

Resting Energy Expenditure in Elite Athletes: Development of New Predictive Equations Based on Anthropometric Variables and Bioelectrical Impedance Analysis Derived Phase Angle

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Abstract

Background

An accurate estimation of athletes' energy needs is crucial in diet planning to improve sport performance and to maintain an appropriate body composition. This study aimed to develop and validate in elite athletes new equations for estimating resting energy expenditure (REE) based on anthropometric parameters as well as bioimpedance analysis (BIA) derived raw variables and to validate the accuracy of selected predictive equations.

Methods

Adult elite athletes aged 18-40 years were studied. Anthropometry, indirect calorimetry and BIA were performed in all subjects. The new predictive equations were generated using different regression models. Prediction accuracy of the new equations was assessed and compared with the one of five equations for estimating REE in normal-weight subjects and three athletes-specific predictive formulas as suggested in the literature.

Results

One-hundred and twenty-six male athletes from different sport specialties were randomly assigned to the calibration (n=75) or validation group (n=51). REE was directly correlated with individual characteristics, except for age, and raw BIA variables. Most of the equations from the literature were reasonably accurate at the population level (bias $\pm 5\%$). The new equations showed a mean bias -0.3% (Equation A based on anthropometric parameters) and -0.6% (Equation B based on (BIA) derived raw variables). Individual accuracy was $\sim 75\%$ in six out of eight of the selected equations and was even higher for Equation A (82.4%) and equation B (92.2%).

Conclusion

In elite athletes, BIA-derived phase angle is a significant predictor of REE. The new equations have a very good prediction accuracy at both group and individual levels. The use of PhA as predictor of REE requires further research with respect to different sport specialties, training programs and training level.

Background

Total energy expenditure of most athletes is expected to be greater compared to general population because of training, competition and changes in body composition [1]. Estimating their energy needs is crucial in diet planning to improve sport performance and manage body mass in weight-category sports [2, 3]. Actually, under- or over-estimating athletes' energy requirements might result in loss of fat-free mass (FFM), increased fat mass (FM), impaired performance and increased risk of injuries [1, 2].

Energy requirements may be estimated based on resting energy expenditure (REE), which is the amount of energy expended at rest by a fasted individual in a thermoneutral environment, representing 60–70% of total energy expenditure in normal-weight healthy adults and variable percentages in athletes [4]. In nutrition and dietetics, REE is frequently estimated by using predictive equations based on easily available variables such as age, stature, body weight, etc. The Harris and Benedict (HB) [5], Schofield [6], FAO/WHO/UNU [7], Mifflin [8] and Owen [9] formulas are the most used in healthy individuals. Taking into account different body composition (i.e. high FFM and body cell mass with low FM) relative to general population [10–12], few specific predictive equations for REE have been developed for athletes [13–15]. However, they exhibit some limitations such as limited sample size [13], performance level [15] or ethnicity [14].

In addition to anthropometric measures, bioelectrical impedance analysis (BIA) is widely used as a field method for assessing body composition in athletes and might be valuable in estimating REE since the main determinant of REE is fat free mass (FFM). However, the interpretation of BIA results depends to a large extent on the equation used to estimate FFM [16]. Alternatively, raw BIA variables such as bioimpedance index (BI-Index) and phase angle (PhA) might be taken into account. Given that BI-index is a direct proxy marker of FFM, while PhA is related to body cell mass [17], a relationship between energy expenditure and BI-index and PhA has already been observed in normal-weight or overweight subjects [18] as well as in patients with obesity [19] and Crohn's disease [20]. Not surprisingly, the results of these studies showed that the raw BIA variables may improve the prediction power under physiological conditions [18], but only by a limited extent in subjects possibly with altered body water distribution [19, 20].

Based on this background, the primary aim of this study was to develop and validate new predictive equations of REE specific for elite athletes, considering not only the anthropometric measures, but also the raw BIA variables as predictors. Additionally, we evaluated in elite athletes of different sports the accuracy of selected predictive equations of REE (for general population or athletes) at both population and individual level.

