Predictive equation for estimating the basal metabolic rate of Malaysian Armed Forces naval trainees

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ABSTRACT

Introduction: The basal metabolic rate (BMR) is essential in deriving estimates of energy requirements for a population. The aim of this study was to measure the BMR in order to derive a predictive equation for the Malaysian Armed Forces (MAF) naval trainees.

Methods: A total of 79 naval trainees aged 18 to 25 years from a training centre (Group A) and on board a ship (Group B) participated in the study. Anthropometric measurements included height and weight. Body fat and free fat mass were measured using the bioelectrical impedance analysis method. BMR was measured by indirect calorimetry with a canopy system.

Results: The mean height, weight and body fat for Group A was 1.67 +/− 0.04 m, 61.0 +/− 3.9 kg and 12.7 percent +/− 2.5 percent, respectively, and 1.67 +/− 0.05 m, 62.3 +/− 6.2 kg and 14.0 percent +/− 3.5 percent, respectively, for Group B. The mean BMR for Group A (6.28 +/− 0.40 MJ/day) did not differ significantly (p is more than 0.05) from that of Group B (6.16 +/− 0.67 MJ/day). The Food and Agriculture Organization/World Health Organization/United Nations University and the Henry and Rees equations overestimated the measured BMR by 9 percent (p is less than 0.001) and 0.5 percent (p is more than 0.05), respectively, while the Ismail et al equation underestimated the measured BMR by 5.6 percent (p is less than 0.001). A predictive equation, BMR = 3.316 + 0.047 (weight in kg) expressed in MJ/day with weight as the only independent variable, was derived using regression analysis.

Conclusion: We recommend that this predictive equation be used to estimate the energy requirements of MAF naval trainees.

Keywords: armed forces, basal metabolic rate, energy requirement, indirect calorimetry, predictive equation

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INTRODUCTION

The estimation of daily energy requirements is vital to many aspects of public health nutrition, such as in predicting the food requirements of a country or population,[1,2] and in determining the individuals who have chronic energy deficiency.[3] It is a well-recognised feature of dietary surveys that individuals underreport the amount of food they consume,[4] which can lead to erroneous estimates of dietary energy requirements. This classification of misreporting is based on the fact that the food intake falls below a critical multiple of the basal metabolic rate (BMR).[5] Hence, accurate prediction of the BMR of individuals is an important issue in public health nutrition. BMR is defined as the daily rate of energy metabolism that needs to be sustained by an individual in order to preserve the integrity of vital functions.[6] It is used to gauge the physiological and biochemical integrity of the individual concerned. Ideally, it should be measured under conditions that are not influenced by external environmental factors such as ambient temperature, physical exertion and the effects of food or drugs.[7]

The prediction of BMR has attracted attention since the publication of the Food and Agriculture Organization/World Health Organization/United Nations University (FAO/WHO/UNU) Expert Consultation report in 1985,[1] which adopted the principle of relying on estimates of energy expenditure rather than energy intake to estimate human energy requirements. BMR forms the basis of this factorial approach because it constitutes between 60% and 75% of the total daily energy expenditure. The energy expenditure of different age and gender groups are currently estimated as multiples of BMR. Therefore, the current recommendations of energy intake for various countries, including Malaysia,[8,9] as well as the international FAO/WHO/UNU recommendations of energy intake for adults,[1,2] are expressed as multiples of BMR. These multiples of BMR are referred to as physical activity levels. Underestimation or overestimation

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Table I. Physical characteristics and body composition of the participants.

Participants	Mean ± SD (range)				
	Age (yrs)	Weight (kg)	Height (m)	BMI (kg/m²)	Fat (%)
Group A (n = 45)	21.7 ± 1.4	61.0 ± 3.9	1.67 ± 0.04	21.7 ± 1.2	12.7± 2.5
	(19–24)	(52.6–70.6)	(1.60–1.77)	(19.4–24.3)	(7.6–16.7)
Group B (n = 34)	21.0 ± 1.7*	62.3 ± 6.2	1.67 ± 0.05	22.4 ± 1.9	14.0 ± 3.5
	(18–25)	(48–77)	(1.57–1.77)	(18.7–25.3)	(7.1–20.5)
Total (n = 79)	21.4 ± 1.6	61.6 ± 5.0	1.67 ± 0.05	22.0 ± 1.6	13.3 ± 3.1
	(18–25)	(48–77)	(1.57–1.77)	(18.7–25.3)	(7.1–20.5)

