

Are Predictive Equations for Estimating Resting Energy Expenditure Accurate in Asian Indian Male Weightlifters?

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Abstract

Background: The accuracy of existing predictive equations to determine the resting energy expenditure (REE) of professional weightlifters remains scarcely studied. Our study aimed at assessing the REE of male Asian Indian weightlifters with indirect calorimetry and to compare the measured REE (mREE) with published equations. A new equation using potential anthropometric variables to predict REE was also evaluated. **Materials and Methods:** REE was measured on 30 male professional weightlifters aged between 17 and 28 years using indirect calorimetry and compared with the eight formulas predicted by Harris–Benedicts, Mifflin–St. Jeor, FAO/WHO/UNU, ICMR, Cunninghams, Owen, Katch–McArdle, and Nelson. Pearson correlation coefficient, intraclass correlation coefficient, and multiple linear regression analysis were carried out to study the agreement between the different methods, association with anthropometric variables, and to formulate a new prediction equation for this population. **Results:** Pearson correlation coefficients between mREE and the anthropometric variables showed positive significance with suprailiac skinfold thickness, lean body mass (LBM), waist circumference, hip circumference, bone mineral mass, and body mass. All eight predictive equations underestimated the REE of the weightlifters when compared with the mREE. The highest mean difference was 636 kcal/day (Owen, 1986) and the lowest difference was 375 kcal/day (Cunninghams, 1980). Multiple linear regression done stepwise showed that LBM was the only significant determinant of REE in this group of sportspersons. A new equation using LBM as the independent variable for calculating REE was computed. REE for weightlifters = $-164.065 + 0.039$ (LBM) (confidence interval $-1122.984, 794.854$). This new equation reduced the mean difference with mREE by $2.36 + 369.15$ kcal/day (standard error = 67.40). **Conclusion:** The significant finding of this study was that all the prediction equations underestimated the REE. The LBM was the sole determinant of REE in this population. In the absence of indirect calorimetry, the REE equation developed by us using LBM is a better predictor for calculating REE of professional male weightlifters of this region.

Keywords: Indirect calorimetry, prediction equations, resting energy expenditure, weightlifters

INTRODUCTION

Weightlifting is an intense sport which places a large physical demand on the individual. The body composition of weightlifters is considerably different from that of other athletes. They have a higher muscle mass and a lower fat percentage, thus placing a greater demand on their total daily energy expenditure as compared to participants of other categories of sport. The major component of the total energy requirement is the resting energy expenditure (REE), and this contributes 60% to nearly 75% of the daily requirement. The REE is the amount of energy required by an individual to maintain the body functions in the resting and fasting state. This REE varies with age, gender, weight, height, state of nutrition, climatic conditions, body

temperature, and body composition. The gold standard for measuring the REE is the indirect calorimetric method. Since this method requires sophisticated instruments with extensive laboratory and trained personnel, it is not feasible to perform it in everyday practice. Various prediction equations have been present to compute the REE using suitable anthropometric variables. The most widely used equation is the Harris–Benedicts,^[1] followed by Mifflin–St.

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Jeor,^[2] FAO/WHO/UNU,^[3] ICMR,^[4] Cunninghams,^[5] Owen,^[6] Katch-McArdle,^[7] and Nelson^[8] equations. These equations were derived from populations of specific demography and physical backgrounds and may not always hold well when applied to different populations.

This study was undertaken with the hypothesis that numerous equations that have been used to predict REE will not be applicable for professional weightlifters because of their unique physique and sport background. This is the first study to evaluate simultaneously the accuracy of the eight equations predicted by Harris–Benedicts,^[1] Mifflin-St. Jeor,^[2] FAO/WHO/UNU,^[3] ICMR,^[4] Cunninghams,^[5] Owen,^[6] Katch-McArdle,^[7] and Nelson^[8] for computing REE among professional male weightlifters. The reference standard was the REE measured by the gold standard - indirect calorimetry.

The purposes of the present study were:

1. To determine the REE of professional weightlifters using the indirect calorimetric method (measured REE [mREE]) considered to be the gold standard
2. To compare the mREE with predicted REE (pREE) using standard equations by Harris-Benedicts,^[1] Mifflin-St. Jeor,^[2] FAO/WHO/UNU,^[3] ICMR,^[4] Cunninghams,^[5] Owen,^[6] Katch-McArdle,^[7] and Nelson,^[8] and thereby examine the accuracy and precision of these equations for use in professional weightlifters
3. To predict the REE of professional weightlifters using potential anthropometric variables.