Methods

Study design and subjects

In the present study we have retrospectively analyzed routine data collected between January 2012 and December 2019 in elite athletes involved in heavy training. Subjects with the following inclusion criteria: (1) both genders, (2) age between 18–45 years and (3) athletes who had been undergoing at least 24 hours of training a week, were selected for this study. Subjects affected by overt metabolic and/or endocrine diseases and/or regularly taking any medications or using any drugs affecting energy metabolism, were excluded. This study was conducted in accordance with the Declaration of Helsinki and was approved by the Federico II University Ethical Committee.

All measurements were performed early in the morning (8.30 a.m.) after an overnight fast (8–10 hours) according to standardized conditions, i.e., abstention from alcohol, smoking, and vigorous physical activity for 24 hours prior to the assessment.

Anthropometry and Bioelectrical Impedance Analysis

Body weight was measured to the nearest 0.1 kg using a platform beam scale and stature was measured to the nearest 0.5 cm using a stadiometer (Seca 709; Seca Hamburg, Germany). Measurements were taken while the subject wore light clothes and no shoes. Body mass index (BMI) (kg/m^2) was calculated as body weight (kg) divided by squared stature (m).

BIA was performed by phase-sensitive device (Human IM Plus II, DS Medica S.r.l., Milan, Italy). Measurements were carried out in standardized conditions (i.e. ambient temperature between 23 and 25 °C, fast > 3 h, empty bladder, supine position for at least 10 min before starting the measurement). In addition, after cleaning skin surface, patients were asked to lay with upper and lower limbs slightly abducted, so there was no contact between the extremities and trunk. The measuring electrodes were placed on the anterior surface of the wrists and ankles, and the injecting electrodes were placed on the dorsal surface of the hands and the feet, respectively (overall, eight electrodes). Data for impedance, resistance and PhA from the non-dominant side of the body, measured at 50 kHz, were considered. BI-index was calculated as the ratio $\text{stature}^2/\text{resistance}$ (cm^2/ohm).

Resting Energy Expenditure

REE was measured by indirect calorimetry [21] using a canopy system (Vmax® Encore system, CareFusion Corporation, U.S.). The instrument was routinely checked by burning ethanol, whereas oxygen and carbon dioxide analyzers were calibrated on the test day using nitrogen and standardized gases (mixtures of nitrogen, carbon dioxide and oxygen).

Measurement conditions for by indirect calorimetry were defined following the suggestions made by Compher et al. [22] and Fullmer et al. [23]. REE was measured at an ambient temperature of 22–25 °C with the subjects fasting (12–14 hours) and laying down, but awake, on a bed in a quiet environment. In women REE was assessed during the postmenstrual phase to avoid any potential effects of the menstrual cycle. After a 15-minute adaptation period, oxygen consumption and carbon dioxide production were measured for 45 minutes, discarding the first 5 minutes. Energy expenditure was calculated using the abbreviated Weir's formula, neglecting protein oxidation [24]. Data were excluded from analysis if the respiratory quotient was outside the expected range (0.71-1.00) and when measured REE was ± 3 standard deviations outside the mean REE.

Predictive equations

The most used predictive equations for estimating REE in normal-weight subjects (Harris & Benedict [5], Schofield [6], FAO/WHO/UNU [7], Mifflin [8] and Owen [9]) were selected. Additionally, three athletes-specific formulas from the literature (De Lorenzo [13], Wong [14] and ten Haaf weight-based formula [15]) were chosen (Table 1). Accuracy of the new predictive equations was calculated and then compared with the previous ones at the population as well as at individual levels.