Group A: trainees from the training centre; Group B: trainees on board the ship
*Significantly different at $p < 0.05$.
SD: standard deviation; BMI: body mass index

of BMR could result in errors during the planning of population energy allowances and the calculation of the energy requirements of an individual. A number of formulas have been proposed to predict BMR using fundamental variables such as weight, height, gender and age.[6] However, it has been reported that these predictive equations tend to produce unsystematic and incorrect results, which may vary from 70% to 140% when compared with measured energy consumption.[10] The Schofield equations are commonly used to predict the BMR of populations living in temperate climates. However, it has been found that these equations produce questionable results when predicting the BMR of populations living in tropical climates.[11] Several other studies have revealed an overestimation of the BMR of Asians by 10%–11%.[12-16]

BMR measurement is a time-consuming exercise that requires special equipment,[10] and thus is only suitable for small-scale studies. Hence, much attention has been paid to determining the accuracy of current BMR predictive equations, particularly in developing countries.[11,13-16] Although reported equations derived from relatively large populations of healthy subjects may be useful, studies comparing measured BMR with BMR obtained by means of prediction equations in military populations are scarce. Currently, no specific predictive equation for BMR has been developed for the armed forces. Comparison of BMR in previous studies between the general population and the local armed forces could not be done accurately because of the different techniques utilised. The BMR of armed forces personnel is expected to be higher compared to that of the general population because a greater proportion of their body weight is typically made up of muscle mass and viscera. In addition, it is important to note that the current predictive equation by Ismail et al,[16] which was developed for males aged 18–30 years old, was derived from the general Malaysian population. The predictions of BMR by FAO/WHO/UNU and Ismail et al are expected to respectively overestimate and underestimate BMR among armed forces trainees.[1,16] The present study aimed to derive a BMR predictive equation specifically for Malaysian Armed Forces (MAF) naval trainees and to compare the measured BMR values with those estimated using the FAO/WHO/UNU, Henry and Rees, and Ismail et al predictive equations.[1,11,16]

METHODS

This cross-sectional study was conducted on two groups of Royal Malaysian Navy (RMN) male trainees aged 18–25 years. The study utilised random sampling. Group A trainees were based in a training centre in Lumut, Perak, while Group B trainees were training on board a ship. Approval for the study was obtained from the Research and Development Secretariat of the Science Technology Research Institute of Defence (STRIDE), Ministry of Defence, Malaysia. A total of 79 participants, 45 from Group A and 34 from Group B, participated in the study. All participants were within the normal body weight range, based on a body mass index (BMI) of 18.5–24.9 kg/m^2, and were healthy at the time of measurement. The trainees provided written, informed consent prior to their involvement in the study.

Anthropometric and body composition measurements were taken. Body weight was measured in light clothing and barefoot to the nearest 0.1 kg using the digital TANITA balance HD312 (Tanita Corp, Tokyo, Japan). Height without shoes was measured to the nearest 0.1 cm using the SECA bodymeter 208 (SECA, Hamburg, Germany). BMI was calculated using the weight and height (kg/m^2) data. Body composition was measured by bioelectrical impedance analysis using the Bodystat® 1500 (Bodystat Ltd, Douglas, Isle of Man). In order to obtain an accurate data set, the trainees were briefed on the experimental protocol, which included fasting for 12–14 hours, not conducting any heavy physical activity the previous day,

Table II. Basal metabolic rate of the participants.

Participants	Mean BMR ± SD (range)			
	kcal/day	MJ/day	kJ/kg/day	kJ/kg FFM/day
Group A (n = 45)	1,501 ± 95	6.28 ± 0.40	103 ± 8	117 ± 10
	(1,289–1,778)	(5.39–7.44)	(91–133)	(97–139)
Group B (n = 34)	1,473 ± 159	6.16 ± 0.67	99 ± 9	115 ± 10
	(1,213–1,837)	(5.08–7.69)	(84–121)	(99–141)
Total (n = 79)	1,487 ± 127	6.22 ± 0.53	102 ± 9	116 ± 10
	(1,213–1,837)	(5.08–7.69)	(84–133)	(99–141)

Group A: trainees from the training centre; Group B: trainees on board the ship
SD: standard deviation; BMR: basal metabolic rate

Table III. Comparison between predicted BMR and measured BMR.

