Predictive equation for basal metabolic rate of young Indian soldiers

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ABSTRACT

Background: Currently, no specific predictive equation for BMR has been developed for the Indian armed forces whose BMR 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 bones as many studies show that the bones of active people are denser than those of sedentary people. **Aims and Objective:** The present study aimed to identify a best suitable BMR predictive equation specifically for the young Indian soldiers and to compare the measured BMR values with those estimated using other equations. **Materials and Methods:** Cross-sectional study on healthy individuals using random sampling. Anthropometric and body composition measurements, oxygen consumption (VO2) and carbon dioxide production (VCO2) during experiment were determined by the process of breath-by-breath gas analysis using K4b2 system. Data was analyzed using the Statistical Package for the Social Sciences version 12.0 (SPSS Inc, Chicago, IL, USA). The relationship between the measured BMR and the recorded variables were evaluated using Pearson's correlation coefficients and linear regression analysis. The results were considered significant at 5% level. **Result:** Mean measured BMR was significantly lower by 1.41%, 20.11%, 14.71%, 19.21%, and 21.8% ($p < 0.001$) compared to the mean BMR predicted using the Weir, FAO/WHO/UNU, ICMR, Miffin and Harris and Benedict predictive equations respectively. **Conclusion:** BMR in Indian soldier is lower than predicted by the FAO/WHO/UNU 1985 equations by an average of 20.1% suggesting that lower energy needs of present study with similar body weight may put them at greater risk for developing obesity, especially in overweight people.

Key words: Indian army, BMR, Prediction, Anthropometry, Body composition

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INTRODUCTION

Basal Metabolic Rate (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.[1] It is used to gauge the physiological and biochemical integrity of the individual concerned. BMR measurement being a time-consuming exercise that requires special equipment thus is only suitable for small-scale studies.[2] Hence, much attention has been paid to determining the accuracy of current BMR predictive equations, particularly in developing countries.[3-7] Ideally, BMR 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.[8] In 1948, the newly established FAO Standing Advisory Committee considered that 'the problem of assessing the calorie and nutrient requirements of human beings, with the greatest possible degree of accuracy, is of basic importance to FAO.[9] 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

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specific predictive equation for BMR has been developed for the Indian armed forces.

Many studies show that the bones of active people are denser than those of sedentary people.[10] The BMR of the Indian 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 bones, as defence personnel are known to be more active than the general population.

Over prediction of BMR for Indians and those of the tropical living populations have been reported time and time again.[1,3] In 1985, the WHO proposed new equations in response to the impossibility of measuring BMR by direct calorimetry. These equations originated from a review of studies analyzed by Schofield,[1] including approximately 11,000 BMR measurements taken using indirect calorimetry. However, several studies demonstrated that those equations overestimated BMR when used with different ethnic groups.[11] Several other studies have revealed an overestimation of the BMR of Asians by 10%–11%.[4-7,12] In one study undertaken on 58 men of a rural Indian population, the BMR values agreed well with values predicted by equations based on BMR measurements in Asian men of higher body weight, but were below values predicted by the new FAO/WHO/UNU prediction equations by an average of 12.1 per cent.[13]

However, a contrasting result was reported in another study, the purpose of which was to establish whether international predictive equations overestimate the basal metabolic rate (BMR) of tropical populations. BMR was measured in healthy, physically active urban dwellers of low socioeconomic status (178 men and women aged 22-38 y) in Bangalore, Southern India. The BMR of both men and women, regardless of their nutritional status, was accurately estimated by age-and sex-specific FAO/WHO/UNU equations. These findings suggest the absence of an enhanced metabolic response in weight-stable chronically undernourished adults.[14]

A number of formulas have been proposed to predict BMR using fundamental variables such as weight, height, gender and age.[1] 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.[2] 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.[2]

AIMS AND OBJECTIVE

The present study aimed to identify a best suitable BMR predictive equation specifically for the young Indian soldiers aged 18-25 years and to compare the measured BMR values with those estimated using the Weir, FAO/WHO/UNU, ICMR, Miffin and Harris and Benedict equations.

The present study also aimed to compare the BMR of Indian soldiers with other local and international measured BMR values.