Table 1
Resting energy expenditure predictive equations in their original unit (kcal/day, except Schofield and FAO/WHO/UNU (MJ/day))

Equation	Formula
Harris and Benedict [5]	(Males) $13.75 \times \text{Weight (kg)} + 5 \times \text{Stature (cm)} - 6.76 \times \text{Age (years)} + 66.47$
Schofield [6]	Males (18–30 years) $63 \times \text{Weight (kg)} - 42 \times \text{Stature (m)} + 2953$
	Males (30–60 years) $48 \times \text{Weight (kg)} - 11 \times \text{Stature (m)} + 3670$
FAO/WHO/UNU [7]	Males (18–30 years) $15.3 \times \text{Weight (kg)} - 27 \times \text{Stature (m)} + 679$
	Males (30–60 years) $11.6 \times \text{Weight (kg)} - 16 \times \text{Stature (m)} + 879$
Mifflin [8]	$9.99 \times \text{Weight (kg)} + 6.25 \times \text{Stature (cm)} - 4.92 \times \text{Age (years)} + 166 \times \text{Gender (M = 1, F = 0)} - 161$
Owen [9]	Males $10.2 \times \text{Weight (kg)} + 879$
De Lorenzo [13]	$9 \times \text{Weight (kg)} + 11.7 \times \text{Stature (cm)} - 857$
Wong [14]	$13 \times \text{Weight (kg)} + 192 \times \text{Gender (M = 1, F = 0)} + 669$
Ten Haaf [15]	$11.936 \times \text{Weight (kg)} + 587.728 \times \text{Stature (cm)} - 8.129 \times \text{Age (years)} + 191.027 \times \text{Gender (M = 1, F = 0)} + 29.279$

Statistical analysis

Statistical analyses were performed using IBM SPSS (version 26). All data are presented as mean \pm standard deviations (SD), unless otherwise specified, and significance was defined as $p < 0.05$. To examine if variables were normally distributed, the Kolmogorov-Smirnov Test and the Shapiro-Wilk Test were used. As presented in Table 2, subjects were randomly assigned to a calibration or a validation group (60% and 40% of the total sample, respectively) in a way that the ratio between them remained constant [19].

Table 2
Characteristics of the study sample for the calibration and validation groups

	All (n = 126)			Calibration group (n = 75)			Validation group (n = 51)		
Age, years	26.9	±	9.1	26.8	±	9.0	27.1	±	9.5
Weight, kg	71.3	±	10.9	71.4	±	11.3	71.1	±	10.6
Stature, cm	177	±	7	177	±	7	177	±	7
BMI, kg/m ²	22.8	±	2.7	22.8	±	2.8	22.8	±	2.6
MREE, kcal/die	1831	±	250	1834	±	261	1826	±	234
RQ	0.821	±	0.07	0.832	±	0.07	0.822	±	0.07
BI-index, cm ² /Ω	65.9	±	9.6	65.9	±	9.8	66.0	±	9.4
Phase angle, degrees	7.76	±	0.76	7.79	±	0.74	7.73	±	0.78
Data are expressed as mean ± standard deviation.									
BMI = body mass index; MREE = measured resting energy expenditure; RQ = respiratory quotient; BI-index = bioimpedance index.									

Linear correlation was applied for evaluating associations between variables. Multivariate linear regression analysis was performed to develop the new predictive equations, with REE measured by indirect calorimetry as dependent variable. We generated models as follows: in Model 1, age, sex, weight, stature and BMI were set as predictors, while in Model 2 we added the raw BIA variables (BI-index and PhA). Coefficient of determination (R^2) and standard error of the estimate (SEE) were considered for assessing the predictive power of formulas. The regression equations, derived from the calibration subset, were applied to the validation group.

Mean difference between predicted REE (PREE) and measured REE (MREE) as well as bias, i.e. the average percent difference, were both used as a measure of accuracy at the population level. Bias was found acceptable if within $\pm 5\%$ [25, 26]. While the percentage of patients with a PREE within 90–110% of MREE was used as a measure of accuracy at the individual level. According to the range, values lower than 90% were classified as underprediction, while values higher than 110% as overprediction. The root mean squared error (RMSE) was used to define the predictions obtained with these models. Finally, comparisons of PREE-MREE differences vs mean PREE-MREE values were performed by Bland and Altman plots to estimate the limits of agreement [27].