	Predictive equation	Mean BMR ± SD (MJ/day)	Difference (%)[a]
Present study	BMR = 0.047 (W) + 3.316 MJ/day	6.22 ± 0.53	-
FAO/WHO/UNU[1]	BMR = 0.0640 (W) + 2.84 MJ/day	6.78 ± 0.32*	9.0
Henry et al[11]	BMR = 0.0560 (W) + 2.800 MJ/day	6.25 ± 0.28	0.5
Ismail et al[16]	BMR = 0.0550 (W) + 2.480 MJ/day	5.87 ± 0.28*	−5.6

*Significantly different between measured BMR and predicted BMR at $p < 0.001$.

$$^{a}\text{Difference} = \frac{\text{Predicted BMR} - \text{Measured BMR}}{\text{Measured BMR}} \times 100\%$$

BMR: basal metabolic rate; SD: standard deviation

and ensuring they were in normal hydration status. BMR was measured by indirect calorimetry with a canopy system in a post-absorptive state using the Deltatrac™ Metabolic Monitor MBM-200 (Datex Instrumentarium Corporation, Helsinki, Finland). The Deltatrac was calibrated using an "alcohol burning test kit" for the respiratory quotient and flow accuracy. Pressure calibration was carried out based on barometric reading, followed by gas calibration using 95% oxygen and 5% carbon dioxide (Calibration gas, Datex Instrumentation, Helsinki, Finland). BMR measurements were taken in the morning in a thermoneutral environment. The measurement was conducted in the accommodation room for Group A and a special bay room for Group B under standardised conditions. The participants rested quietly in a supine position for half an hour prior to BMR measurement, which takes 30 minutes to be conducted. The BMR values were derived from oxygen consumption and carbon dioxide production using the Weir equation.[17]

The recorded data was analysed using the Statistical Package for the Social Sciences version 12.0 (SPSS Inc, Chicago, IL, USA). The results were expressed as the mean and standard deviation. The independent *t*-test was used to compare the mean BMR of Groups A and B. The relationship between the measured BMR and the recorded variables, such as weight, height, percentage of body fat and fat free mass (FFM), were evaluated using Pearson's correlation coefficients and linear regression analysis. The best subset was used to develop the predictive equations for BMR. The paired *t*-test was used to compare the measured BMR and the BMR values predicted using the FAO/WHO/UNU, Henry and Rees, and Ismail et al equations.[1,11,16] The results were considered to be significant at the 5% level.

RESULTS

The physical characteristics of the trainees are shown in Table I. 95% of the trainees were Malay and 5% were from other ethnic groups. Since there were no significant differences ($p > 0.05$) in the body weight, height, BMI and body fat percentage between Groups A and B, the study samples were considered to be homogenous. Table II shows that Group A recorded a slightly higher mean BMR (6.28 ± 0.40 MJ/day) than Group B (6.16 ± 0.67 MJ/day), although an independent t-test found that this difference was not significant ($p > 0.05$). There was no significant difference in the mean BMR when it was stated as kJ/kg/day and kJ/kg FFM/day ($p > 0.05$). The BMR data was thus grouped together and treated as a whole, yielding an overall mean of 6.22 ± 0.53 MJ/day.

Predicted BMR was also compared with measured BMR. In order to validate the accuracy of the FAO/WHO/UNU, Henry and Rees and Ismail et al predictive equations[1,11,16] for the 18–30 year age group in estimating the BMR of our study population, the BMR