MATERIALS AND METHODS

This cross-sectional study was conducted on young Indian soldiers aged 18– 25 years on 29 healthy individuals and following parameters were studied: age, height, weight, BMI, VO_2 and VCO_2. Mean BMR calculated from values of O2 consumption and CO2 productions was 1349.13kcal/day among the males in the present study. The study utilized random sampling. Approval for the study was obtained from the Defence Research and Development Organization (DRDO), Ministry of Defence, India. All participants were within the normal body weight range, based on a body mass index (BMI) of 18.5–24.7 kg/m^2, and were healthy at the time of measurement. The participants provided written, informed consent prior to their involvement in the study. All experiments were conducted in controlled environment of 22°C–25°C, 50–55% relative humidity and at the same hour of the day between 0630 AM and 0730 AM prior breakfast every morning.

Anthropometric and body composition measurements were taken and body weight, measured in light clothing and barefoot to the nearest 0.1 kg and height, without shoes, were measured to the nearest 0.1 cm using the SECA 767 electronic personal scale (Medical Scales and Measuring Systems, Germany). BMI was calculated using the weight and height (kg/m^2) data. 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, and ensuring they were in normal hydration status.

Oxygen consumption (VO2) and carbon dioxide production (VCO2) of each of the individual in supine position during experiment were determined by the process of breath-by-breath gas analysis using K4b2 system (K4b2, Cosmed S.r.l, Italy). BMR was calculated from measured oxygen consumption values in the present study. Before the experiment, every day the K4b2 system was calibrated with room air and standard gas mixture (16% O2 and 5% CO2). Portable unit and battery of the K4b2 system were fixed on the chest and back of the individual, respectively, with a harness. A flexible face mask that covered the subject's mouth and nose was secured to participants with a nylon mesh hairnet and velcro straps. The face mask contains flow meter and connects to the portable unit via capillary tube. After fitting the K4b2 system with the subjects both the data logger and telemetry mode of the system were put on. The subjects were then asked to breathe normally through the face mask for about 15 min supine position for the recording of resting VO2 and VCO2 parameters.

In addition, BMR was predicted using the equations formulated by Weir, FAO/WHO/UNU, ICMR, Miffin and Harris and Benedict for 18-29 years age group males.

The participants rested quietly in the supine position for 10 minutes prior to BMR measurement, which took approximately 30 minutes to complete the experiment. The recorded data was analyzed 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 relationship between the measured BMR and the recorded variables, such as age, weight, height, VO2, VCO2, were evaluated using Pearson's correlation coefficients and linear regression analysis. The best subset was used to develop the predictive equations for BMR. The results were considered significant at 5% level.

RESULT

The physical characteristics of the 29 young Indian soldiers are shown in Table 1. Mean ± SD showed normal BMI range and VO_2 (ml/min) value of 191.01 ± 26.48 and VCO_2 (ml/min/kg) value of 177.75 ± 27.51.

Basal metabolic rates of the human subjects in Kcal/day, MJ/day and Kcal/kg/day are shown in Table 2 with a mean ± SD value of 1349.13 ± 185.73, 8.13 ± 1.12 and 21.30 ± 2.65, respectively.

The O_2 consumption and CO_2 production results measured by indirect calorimetry are listed in detail in Table 4.

In comparison to predicted values using Weir, FAO/WHO/UNU, ICMR, Miffin and Harris and Benedict predictive equations, the BMR of the study participants were 1.41%, 20.11%, 14.71%, 19.21%, 21.88% lower than the Weir, FAO/WHO/UNU, ICMR, Miffin and Harris and Benedict predictive equations, respectively.

Predicted BMR was also compared with measured BMR. In order to validate the accuracy of the Weir, FAO/WHO/UNU, ICMR, Miffin and Harris and Benedict, for 18-29 years age group males in estimating the BMR of our study population, the BMR values predicted using these equations were compared with the measured BMR (Table 3). The mean measured BMR was significantly lower by 1.41%, 20.11%, 14.71%, 19.21%, and 21.8% ($p<0.001$) compared to the mean BMR predicted using the Weir, FAO/WHO/UNU, ICMR, Miffin and Harris and Benedict predictive equations respectively.[9,15-18] Linear regression equations of the BMR of the Indian Army recruits with their body weight were obtained for the 18-29 year age group.

In comparison with the measured value, the predicted value of 1351.86 Kcal/day is only about 1.5% lower than that measured value of 1349.13 Kcal/day, well within the 5% value acceptable.

