, fat free mass and fat mass. On the other hand, Spurr *et al.* (1992) in studying Colombian children 2 – 16 years concluded that ethnicity was an insignificant contributor in determining resting energy expenditure.

Ismail *et al.* (1998) presented BMR data of a study of adult Malaysians and recommended a set of equations for the estimation of the BMR of Malaysian adults. With the exception of a study by Ismail *et al.* (1991) carried out on students aged between 13 and 15 years from the Royal Military College in Kuala Lumpur, the basal metabolic rate of Malaysian adolescents had not been previously reported.

This paper will present the BMR data of adolescents measured from 1992 – 1995 in a longitudinal study undertaken with the objective of relating growth during the early adolescence period with BMR. Regression equations for the estimation of BMR of young Malaysian adolescents will also be presented.

METHODOLOGY

Subjects

The subjects of this study comprise schoolchildren of Malays ethnicity from Bandar Baru Bangi, a suburb 30 km from Kuala Lumpur. Subjects were volunteers who conform to normal weight-for-age and height-for-age when compared with the National Center for Health Statistics reference data (WHO, 1983).

The initial study group comprised 70 boys aged between 10.9 and 12.6 years, and 69 girls aged between 10.0 and 11.6 years. The subjects were measured serially every six months for three years. At the completion of the study, 54 boys and 53 girls remained, conforming to a drop out rate of 23%.

Age of subjects was calculated from the date of birth recorded from the children's birth certificate, using the concept of decimal age where the age scale has been calibrated in tenths of a year and not in months (Tanner, 1978). Subjects were categorised into six age groups, namely 10 years (10.00 – 10.99 years), 11 years (11.00 – 11.99 years), 12 years (12.00 – 12.99 years), 13 years (13.00 – 13.99 years), 14 years (14.00 – 14.99 year) and 15 years (15.00 – 15.99 years).

Anthropometry

Anthropometric measurements were done according to standardised techniques as described by Cameron (1984). Parameters include body weight, height, and skinfold thicknesses at five sites, namely biceps, triceps, subscapular, suprailiac and calf.

Body weight as measured with a beam balance (SECA Model 713) to the nearest 0.1 kg. The beam balance was periodically calibrated for accuracy with the use of a known weight. Height measurements were read to the nearest 0.5 cm from a scale marked in centimetres up to a height of two meters and fixed to the beam balance.

Skinfold thickness measurements were taken with a Harpenden skinfold calliper (British Indicators, U.K.) to the nearest 0.1 mm. Percentage of body fat was calculated from regression equations developed by Parizkova & Roth (1972). Body mass index (BMI) and lean body mass (LBM) were also calculated.

Measurement of BMR

BMR was measured by indirect calorimetry using an open-circuit, canopy ventilated system, namely the Deltatrac metabolic monitor MBM-100 (Datex/Instrumentarium Corp., Helsinki, Finland). All measurements were made under standardised conditions in a thermoneutral environment (26 – 28^{o}C) with no external stimulation. Subjects were measured in a post-absorptive state, lying still and relaxed, and rested for not less than 30 minutes.

The Deltatrac was calibrated using an "Alcohol Burning Test Kit" for respiratory quotient and flow accuracy. Atmospheric pressure calibration was carried out daily based on barometric reading. Gas calibration was also done daily with a reference gas mixture, which contained 95% oxygen and 5% carbon dioxide (SD 0.003%).

Approximately 30 minutes of respiratory gas exchange data were collected. The first 5 – 10 minutes of data were discarded, as recommended by Isbell *et al.* (1991). This allowed the subject time to acclimatise to the canopy and instrument noise. The average of the last twenty minutes of measurements was used to determine BMR.

Data analysis

Comparison of the parameters measured was done between different age groups and between the sexes using Student's t-tests and analysis of variance (ANOVA). Measured (actual) BMR was compared with BMR predicted from the following regression equations:

FAO/WHO/UNU (1985)

Boys BMR = 73.2W + 2720
Girls BMR = 84.0W + 2122

Henry & Rees (1991)

Boys BMR = 51.0W + 3120
Girls BMR = 47.0W + 2951

where W = Body weight (kg)
and BMR is expressed in kJ/day

Specific anthropometric parameters were correlated with BMR and regression equations for BMR were derived.