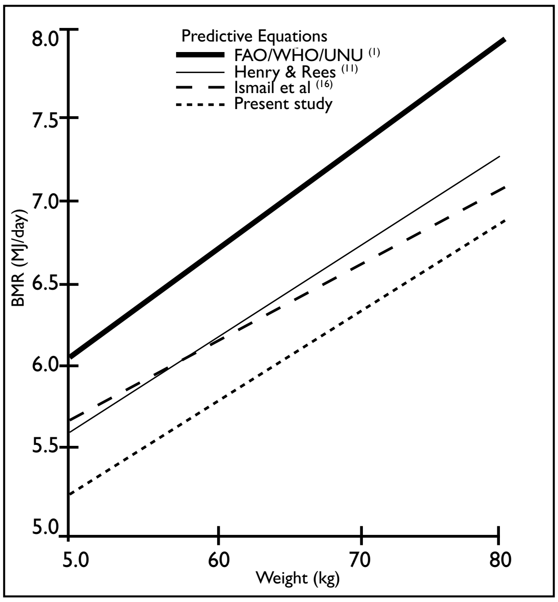

Fig. 1 Comparison between the measured BMR and BMR predicted by the FAO/WHO/UNU, Henry et al and Ismail et al equations.[1,11,16]

values predicted using these equations were compared with the measured BMR (Table III). The mean measured BMR was significantly lower by 9% ($p < 0.001$) compared to the mean BMR predicted using the FAO/WHO/UNU equations.[1] The Henry and Rees equation overestimated the measured BMR by only 0.5%,[11] and the difference was not significant ($p > 0.05$). Regression analysis was employed to determine the relationship of BMR with physical characteristics. Linear regression equations of the BMR of the MAF naval trainees with their body weight were obtained for the 18–30 year age group. The regression equation derived for the BMR ($R = 0.45$, standard error of mean = 0.05) of MAF naval trainees was as follows: BMR = 3.316 + 0.047 (W), where BMR is expressed in MJ/day and W = body weight (in kg).

Fig. 1 presents the relationship between BMR and body weight. The linear regression equation of BMR on body weight derived from this study was compared with the equations recommended by FAO/WHO/UNU, Henry and Rees, and Ismail et al for the 18–30 year age group.[1,11,16] Our study found that the FAO/WHO/UNU equation[1] overestimated the BMR of armed forces personnel, while the Ismail et al equation[16] underestimated the BMR of our study population. In comparison, the Henry and Rees equation[11] showed a smaller degree of deviation.

DISCUSSION

The mean measured BMR of the trainees in this study was 6.22 ± 0.53 MJ/day. A comparison of the BMR data sets of the present study with other local armed forces studies, foreign armed forces and the general populations is shown in Table IV. In general, the mean BMR found in the present study was higher than that of other Malaysian armed forces studies[18,19] and the Malaysian population,[16] but was lower when compared to that of athletes and the United States Armed Forces.[20,21] When BMR is presented using body weight as the metabolic reference standard (kJ/kg/day), it was found that the mean BMR between the present study and studies on army recruits and athletes[18,20] was similar. However, it should be noted that the techniques used to measure BMR in these studies differ, with the exception of the athletes study which used the Deltatrac,[20] while most of the older studies measured BMR using the Douglas bags technique.[16,18,19,21]

Previous studies have highlighted the overestimation of BMR in many communities[7,11,12,16] using the Schofield equation,[6] which was adopted in the FAO/WHO/UNU study,[1] especially when the study populations were different from those included in the original data set.[22] When compared to the FAO/WHO/UNU equations,[1] the mean measured BMR of the trainees in this study was significantly lower by 9% ($p < 0.001$). The results confirm the findings of earlier studies, which reported that the BMR was 8%–10% lower in the tropics than in temperate climates.[6,11] An error in the estimation of BMR would be amplified when the data is used to predict total energy requirements. On the other hand, the Henry and Rees equation[11] showed an overestimation of the measured BMR by only 0.5%, and the difference was not significant ($p > 0.05$). It has been reported that Asian populations living in the tropics have lower basal metabolism compared to BMR predicted from body weight.[11] Studies on two groups of local armed forces personnel showed that the FAO/WHO/UNU equation overestimated measured BMR by 11%–15%.[1,18] A study on Malaysian adults showed that the FAO/WHO/UNU and Henry and Rees equations also overestimated measured BMR by 13% and 6%, respectively.[1,11] When a comparison was made between the measured and predicted BMRs using the Ismail et al equation,[16] it was found that this equation underestimated the measured BMR by 5.6% ($p < 0.001$). Since this predictive equation did not originate from military groups but rather, from largely sedentary young adults, care needs to be taken when extrapolating BMR predictive equations derived from general populations to military personnel, who are typically more physically active, and are therefore expected to have a higher BMR. Military personnel also typically have a greater proportion of their body weight

Table IV. Comparison of BMR with other local and foreign studies.