MATERIALS AND METHODS

Participants

The cross-sectional study covered 30 selected professional male weightlifters in the age group of 17–28 years who were actively competing at national/international level from Vellore district, Tamil Nadu in South India. They all practiced for more than 4–5 h daily, 5–6 days a week for more than a year. Individuals with chronic illness were excluded from the study. The participants were informed about the objective of the study, and all their concerns were clarified in Tamil, their mother tongue. They spent 1–2 h of their time for the study in the laboratory. The study was approved by the Institutional Review Board of Christian Medical College and Hospital, Vellore, Tamil Nadu, India (IRB Min No. 7443, date: March 16, 2011), and informed consent was obtained from all the participants.

Indirect calorimetry

The individuals were subjected to indirect calorimetry in the fasting state (Jaeger, Oxycon Pro, Germany year, 2006). This equipment consists of a ventilated hood system made of clear plastic with a volume of 30 L that is placed over the face of the individual. Gas analyses are performed by using a paramagnetic oxygen analyzer and an infrared carbon dioxide analyzer. It calculates the respiratory quotient (RQ) from the oxygen consumption in ml/min (VO_2) and carbon dioxide production

ml/min (VCO_2) ($\text{RQ} = \text{VCO}_2/\text{VO}_2$). The RQ identifies the type of fuel oxidized for energy. RQ for carbohydrate is 1, for fat 0.7, and for protein is 0.8. On a mixed diet, the RQ is close to 0.8. The Weir equation ($3.9 [\text{VO}_2] + 1.1 [\text{VCO}_2] \times 1.44$) computes the REE from RQ. The instrument was calibrated regularly according to manufacturer's instructions. The equipment and data output were handled by the same trained personnel throughout the study. For the indirect calorimetry, the participants arrived in an overnight fasting state. They were told to refrain from smoking, alcohol, and weightlifting practice for the previous 12 h. They were made comfortable, 45 min before the test. During the 40 min duration of the test, they were in a supine position and watched television without sleeping. The temperature was set at 23°C–24°C. The average reading for the 40 min was taken as the final result for the study and is represented as mREE.

Anthropometric measurements

The anthropometric measurements of the weightlifters were recorded by following standard procedures. The weight of the respondent was measured using a standard digital scale to the nearest 0.1 kg (Tanita, Corporation of Japan, UM 076). The height of the weightlifters was measured to the nearest 0.1 cm using the anthropometer (Holtain Ltd., Crymych, Dyfed, Britain, UK). The waist circumference (WC) and hip circumference (HC) were measured using a standard tape to the nearest 0.1 cm. The skinfold thickness (SFT) was measured at five regions - triceps, biceps, subscapular, supriliac, and abdomen using a Harpenden caliper (CMS Instruments, London). The body composition of the weightlifters was analyzed using the dual energy X-ray absorptiometry scanner (DXA) (Hologic Delphi W [S/N 70471 DXA scanner]).

Predicted equations for resting energy expenditure

A number of equations have been published to compute the REE of individuals. In this study, the equations reviewed were Harris-Benedicts,^[1] Mifflin-St. Jeor,^[2] FAO/WHO/UNU,^[3] ICMR,^[4] Cunninghams,^[5] Owen,^[6] Katch-McArdle,^[7] and Nelson^[8]. The REE computed from these equations is called as pREE.

Equations used to predict resting energy expenditure

Harris-Benedicts = $66.47 + 13.75$ (weight in kg) + 5 (height in cm) – 6.76 (age)

Mifflin-St. Jeor = $5 + 10$ (weight in kg) + 6.25 (height in cm) – 5 (age)

FAO/WHO/UNU = 15.3 (weight in kg) + 679

ICMR = 14.5 (weight in kg) + 645

Cunninghams = $500 + 22$ (lean body mass [LBM] in kg)

Owen = $655.096 + 1.8496$ (height in cm) + 9.5634 (weight in kg) – 4.6759 (age)

Katch-McArdle = $370 + 21.6$ (LBM in kg)

Nelson = 25.80 (fat free mass in kg) + 4.04 (fat mass in kg).

Statistical methods

All data were analyzed using SPSS version 16.0 (Chicago, USA, SPSS Inc.) for Windows. The anthropometric measurements and the mREE and pREE from different formulas are presented using descriptive statistics. Intraclass correlation coefficient (ICC) was used to evaluate the agreement between the mREE and pREE. Pearson correlation coefficient was computed to determine the association of the anthropometric variables with mREE. Multiple linear regression analysis using potential anthropometric determinants was carried out to obtain a new predictive equation for computing REE for professional male weightlifters.

RESULTS

The baseline characteristics of the study individuals are shown in Table 1.

The age of the participants ranged from 18 to 28 years. They had a mean height of 168.83 ± 6.32 cm and mean weight of 75.95 ± 14.73 kg. Their mean body mass index (BMI) indicated that they were overweight (26.09 ± 4.28). The DXA scan however shows that they have a relatively low-fat percentage of $15.15 \pm 5.28\%$ and a high LBM (60.98 ± 9.19 kg) indicating a high muscle mass. This indicates that BMI should not be used as the sole means of assessing nutritional status among this category of sportspersons.