RESULTS AND DISCUSSION

Anthropometric assessment of subjects

Table 1 shows the physical characteristics of the subjects at each age group. At eleven and twelve years, girls were significantly taller and heavier than boys. However, by age thirteen, the boys' mean height had caught up with the girls'. In all known populations, the adolescent spurt begins at an earlier age in girls than in boys and when girls reach adolescence they become taller than boys of the same age. Later, the boys have their adolescent spurt, catch up with girls and finally become taller (Preece *et al.*, 1992).

Table 1. Physical characteristics of subjects by age groups (mean ± SD)

Age groups	No. of data-points	Weight (kg)	Height (cm)	BMI (kg/m^2)	Body fat (%)	LBM (kg)
<u>Boys</u>						
11 years	83	33.1 ± 5.7	140.6 ± 5.2	16.7 ± 2.3	19.2 ± 5.2	26.5 ± 3.4
12 years	108	36.2 ± 6.1	146.0 ± 6.7	16.9 ± 2.1	18.8 ± 4.7	29.2 ± 4.1
13 years	109	42.1 ± 6.9	154.7 ± 6.6	17.5 ± 2.1	18.3 ± 4.7	34.2 ± 4.8
14 years	56	46.0 ± 6.2	159.5 ± 6.0	18.0 ± 1.9	17.9 ± 4.2	37.6 ± 4.3
15 years	4	49.9 ± 6.9	164.5 ± 4.5	18.4 ± 1.9	21.4 ± 3.6	39.1 ± 5.0
All	360	38.9 ± 7.8	149.7 ± 9.3	17.2 ± 2.2	18.6 ± 4.8	31.5 ± 5.8
Girls						
10 years	55	32.7 ± 5.5	140.1 ± 5.1	16.6 ± 2.4	23.0 ± 5.4	24.9 ± 3.0
11 years	118	35.5 ± 6.7*	143.6 ± 5.7*	17.2 ± 2.7	23.9 ± 5.5*	26.7 ± 3.6
12 years	103	41.9 ± 7.2*	151.1 ± 5.2*	18.3 ± 2.8*	25.7 ± 5.6*	30.8 ± 3.8*
13 years	70	43.4 ± 6.6	152.6 ± 5.1	18.6 ± 2.9*	26.7 ± 4.9*	31.6 ± 3.3*
14 years	7	41.2 ± 6.1	151.9 ± 5.8	17.9 ± 3.0	25.4 ± 4.2	30.5 ± 3.2
All	353	38.6 ± 7.8	147.2 5 7.2	17.7 ± 2.8	24.9 ± 5.5	28.7 ± 4.3

* Significantly different from boys in the same age group at $p<0.05$

Comparison across age groups show that the mean body fat percentage of boys was lower whilst LBM was higher among the higher age groups. Amongst girls, the means of both parameters were higher among the higher age groups although the average increase in LBM was not as great as amongst boys. These changes in body composition occur jointly with the growth spurt (Riumallo & Durnin, 1988). In studying the increments of body composition between 10 and 18 years, Chumlea *et al.* (1983) reported similar findings, where boys had a mean annual decrease in body fat of 1.15% per year, and a mean annual increment in LBM of 4.38 kg/year.

Basal metabolic rate

Basal metabolic rate is influenced by body weight and lean body mass. The BMR data in Table 2 is therefore presented in three forms; namely (i) total or absolute BMR, in MJ/day and kcal/min, (ii) adjusted for body weight, in kJ/kg/day, and (iii) adjusted for lean body mass, in kJ/kg LBM/day.