The regression equation derived for the BMR (R = 0.495, standard error of mean = 0.69) of Indian Army recruitees was as follows: BMR = 1.647 + 0.063 (W), where BMR is expressed in MJ/day and W = body weight (in kg).

Figure 1 presents the relationship between BMR and body weight. The linear regression equation of BMR on

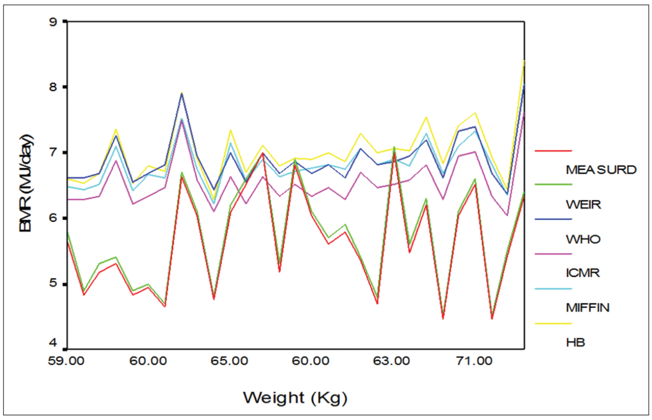

Figure I: Comparison between measured BMR and BMR predicted by the Weir, FAO/WHO/UN, ICMR, Miffin and Harris and Benedict equations

Table 1: Physical characteristics and body composition

Participants				Mean±SD (range)		
	Age (years)	Weight (kg)	Height (m)	BMI (kg/mt²)	VO2 (ml/min)	VCO2 (ml/min/kg)
n=29	20.14 ± 2.9 (17.24–23.04)	63.34±6.1 (57.24–69.44)	1.75±0.5 (1.25–2.25)	20.57±1.4 (19.17–21.27)	191.01±26.48 (164.53–217.49)	177.75±27.51 (150.24–205.26)

SD: Standard deviation, BMI: Body mass index body weight derived from this study was compared with the equations recommended by Weir, FAO/WHO/UNU, ICMR, Miffin and Harris and Benedict predictive equations for the 18–29 year age group.[9,15-18] Our study found that the Weir, FAO/WHO/UNU, ICMR, Miffin and Harris and Benedict predictive equations all overestimated the BMR of the Indian armed forces personnel.

DISCUSSION

The mean measured BMR of the recruits in the present study was 5.64 ± 0.78 MJ/day. A comparison of the measured BMR of the present study with other populations is shown in Table 5. The measured BMR found was higher than those other studies undertaken on Indian populations by Ismail, McNeill and Ferro Luzzi respectively.[7,13,14] The measured BMR was similar to those of the Malaysian Armed Forces[19] and lower than the UK study population.[20]

Earlier studies have highlighted the overestimation of BMR in many communities[3,7,8,12] using the Schofield equation[1] which was adopted in the FAO/WHO/UNU study,[21] especially when the study populations were different from those included in the original data set.[22] The mean measured BMR when compared to that predicted by the FAO/WHO/UNU 1985 equations was lower by as much as 20.1%, ($p < 0.001$) which confirm the findings of earlier studies, which reported that the BMR was lower in the tropics than in temperate climates.[1,3] It has been reported that Asian populations living in the tropics have lower basal metabolism compared to BMR predicted from body weight.[3]

The present study found significantly lower BMRs than predicted by Weir, FAO/WHO/UNU, ICMR, Mifflin and Harris and Benedict predictive equations. The predictive power of body weight, height and a combination of body weight and height, body weight and age, a combination of weight, height and age for BMR were studied. The results show that between body weight, height and age, weight was the best single predictor for BMR, followed by height and age. A regression equation with body weight as the independent variable yielded an R value of 0.495. 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 value=0.495). Since body weight has been found to be the most suitable variable for the prediction of BMR,[1,3,21] the BMR regression equation in the present study was developed using body weight as the only independent variable.

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.[1] 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.[8]

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,[21] 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.