Results

One hundred and twenty-six male elite athletes from different sport specialties were included in the analysis. As mentioned above, data on anthropometric measures, raw BIA variables and MREE are reported for the calibration and validation groups in Table 2. Athletes from seven sports were recruited, practicing masters swimming (n = 24, 19%), cycling (n = 22, 17.5%), running (n = 21, 16.7%), karate (n = 17, 13.5%), water polo (n = 16, 12.7%), ballet dance (n = 15, 11.9%) and boxing (n = 11, 8.7%). Individual characteristics for each sport specialty are reported in Table 3. We found that BMI was the highest in water polo players (25.9 ± 1.8 kg/m²) and the lowest in runners (20.6 ± 1.2 kg/m²). MREE was the highest in water polo players (2195 ± 244 kg/day) and the lowest in ballet dancers (1567 ± 107 kg/day). PhA varied between 8.57 ± 0.65 degrees in boxers and 6.96 ± 0.54 degrees in master swimmers.

Table 3
Characteristics of the study sample according to sport specialty

	Cycling		Water polo		Masters swimming		Karate		Ballet Dance		Boxing		Runni
	(n = 22)		(n = 16)		(n = 24)		(n = 17)		(n = 15)		(n = 11)		(n = 21)
Age (years)	27.0	± 2.7	24.2	± 6.6	40.4	± 4.5	18.8	± 2.7	19.1	± 1.1	20.7	± 2.7	29.0
Weight (kg)	69.2	± 5.2	88.8	± 4.9	76.6	± 10.0	69.5	± 10.4	64.1	± 5.2	70.0	± 5.2	61.1
Stature (cm)	181	± 6	185	± 3	176	± 5	176	± 7	175	± 4	169	± 5	172
BMI (kg/m ²)	21.2	± 1.3	25.9	± 1.8	24.6	± 2.8	22.5	± 2.7	20.9	± 0.9	24.7	± 0.6	20.6
MREE (kcal/die)	1866	± 142	2195	± 244	1766	± 188	1928	± 207	1567	± 107	1946	± 127	1641
RQ	0.785	± 0.031	0.865	± 0.046	0.815	± 0.081	0.804	± 0.049	0.850	± 0.049	0.807	± 0.082	0.870
BI-index (cm ² /Ω)	65.4	± 8.0	78.8	± 8.3	67.6	± 7.7	64.0	± 8.7	67.7	± 6.3	65.9	± 5.7	55.2
PhA (degrees)	8.31	± 0.79	8.11	± 0.49	6.96	± 0.54	7.59	± 0.60	7.75	± 0.53	8.57	± 0.65	7.60

Data are expressed as mean ± standard deviation. BMI = body mass index; MREE = measured resting energy expenditure; RQ = respiratory quotient; BI-index = bioimpedance index; PhA = phase angle

Developing new predictive equations

Linear correlations showed that MREE of the athletes was directly correlated with individual characteristics and raw BIA variables, except for age ($r = -0.124$, $p = 0.290$). Overall, a strong correlation was found between MREE and body weight ($r = 0.768$, $p < 0.001$), followed by BMI ($r = 0.623$, $p < 0.001$), BI-index ($r = 0.606$, $p < 0.001$), stature ($r = 0.489$, $p < 0.001$) and PhA ($r = 0.327$, $p = 0.004$).