Amongst the boys, the mean absolute BMR is significantly ($p<0.05$) higher in the higher age groups. Mean absolute BMR of girls appeared to be highest amongst the 12 year olds. Mean BMR of girls at 13 and 14 years showed no significant difference from the younger age groups. This may indicate that among girls, the increase in total BMR over the pubertal years has slowed down or stopped at approximately 13 years old. In contrast, when BMR is presented

Table 2. BMR of subjects according to age groups (mean ± SD)

Age groups	No. of data points	BMR MJ/day	BMR kcal/min	BMR kJ/kg/day	BMR kJ/kg LBM/day
Boys					
11 years	83	4.96 ± 0.63^{a}	0.82 ± 0.10	152 ± 15^{a}	187 ± 13^{a}
12 years	108	5.28 ± 0.71^{b}	0.88 ± 0.12	147 ± 14^{b}	181 ± 13^{b}
13 years	109	5.73 ± 0.68^{c}	0.95 ± 0.11	138 ± 13^{c}	168 ± 13^{c}
14 years	56	5.92 ± 0.63^{d}	0.98 ± 0.10	130 ± 11^{d}	158 ± 13^{d}
15 years	4	5.82 ± 0.85^{abcd}	0.97 ± 0.14	117 ± 13^{cd}	149 ± 13^{cd}
All	360	5.45 ± 0.76	0.90 ± 0.13	142 ± 16	175 ± 17
Girls					
10 years	55	4.58 ± 0.53^{a}	0.76 ± 0.09	142 ± 15^{a}	184 ± 15^{a}
11 years	118	4.85 ± 0.63^{b}	0.80 ± 0.10	138 ± 15^{a}	182 ± 15^{a}
12 years	103	5.05 ± 0.55^{c}	0.84 ± 0.09	122 ± 15^{b}	165 ± 16^{b}
13 years	70	4.94 ± 0.51^{bc}	0.82 ± 0.09	115 ± 13^{c}	157 ± 14^{c}
14 years	7	4.91 ± 0.61^{abc}	0.81 ± 0.10	120 ± 15^{bc}	161 ± 15^{c}
All	353	4.88 ± 0.59	0.81 ± 0.10	129 ± 18	172 ± 18

Values with different alphabet tags show significant difference between age groups: $p<0.05$

after being adjusted for body weight and LBM, the mean BMR appeared to be significantly ($p<0.05$) lower amongst the higher age groups.

The results of the present study confirms the findings of early studies on the BMR of adolescents, that is a definite increase in (total) metabolism before and during early puberty, followed by a subsequent decline after puberty is established (Topper & Mullier, 1932). BMR of children increases from birth to puberty because of an increase in size and body weight (Benedict & Talbot, 1921). In contrast, when expressed per kg body weight or LBM, they peak during the first year of life and then decrease exponentially from 1 to 20 years of age (Davies *et al.*, 1991). Molnar & Schutz (1997) reported a similar finding, that is a slight but significant decrease in adjusted BMR between the age of 10 and 16 years.

Comparison of measured BMR with predicted BMR

In order to verify the accuracy of the FAO/WHO/UNU (1985) and the Henry & Rees (1991) predictive equations in estimating the BMR of our study population, measured BMR data was compared with BMR calculated from these two equations. The results are shown in Table 3.

Table 3. Comparison of measured BMR with predicted BMR (mean ± SD) and the percentages by which the actual BMR is overestimated (+) and underestimated (-) by the predictive equations

Age groups	No of data points	BMR (MJ/day)			% Difference [3]	
		Measured	Predicted [1]	Predicted [2]	Predicted [1]	Predicted [2]
Boys						
11 years	83	4.96 ± 0.63	5.14 ± 0.42 ***	4.90 ± 0.48	+ 4.5	- 0.5
12 years	108	5.28 ± 0.71	5.37 ± 0.45 *	5.16 ± .051 **	+ 2.6	- 1.5
13 years	109	5.73 ± 0.68	5.80 ± 0.51	5.66 ± 0.58 *	+ 1.8	- 0.9
14 years	56	5.92 ± 0.63	6.09 ± 0.45 **	5.98 ± 0.52	+ 3.4	+ 1.6
15 years	4	5.82 ± 0.85	6.37 ± 0.51	6.31 ± 0.58	+ 10.5	+ 9.4
All	360	5.45 ± 0.76	5.57 ± 0.57 ***	5.39 ± 0.66 *	+ 3.0	- 0.5
Girls						
10 years	55	4.58 ± 0.53	4.79 ± 0.28 ***	4.49 ± 0.26	+ 5.4	- 1.2
11 years	118	4.85 ± 0.63	4.93 ± 0.34 * †††	4.62 ± 0.31 *** †††	+ 2.7	- 3.7
12 years	103	5.05 ± 0.55 ††	5.26 ± 0.37 *** †	4.92 ± 0.34 ** †††	+ 4.9	- 1.8
13 years	70	4.94 ± 0.51 †††	5.33 ± 0.34 *** †††	4.99 ± 0.31 †††	+ 8.6	+ 1.6
14 years	7	4.91 ± 0.61	5.22 ± 0.31	4.89 ± 0.29	+ 7.4	+ 0.5
All	353	4.88 ± 0.59	5.09 ± 0.40 ***	4.77 ± 0.37 ***	+ 5.0	- 1.6