Table 1: Baseline characteristics of professional male weightlifters ($n=30$)

Baseline characteristics	Mean \pm SD	Range
Age (years)	21.5 \pm 2.87	18-28
Years of training	5.04 \pm 2.68	1.00-12.00
Height (cm)	168.83 \pm 6.32	157.50-182.00
Weight (kg)	75.95 \pm 14.73	56.59-127.64
WC (cm)	78.57 \pm 11.36	64.00-112.50
HC (cm)	95.38 \pm 9.23	80.50-122.00
BMI	26.09 \pm 4.27	21.26-38.46
Waist-hip ratio	0.82 \pm 0.056	0.73-0.95
RER (VCO ₂ /VO ₂)	0.85 \pm 0.079	0.7-1.05
Skinfold measurements		
Biceps (cm)	0.5943 \pm 0.31827	0.30-1.84
Triceps (cm)	0.9753 \pm 0.61967	0.38-2.98
Subscapular (cm)	1.5893 \pm 0.71038	0.78-4.22
Abdominal (cm)	1.9427 \pm 1.15252	0.50-5.22
Suprailiac (cm)	0.9827 \pm 0.61608	0.30-2.58
Body composition-DXA scan		
Total body area (cm ²)	2159.78 \pm 161.28	1885.14-2659.89
Total BMD (g/cm ²)	1.37 \pm 0.093	1.20-1.57
Total BMC (kg)	2.96 \pm 0.35	2.49-3.88
Total LBM (kg)	60.98 \pm 9.19	46.48-88.51
LBM+BMC (kg)	63.94 \pm 9.49	48.96-92.39
Total fat content (kg)	11.42 \pm 6.97	1.03-35.24
Total fat percentage	15.15 \pm 5.28	8.40-30.30

BMI: Body mass index, SD: Standard deviation, WC: Waist circumference, HC: Hip circumference, RER: Respiratory exchange ratio, BMD: Body mineral density, BMC: Body mineral content, LBM: Lean body mass, DXA: Dual-energy X-ray absorptiometry

The waist-hip ratio (0.82 ± 0.06) reiterates a healthy picture. The SFT at the abdominal site was the highest and measured 1.9427 ± 1.15252 cm. The respiratory exchange ratio (0.85 ± 0.08) indicated that carbohydrates and fats were the major substrates for energy metabolism.

The data on REE derived from indirect calorimetry are presented in Table 2. The mean REE was 2216.47 ± 514.67 kcal/day. All 8 predictive equations underestimated the REE of the weightlifters when compared with the mREE. The predictive equations underestimated mREE by $>10\%$ in more than two-third of the individuals. The highest mean difference was 636 kcal/day (Owen, 1986) and the lowest difference was 375 kcal/day (Cunninghams, 1980). However, the ICC between the mREE and pREE showed statistically significant agreement. The ICC estimate of Nelson's (1992) equation was 0.557 indicating highest agreement. Although there is statistical agreement between the mREE and pREE, the calorie deficit of 375–636 kcal/day is of nutritional significance as it could result in a reduced food intake which will consequently have a negative impact on their sport performance in the long run. Further, correlations between the anthropometric variables and mREE derived from indirect calorimetry were analyzed. As outlined in Table 3, positive correlations were seen with suprailiac SFT, LBM, WC, HC, bone mineral content, and body mass.

Since none of the predictive equations accurately measured mREE among this group of sportspersons, we aimed at deriving a novel equation utilizing the various anthropometric variables that correlated significantly with mREE. Multiple stepwise linear regression revealed that LBM was the only significant determinant of REE in this group of sportspersons. A new equation was developed using LBM as the independent variable for computing REE. This was as follows:

REE for weightlifters = $-164.065 + 0.039$ (LBM) (confidence interval – 1122.98, 794.85).

This new equation reduces the mean difference with mREE by 2.36 ± 369.15 kcal/day (standard error = 67.40). Figure 1 depicts the mean and standard deviation of the REE obtained by the gold standard, the new derived equation, and the existing equations.

DISCUSSION

REE forms an integral part of the metabolic milieu in normal healthy individuals. Male professional weightlifters present a unique population in whom the nature of the physical activity and distinct body composition exert an increased burden on the energy expenditure. As such, a correct assessment of REE is the key to appropriate dietary recommendations in these sportspersons. Although there are a number of predictive equations that have been derived to assess REE, their validity in a weightlifter population has not been attempted before.