Then, multiple regression analysis was performed to assess the relationship between MREE and different sets of potential predictors. Basic anthropometric measures (weight, stature and BMI) and age (although not significant in bivariate analysis) were considered first in Model 1 to generate the following equation A:

REE (kcal/day) =	17.2×Weight	-5.95 × Age	+ 748
	(1.5)	(1.9)	(117.9)
	<i>0.794</i>	<i>-0.218</i>	
(unstandardized regression coefficients with SE in brackets and beta coefficients in italics)			

$R^2=0.637$; SEE = 150 kcal/day

When raw BIA variables (BI-index and PhA) were added to the Model 2, PhA was included whereas age was excluded from the model, developing the following equation B:

REE (kcal/day) =	16.3×Weight	+ 95.4 × PhA	-93
	(1.5)	(22)	(197)
	<i>0.755</i>	<i>0.291</i>	
(unstandardized regression coefficients with SE in brackets, and beta coefficients in italics)			

$R^2=0.675$; SEE = 141 kcal/d

Validation of predictive equations

To assess the accuracy of the new predictive equations, 51 athletes were randomly assigned to the validation group, using the statistical software. Prediction accuracy at the population level, evaluated by the difference between PREE and MREE, percent bias and RMSE in kcal/day, is shown in Table 4 for the new

equations and for those selected from the literature.

Table 4
Evaluation of new and selected predictive equations in athletes

REE predictive equations	Difference PREE-MREE kcal/d Mean (SD)	Bias [§] %	RMSE kcal/d
<i>Equations for normal-weight subjects</i>			
HB	- 82 (146)	- 3.9	107
Schofield	- 93 (142)	- 4.4	108
FAO/WHO/UNU	- 92 (140)	- 4.4	107
Mifflin	- 141 (156)	- 7.0	164
Owen	- 222 (140)	- 11.3	225
<i>Equations for athletes</i>			
De Lorenzo	21 (173)	2	94
Wong	- 41 (153)	-1.4	104
Ten Haaf	60 (152)	4	98
Equation A	- 17 (134)	- 0.3	88
Equation B	- 20 (124)	- 0.6	76
Average REE measured with indirect calorimetry = 1826 ± 234 kcal/d.			
REE = resting energy expenditure; MREE: measured resting energy expenditure; PREE: predicted resting energy expenditure; RMSE: root mean square error; HB = Harris and Benedict; FAO = Food and Agriculture Organization.			
§ Mean percentage error between predicted and measured REE.			

The new developed predictive formulas showed a mean bias < 1% (Equation A -0.3%; Equation B -0.6%) with the lowest RMSE values of 88 kcal (Equation A) and 76 kcal (Equation B); while REE seemed to be underestimated by most of the other equations, with the exception of the De Lorenzo and ten Haaf. Overall, the difference between PREE and MREE, expressed as absolute values of HB, FAO, Schofield, De Lorenzo, Wong and ten Haaf equations was < 100 kcal/day. Indeed, most of them provided a reasonably accuracy prediction at the population level, with an acceptable bias (HB -3.9%; Schofield + 4.4%; FAO - 4.4%; De Lorenzo + 2%; Wong - 1.4% and ten Haaf + 4%) with the exception of the Mifflin (-7%) and Owen (-11.3%) .

The accuracy at the individual level (precision), represented by the percentage of athletes with a PREE within ± 10% of MREE, was higher for the new equations (Equation A 82.4%, Equation B 92.2%) compared to the others (~ 45% for the Owen, ~ 65% for the Mifflin and ~ 75% for the Harris-Benedict, FAO, Schofield, De Lorenzo, Wong and ten Haaf equations) as shown in Fig. 1.

Bland-Altman plots of PREE-MREE differences

Lastly, the Bland-Altman method was used to quantify the agreement between PREE-MREE differences against mean PREE-MREE values. Plots for the new formulas highlight the best agreement as shown in Fig. 2. For the other formulas, the 95% limits of agreement were wide (+/- 200–300 kcal/d) with the largest range for the Mifflin and Owen equations.

Discussion

The primary purpose of this study was to develop and cross-validate new equations for estimating REE in a group of elite male athletes of different sports, and then to compare them with existing formulas. Findings show that the new equations provide the best prediction of REE in the validation group, while the use of BIA-derived PhA improves the prediction power of the equation.