Significantly different from male BMR in the same age group: † $p<0.05$ †† $p<0.01$ ††† $p<0.001$
Significantly different from measured BMR : * $p<0.05$ ** $p<0.01$ *** $p<0.001$

Note : Predicted [1] - BMR predicted from the FAO/WHO/UNU (1985) equations.
Predicted [2] - BMR predicted from the Henry & Rees (1991) equations.

[3] $\% \text{ Difference} = \frac{\text{Predicted BMR - Measured BMR}}{\text{Measured BMR}} \times 100$

The FAO/WHO/UNU (1985) equations overestimated the measured BMR of both sexes in all age groups. The BMR of boys and girls on the whole were significantly overestimated by 3% and 5%, respectively. The range of overestimation was 2 – 11% among boys and 3 – 9% among girls.

The Henry & Rees (1991) predictive equations underestimated measured BMR in the lower age groups and overestimated measured BMR in the higher age groups. The range of underestimation among boys (1 – 2%) was smaller than that among girls (1 – 4%). On the other hand, the range of overestimation was larger among boys (2 – 10%) than girls (1 – 2%). Overall, the BMR of boys and girls was underestimated by 1% and 2%, respectively.

Compared to the FAO/WHO/UNU (1985) equations, the equations of Henry & Rees (1991) appeared to give better prediction of BMR amongst the adolescents of this study. On the whole, the percentage difference from measured BMR was smaller, and was significantly different only within two age groups for each gender.

In a preliminary analysis of BMR and race using adult data, Henry & Rees (1988) concluded that peoples living in the tropics, such as the Brazilian, Filipino, Indian, Chinese, Javanese and Malay, had lower BMR than predicted by the Schofield equations (1985) which were the equations adopted by the FAO/WHO/UNU (1985).

Further analysis which included the data of children and adolescents also came to the conclusion that the actual BMR of tropical peoples, including Malays, was on average 8% below that predicted by the FAO/WHO/UNU equations (Henry & Rees, 1991). In their analysis, BMR was overpredicted by 7% among males aged 10 - 18 years, and 8% among females aged 10 - 18 years.

Spurr & Reina (1988) had also shown that the BMR in mestizo boys was 7% lower than predicted by the Schofield equations. The results of the present study confirm the finding that the FAO/WHO/UNU (1985) equations overpredicts the BMR of adolescents living in the tropics, specifically Malay adolescents.

Correlation between BMR and physical characteristics

Correlation analysis was carried out to determine the relationship between BMR and various physical parameters. The correlation coefficient (r) shows the degree of correlation between BMR and each variable. The coefficient of determination (r^2) in turn measures the predictive power of the independent variable for a model or an equation. Generally, the larger the value of r^2, the better the predictive power of the model.