Reference	Participant	Age (yrs)	Body weight (kg)	BMR		
				MJ/day	kJ/kg/day	kJ/kg FFM/day
Ismail et al[16]	Malaysian adult men (n = 84)	18–29	58.6	5.70	97	119
Isa[18]	Army recruits; Training Camp (n = 35)	18–23	56.2	5.74	102	119
Isa[18]	Army; Field Training Camp (n = 35)	27–37	63.9	5.80	91	110
Isa[19]	RMN trainees; on board a ship					
	Group I (n = 10)	24–37	68.3	5.77	84	105
	Group II (n = 10)	19–31	71.3	5.83	82	102
Poh et al[20]	Athletes (n = 51)	18–29	67.7	7.08	104	121
Consolazio[21]	US Military (n = 8)	-	73.2	6.57	-	-
Present study	RMN trainees (n = 79)	18–26	61.6	6.23	102	116

BMR: basal metabolic rate; RMN: Royal Malaysian Navy; US: United States

made up of muscle mass and viscera, which inherently expends higher energy. Thus, the higher FFM may provide a partial explanation of the current findings of a higher BMR in military subjects.

In order to derive the regression equation for BMR, various anthropometric variables need to be considered in the regression analysis. The dependent variable was BMR and the independent variables were body weight, height, FFM and age. A stepwise method was used to establish the regression equation. Body weight, an easily and accurately measurable variable, is usually retained in a stepwise regression as the best single predictor of BMR.[6,11] The value of R^2 measured the power of the independent parameter of a predictive model or equation. The larger the value of R^2, the better the prediction model produced. The predictive power of body weight, height, FFM and a combination of body weight and height, body weight and FFM, body weight and age, a combination of weight, height, FFM and age for BMR were studied. When only one variable was considered as an independent variable, FFM yielded the greatest R^2 value ($R^2 = 0.25$). The results show that between body weight, height, FFM and age, FFM was the best single predictor for BMR, followed by body weight and height. A regression equation with body weight as the independent variable yielded an R^2 value of 0.21. Regression equations of BMR with body weight and a combination of body weight and height as the independent variable yielded the same predicted power ($R^2 = 0.21$). A combination of body weight and age as the independent variable yielded the same predicted power as well. In the computation of BMR regression equations for the 1985 FAO/WHO/UNU Expert Consultation on Energy and Protein Requirements, Schofield found that including height as a second predictor after weight did not contribute significantly to the equations for both genders, except for those under three years and those over 60 years of age.[6] The inclusion of body weight and FFM did not contribute significantly to the equations; the value of R^2 remained the same as when using body weight alone. Since body weight has been found to be the most suitable variable for the prediction of BMR,[1,6,11] the BMR regression equation in the present study was developed using body weight as the only independent variable.

The relationship of BMR to body weight (Fig. 1) shows that the FAO/WHO/UNU[1] and the Ismail et al[16] equations were not appropriate for predicting the BMR of our study population. A comparison of these two equations with the equation derived in the present study showed a higher degree of deviation. The Henry and Rees equation[11] provided the closest predictive BMR values but could not accurately predict the BMR of the study population. While predictive equations do have their inherent limitations compared to direct measurements of BMR, our new proposed equation should provide a better estimation of BMR for MAF trainees.

In conclusion, the present study has derived a regression equation for the prediction of BMR in young adult trainees in the armed forces. This confirms previous findings that people living in tropical countries have lower BMR than that predicted by the FAO/WHO/UNU equation,[1] which overpredicted the BMR of the study population by 9%. Our study has also demonstrated that the Ismail et al equation,[16] which was derived from local adult populations, is not suitable for predicting the BMR of military personnel. Similarly, the Henry and Rees equation could not accurately predict the measured BMR of military personnel,[11] although it produced a much smaller deviation. It is thus recommended that the predictive equation derived from this study be used in estimating the energy expenditure, and subsequently for formulating the energy requirements, of MAF naval trainees.

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