Ours is the first study to assess REE in male weightlifters of Asian Indian origin utilizing the gold standard technique of

Table 2: Resting energy expenditure in kcal/day of professional male weightlifters (n=30) computed by indirect calorimetry (measured resting energy expenditure) and by 8 different equations (predicted resting energy expenditure)

Variables	Indirect calorimetry	Katch-McArdle	Cunninghams	FAO/WHO/UNU	ICMR	Harris-Benedict	Mifflin-St. Jeor	Owen	Nelson
Mean REE kcal/day*	2216.47±514.67	1687.14±198.43	1841.53±202.10	1820.74±226.36	1727.04±214.52	1791.37±221.31	1698.94±171.89	1580.2±147.61	1294.0±262.48
Mean difference with mREE kcal/day	-	529.33±402.41	374.93±400.96	395.73±417.98	489.43±420.58	425.09±420.59	517.53±436.24	635.98±440.71	520.75±384.47
Intraclass coefficient (r)	-	0.47	0.47	0.45	0.43	0.44	0.35	0.32	0.57
P	-	0.004	0.004	0.006	0.008	0.007	0.025	0.03	0.001
Number of individuals for whom mREE and pREE differed by more than >10%	-	26	24	19	22	20	23	27	27

*Correlation is significant at the 0.01 level (two tailed). mREE: Measured resting energy expenditure, pREE: Predicted resting energy expenditure

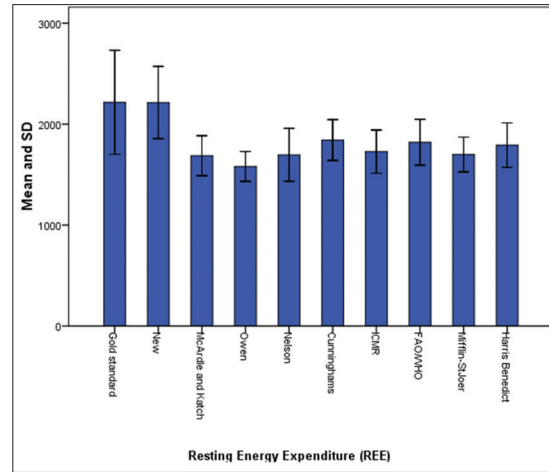


Figure 1: Plot of gold standard and resting energy expenditure

indirect calorimetry. Further, a total of 8 predictive equations has been simultaneously assessed and compared with the indirect calorimetric indices of REE. These 8 equations tested in our study have been in use for a number of years and were validated at different periods of time among varied population. In the current era, population characteristics have changed. These equations need to be looked into and revalidated to meet the changing demography and be more population-specific, more so in cases of unique groups of sportspersons like the weightlifters.

When compared to calorimetry-derived REE, none of the eight equations in our study were found to be accurate. Similar discrepancies were reported when these equations were applied to different population groups. Studies done on healthy young adults^[9-12] found that these equations were inaccurate in predicting REE. A study on male athletes by De Lorenzo *et al.*^[13] found many of the long-standing equations were inadequate in predicting REE. In a study by Thompson and Mannore,^[14] on endurance athletes, only the Cunningham equation^[5] which uses LBM as the predictor of REE was found to provide an accurate estimate. They reported that free fat mass was the best predictor of REE among this group of male athletes. None of the other equations were suitable for use in this category of sportspersons.

The individuals in this study with their high LBM and low-fat percentage have a unique body composition not comparable with any other population group. Their high LBM places a higher than normal demand on their resting energy requirement. The indirect calorimetry has clearly denoted that none of the existing equations hold well as such any predictive equation mandates the use of LBM as the independent variable for REE. In our study, we have proposed an alternative predictive equation that performs better than the existing equations when compared to REE derived from indirect calorimetry. Thus, a predictive equation primarily involving LBM could be useful in assessing REE in Asian Indian male weightlifters.

Table 3: Pearson correlation coefficient (*r*) between measured resting energy expenditure and anthropometric measurements (*n*=30)

Variable	Suprailiac SFT	Total BMC	Total LBM	WC	HC	Total body mass	BMI
mREE (<i>r</i>)	0.510*	0.504*	0.697*	0.569*	0.577*	0.623*	0.595*
<i>P</i>	0.004	0.005	<0.001	0.001	0.001	0.000	0.001

*Mean±SD. SD: Standard deviation, SFT: Skinfold thickness, BMC: Body mineral content, LBM: Lean body mass, WC: Waist circumference, HC: Hip circumference, BMI: Body mass index, mREE: Measured resting energy expenditure

CONCLUSIONS

This is the first study to validate REE computed from long-standing prediction equation against that of the gold standard - indirect calorimetry among professional male weightlifters from an Indian population. The most significant finding was that all the existing prediction equations underestimated the REE. The LBM was the sole determinant of REE in this population.

In the absence of indirect calorimetry, the REE equation developed by us using LBM is a better predictor of REE in professional male weightlifters of Asian Indian origin and is more appropriate than the commonly used eight pREE equations.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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