Table 4 shows the correlation coefficients between BMR and various anthropometric variables. The correlation analysis showed that variables, such as body weight, height, BMI, LBM and fat mass, were all significantly correlated ($p<0.05$) with

Table 4. Correlation coefficients (r) between BMR and specific variables

Variables	Boys	Girls
No. of data points	360	353
Age (years)	0.474	0.205
Body weight (kg)	0.834	0.722
Height (cm)	0.715	0.498
BMI (kg/m^2)	0.637	0.637
LBM (kg)	0.848	0.703
Fat mass (kg)	0.557	0.644

BMR in boys and girls. BMR had the highest correlation with LBM, followed by body weight. Although, the correlation between BMR with height, BMI and fat mass had r-values higher than 0.5, these values were not as good as the correlation for BMR with LBM (boys 0.85, girls 0.70) and body weight (boys 0.83, girls 0.72). Correlation between BMR and age was very low.

Body size clearly affects metabolic rate. However, the quantitative relationship between body size and metabolism is by no means straightforward (Bennett, 1988). In a reanalysis of published data, Cunningham (1980) reported that the best predictor of BMR was LBM calculated from total body water, which he estimated from body weight, sex and age. Webb (1981) explained that LBM was closely related to active tissue mass, thus the high correlation between daily energy expenditure and LBM. In contrast, the correlation of BMR with body weight was lower because body weight includes of parts of the body mass that have low metabolic activity such as the adipose tissue.

Derivation of BMR regression equations

Linear regression equations of BMR with lean body mass, body weight, height and age were obtained for each sex. Table 5 shows the regression equations for BMR in relation to the various anthropometric variables. This table includes the number of data points, the coefficient of determination (r^2) and the standard error of estimates (s.e.). These standard errors are the standard deviations of the residuals and, thus, indicate the variation of the predicted values about the regression line.

Regression equations with LBM as independent variable contributed 72% (r^2) to the BMR variability among boys and 49% to the variability among girls. Regression equations of BMR with body weight as a variable contributed 70% and 52% to the variability amongst the boys and girls, respectively. The effect of including height, as a second predictor did not contribute significantly to the equations, that is, the value of r^2 remains the same as using body weight alone for both the boys and girls. The inclusion of age as a third variable did improve the predictive power of the equations for the boys but not by much (1%).

Table 5. Regression equations of BMR and various anthropometric variables

Regression equations	No. of data points	r^2	s.e.
<u>Boys</u> (11 - 15 years)			
BMR = 110.1 LBM + 1978	360	0.72	401
BMR = 80.4 W + 2319	360	0.70	417
BMR = 70.1 W + 1080.3 H + 1103	360	0.70	414
BMR = 70.0 W + 21.0 H - 122.6 A + 1168	360	0.71	406
<u>Girls</u> (10 - 14 years)			
BMR = 94.7 LBM + 2166	353	0.49	417
BMR = 54.4 W + 2781	353	0.52	405
BMR = 52.2 W + 370.0 H + 2323	353	0.52	405
BMR = 56.2 W + 18.8 H - 199.1 A + 2353	353	0.58	378

Note : BMR is expressed in kJ/day
Keys : W = Body weight in kg LBM = Lean body mass in kg
H = Height in m A = Age in years

However, among the girls the inclusion of age improved the predictive power of the equation rather more significantly (6%).

In the computation of BMR regression equations for the 1981 FAO/WHO/UNU Expert Consultation on Energy and Protein Requirements, Schofield also found that including height as a second predictor after weight, did not contribute significantly to the equations for both sexes, except for the under threes and over 60s (Schofield, 1985; James, 1985). Further investigations that included age as an independent variable also came to the conclusion that the inclusion of age to the equations was of no practical value even for groups under 18 years of age (Schofield, 1985).

Among the criteria cited by Schofield (1985) on choice of independent variables used in the regression equations for predicting BMR were (i) the selection of a variable should be seen as making good sense in physiological terms, (ii) an included variable should make a statistically significant contribution to the prediction of BMR, and (iii) the resulting equations should be simple to use.