Meeting energy requirements is a priority of athletes. Inadequate energy intake might compromise performance and reduces the benefits of training [1, 2]. Energy needs are usually estimated by REE multiplied by the appropriate activity factor. To date, only a few number of predictive equations for REE have been specifically developed for athletes [13–15]. De Lorenzo formula [13] was derived in a sample of 51 male athletes (22 water polo, 12 judo, 17 karate) who exercised at least 3 hours/day; in that paper REE was underestimated by most of the seven equations selected from the literature. Later, Wong et al. [14] proposed gender-specific predictive formulas for elite Malaysian athletes in most cases practicing combat sports. Of note, Malaysian population seemed to have relatively low body frames and size and, therefore, low REE [14]. They found that mean basal metabolic rate measured by indirect calorimetry were similar in males to those estimated using the HB [5], FAO [7] and De Lorenzo [13] equations, but the accuracy of the predictive formulas was not evaluated. Finally, ten Haaf et al. [15] developed two predictive equations for recreational athletes practicing > 3 hour/day two times a week, the first formula being based on weight, the second one on FFM. Authors pointed out that the weight-based equation had a higher precision (83% for males) compared to the De Lorenzo formula (77.4% for males).

In the present study, we developed an equation based on age and main anthropometric variables (weight, stature, and BMI) (Model 1, Equation A). In addition to age, weight emerged as the only significant predictor. Two of the existing formulas for athletes identified also stature as predictor [13, 15] while in the athletes we studied, REE was correlated to stature in univariate analysis, but not in multiple regression analysis, $p = 0.374$). Instead of using BIA-derived body composition (strictly dependent on the BIA formula used), we opted for including raw BIA variables (BI-index and PhA) in the regression model (Model 2, Equation B).

BI-index is directly related to FFM and quite always included as predictor in the BIA equations to predict FFM. More recently, attention has been focused on the role of PhA as a biomarker of body cell mass and muscle quality as well as of water distribution (ratio between extracellular water-ECW and intracellular water-ICW)[28]. Thus, high PhA indicates greater cellularity (e.g. more body cell mass relative to FFM), cellular integrity and cell functions [28]. It may represent a proxy parameter of muscle quality in athletes, being significantly associated with physical activity and muscle strength [29, 30]. A recent systematic review showed that PhA was higher in athletes vs controls whereas it was still uncertain to what extent PhA differs among various sports [31]. In addition, PhA may help in detecting low muscle quality and identifying sarcopenia [32]. In previous studies, we also found that both BI-index and PhA improved the prediction power of REE under physiological conditions [18]. The findings of the present paper confirmed that PhA was as a significant predictor along with weight, with R^2 increasing from 0.637 to 0.675 and SEE decreasing from 150 to 141 kcal/day. On the contrary, BI-index was not recognized as a stronger predictor than weight, possibly because of low body fat percentage and low BMI.

As additional aim, we validated the two new equations and eight formulas selected from the literature (5 for the general population and 3 for athletes), at both population and individual level. On the average, the accuracy was very good for our new formulas, since bias ranged within $\pm 1\%$. Similarly, most of the selected equations, except the Mifflin and Owen ones, showed an acceptable prediction accuracy (bias $\pm 5\%$).

From a practical point of view, evaluating the accuracy of predictive equations at individual level (within $\pm 10\%$) is crucial for the nutritional management of the single athlete. This study shows that precision was high for the new formulas, especially for Equation B ($\sim 92\%$) including PhA in the model while it was lower, being close to 75%, for most of the other formulas (with the exception of the Mifflin and Owen ones for which it was much lower). Looking at the Bland-Altman plots, most of the prediction equations were more accurate at lower ranges of MREE and less accurate with the higher REE values. The new formulas gave the narrowest limits of agreement and the lowest bias.