Table 2: Basal metabolic rate (BMR) of subjects

Participants	Mean BMR±SD (range)		
	Kcal/day	MJ/day	Kcal/kg/day
Present study	1349.13±185.73 (1163.40–1534.86)	8.13±1.12 (7.01–9.25)	21.30±2.65 (18.65–23.95)

SD: Standard deviation, BMR: Basal metabolic rate

Table 3: Comparison between measured BMR and predicted BMR

Participants	Predicted equation	Mean BMR±SD (MJ/day)	Difference (%)
Present study		5.64±0.78	-
Weir	BMR=0.063 (W) +1.754 MJ/day	5.72±0.78*	1.41
FAO/WHO/UNU	BMR=0.064 (W) +2.833 MJ/day	6.90±0.39*	20.1
ICMR	BMR=0.060 (W) +2.713 MJ/day	6.54±0.37*	14.7
Mifflin	BMR=0.059 (W) +3.077 MJ/day	6.84±0.38*	19.2
Harris and Benedict	BMR=0 0.072 (W) +2.445 MJ/day	7.02±0.46*	21.8

*Significantly different between measured BMR and predicted BMR equation at $p<0.001$, SD: Standard deviation, BMR: Basal metabolic rate

Table 4: Figures for O_2 consumption and CO_2 production by indirect calorimetry, the temperature and humidity during indirect calorimetry and the body mass of the sample

	Mean±SD
VO2 (l/min)	0.191 l/min±0.026
VCO2 (l/min)	0.178 l/min±0.027
Humidity (%)	50–55%%
Temperature (°C)	22°C–25°C
Body mass (kg)	63.34±6.18

Table 5: Comparisons of BMR with other populations

Participants	Age (years)	Body weight (Kg)	BMR		Reference
			MJ/day	kJ/kg/day	
n=11 UK	21	56.2	6.51	116	Henry et al. 1987
n=58 India	31	51.6	5.40	105	Mc Neill et al. 1987
n=35 India	28	50.1	5.18	103	Ferro Luzzi et al. 1997
n=35 Malaysian army recruits	18-23	56.2	5.74	102	Isa 1991
n=84 Malaysian adult men	18-29	58.6	5.70	97	Ismail 1998
n=35 Malaysian army field training camp	27-37	63.9	5.80	91	Isa 1991
n=29 Indian army	18-28	63.3	5.73	91	Present study

Underestimation or overestimation of BMR could result in errors during the planning of population energy allowances and the calculation of the energy requirements of an individual.

Several other studies have revealed an overestimation of the BMR of Asians by 10%–11%.[4-6,7,11] These finding suggest that, if using these equations, the lower energy needs of Indians with similar body weight may put them at greater risk for developing obesity, especially in overweight people.

We conducted our BMR measurements under carefully controlled conditions, with consideration of many factors. Studies of BMR after periods of therapeutic low-energy intake suggest that BMR changes in relation to metabolic adjustment. Furthermore, there is a direct correlation between BMI and bias of predictive equations. Thus, to minimize such bias,[23] we selected subjects with BMI in the normal range.

However, our study was carried out over a short period of time, and on a small scale. Thus, our results may not apply to the whole Indian defence population. Further studies validating the BMR of Indian defence personnel on a large scale should be implemented.

CONCLUSION

In conclusion, the present study shows that BMR in Indian adults is lower than predicted by the Weir equation by an average of about 1.41% in (18–29 years) and by an average of 20.1% as predicted by FAO/WHO/UNU 1985 equations. This means that the present predicted equation is more or less similar to the Weir equation value which is considered as the gold standard for estimating BMR.

These findings suggest that the lower energy needs of present study with similar body weight may put them at greater risk for developing obesity, especially in overweight people. Larger-scale studies should be conducted in Indian soldiers to determine which equations are appropriate for Indian defence population.

List of abbreviations

ANOVA: Analysis of Variance
BMI: Body Mass Index
BMR: Basal Metabolic Rate
BSA: Body Surface Area
FAO: Food and Agriculture Organization of the United Nations
ICMR: Indian Council of Medical Research
Kcal/day: Kilo calorie per day
Kcal/kg/day: Kilo calorie per kilogram per day
MJ/day: Mega Joules per day
R: Ratio of VCO2/VO2
VO2: Oxygen consumption
VCO2: Carbon Dioxide eliminated
VO2/kg: Oxygen consumption per kilogram
W: Weight
WHO: World Health Organization

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LRV and MSP - Participated in the conception of the study, data analysis, interpretation of the data, review of literature and writing of the paper. All authors participated in the revision of the manuscript and approved the version submitted for publication.

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