In view of the criteria stated above, equations using three independent variables would obviously be rather complex. The use of body weight and height as independent variables in an equation are more useful and appropriate than LBM. This is because measurement of body weight and height are more easily carried out and can be

Table 6. BMR predictive equations with body weight as independent variable

Age groups	Regression equations	No. of data points	r^2	s.e.
Boys				
11 years	BMR = 86.42 W + 2097	83	0.62	390
12 years	BMR = 93.45 W + 1899	108	0.64	431
13 years	BMR = 79.75 W + 2377	109	0.66	393
14 years	BMR = 74.65 W + 2487	56	0.54	429
11 – 15 years	BMR = 80.38 W + 2319	360	0.70	417
Girls				
10 years	BMR = 75.29 W + 2118	55	0.62	329
11 years	BMR = 76.66 W + 2124	118	0.66	365
12 years	BMR = 52.46 W + 2846	103	0.47	400
13 years	BMR = 50.86 W + 2736	70	0.43	392
10 – 14 years	BMR = 54.44 W + 2781	353	0.52	405

Note : BMR is expressed in kJ/day
W = Body weight in kg

assessed with higher accuracy than LBM. However, as the inclusion of height did not contribute significantly to the predictive power, we may conclude that predictive equations for BMR using body weight, as the only independent variable is the most appropriate. In their analyses, FAO/WHO/UNU (1985), Schofield (1985), and Henry & Rees (1991), came to the same conclusion for the adolescent and adult age groups.

Considering the fact that body weight is the most suitable variable for the prediction of BMR, BMR regression equations were developed for each yearly age group using body weight as the only independent variable. Table 6 provides the regression equations derived for each age group.

Comparison of BMR regression equations with other predictive equations

Linear regression equations of BMR on body weight derived in the present study were compared with the equations recommended by FAO/WHO/UNU (1985) and with those published by Henry & Rees (1991) for the adolescent age group (10 – 18 years). Figures 1 and 2 present the graphical relationship of BMR to body weight.

The figures showed deviation to an extent between the regression equations of the present study and those of the FAO/WHO/UNU (1985) for both sexes. The differences were smallest (about 3%) among the heaviest boys and largest (about 14%)

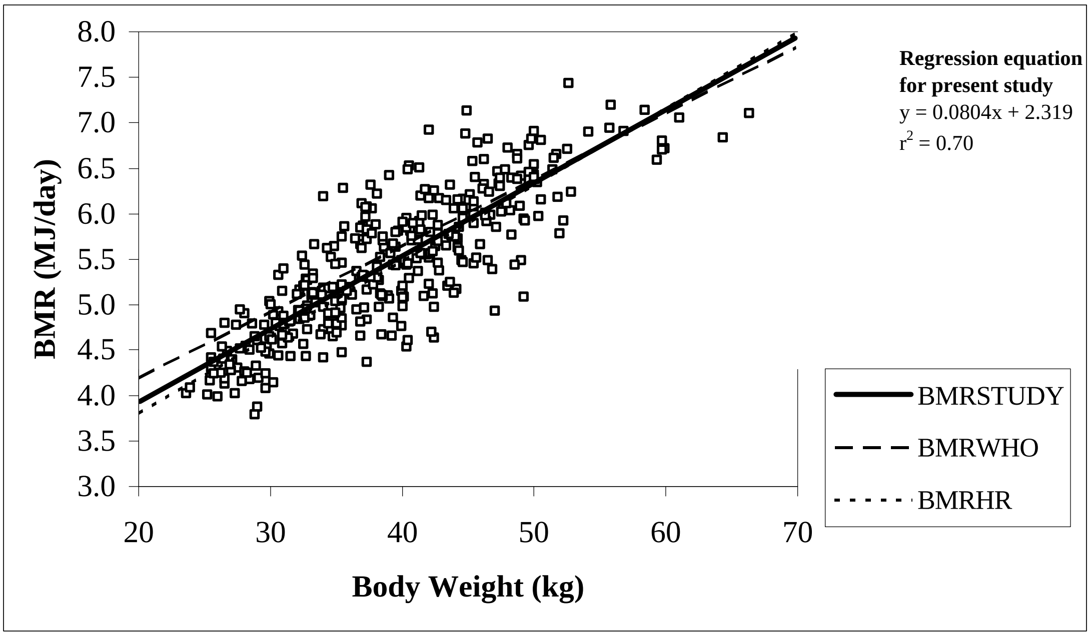

Figure 1: Regression of BMR against body weight of males aged 11 – 15 years compared with FAO/WHO/UNU (1985) and Henry & Rees (1991).

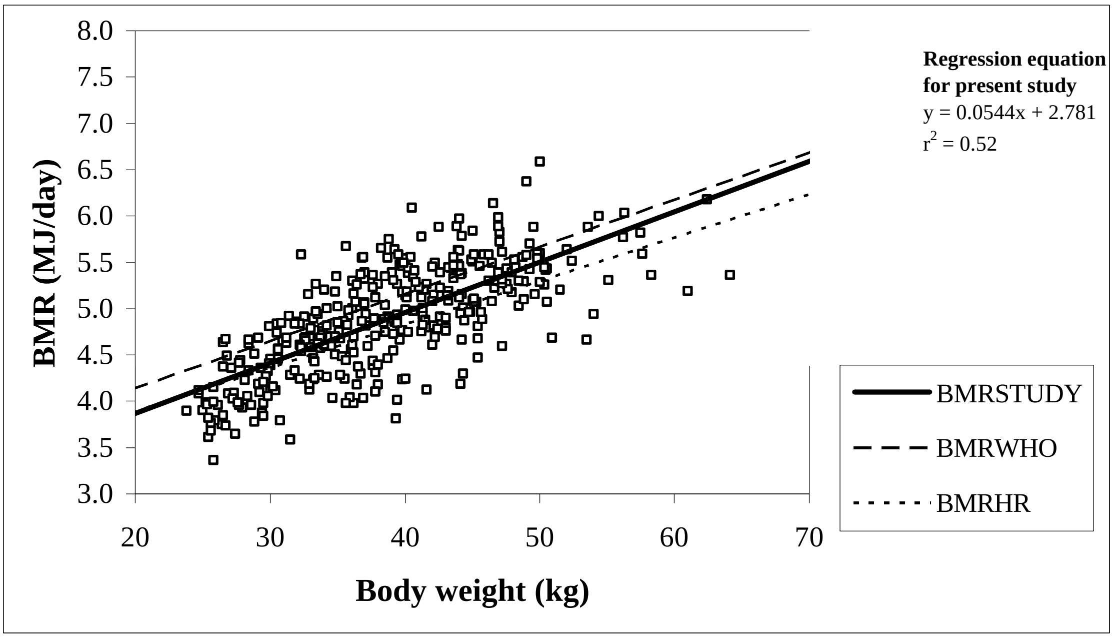

Figure 2: Regression of BMR against body weight of females aged 10 –14 years compared with FAO/WHO/UNU (1985) and Henry & Rees (1991).

among the lightest boys. Among the girls, Figure 2 showed that the two equations run approximately parallel to each other. The differences for girls of any body weight were consistently between 3.5% and 4.0%.

Comparison of the equations of the present study with the Henry & Rees (1991) equations also showed deviation to a smaller degree. The differences were between 3% and 4% among the boys (Figure 1). Figure 2 showed that the equation for girls in the present study intersects the Henry & Rees (1991) equation between 20 - 25 kg, which means there were no differences between the predicted and measured values of BMR at the lower body weights. However, among the heaviest girls, the Henry & Rees (1991) equation was lower by about 5%.

It should be noted however that the FAO/WHO/UNU (1985) and the Henry & Rees (1991) predictive equations were derived for adolescents in the age band of 10 – 18 years. The BMR equations from the present study however were derived from boys aged 11 – 15 years, and girls aged 10 – 14 years. The way in which age affects BMR is not the same at all stages of life. As such, the differences in the regression equations may be due to the differences in age between the groups.

CONCLUSION

The present study on BMR of Malaysian adolescents lends support to the proposition that people living in tropical countries have lower BMR than predicted by the FAO/WHO/UNU (1985) regression equations. On average, the said equations over-predicted BMR by 3% in boys by 5% in girls. The Henry & Rees (1991) equations built on a database of tropical peoples were able to provide better estimation of Malay adolescents. BMR was underestimated by an average of 1% in boys and 2% in girls. Linear regression equations were derived from the present data according to sex and age groups. It is hoped that these equations will be used to estimate the BMR of Malaysian adolescents.

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