To the best of authors' knowledge, this is the first study that developed and cross-validate equations for elite athletes to predict REE based not only on anthropometric measures, but also on raw BIA variables. Overall, we conducted this study in a reasonable large sample of individuals, using recognized and well-documented methods and in line with similar previous studies in healthy subjects. Furthermore, the assessment of BIA with the same device has limited the device-related changes in PhA. Nevertheless, these findings are subject by a number of limitations. Since this is a retrospective study, our findings need to be confirmed in larger samples and in different sports disciplines. Additionally, we studied elite athletes mostly practicing endurance sports. Lastly, female athletes were excluded from the analysis due to the small number of potential participants ($n = 27$); therefore, we have developed new athlete-specific predictive equations for estimating REE in elite male athletes only.

Conclusions

As main finding, in elite athletes BIA-derived PhA is a significant predictor of REE and improved the prediction power of the model. The new equations exhibited a very good accuracy at population level, while precision at the individual level was markedly higher compared to that reported by previous studies in the general population as well as athletes. However, the use of PhA as predictor of REE requires further research with respect to different sport specialties, training programs and training level.

Abbreviations

BI-Index=Bioimpedance Index

BIA= Bioelectrical Impedance Analysis

BMI=Body Mass Index

ECW= Extracellular Water

FAO=Food and Agriculture Organization

FFM= Fat-Free Mass

FM=Fat Mass

HB=Harris and Benedict

ICW= Intracellular Water

MREE= Measured Resting Energy Expenditure

PhA= Phase Angle

PREE=Predicted Resting Energy Expenditure

REE= Resting Energy Expenditure

TBW= Total Body Water

Declarations

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Authors' contributions

MM and ODV formulated the study concept and design. MM, ODV and RS acquired data used in the study and assisted in the interpretation of this data. MM, LS and ODV interpreted data, drafted the manuscript, and completed the data analysis and interpretation. IC, RS and DM helped advise the direction of the manuscript and made substantial revisions. Each author has read and approved the final manuscript prior to submission.

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Federico II University Ethical Committee.

Consent for publication

Not applicable.

Availability of data and materials

All data pertaining to the conclusions of the study are found within the article. The corresponding data set used is available under reasonable requests.

Competing interests

The authors declare that they have no competing interests.

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Figures

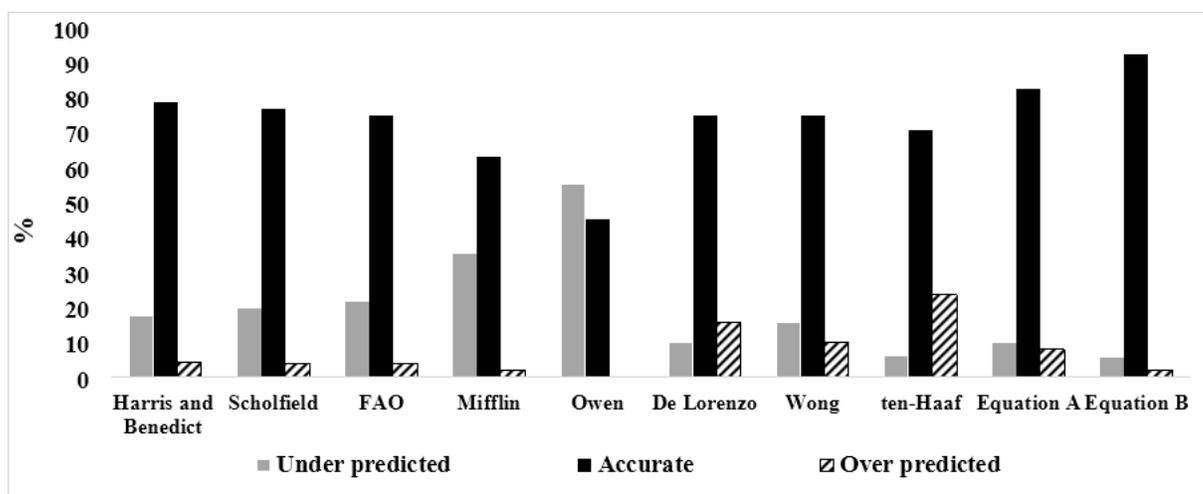


Figure 1

Accuracy of prediction equations for measurements of resting energy expenditure within $\pm 10\%$

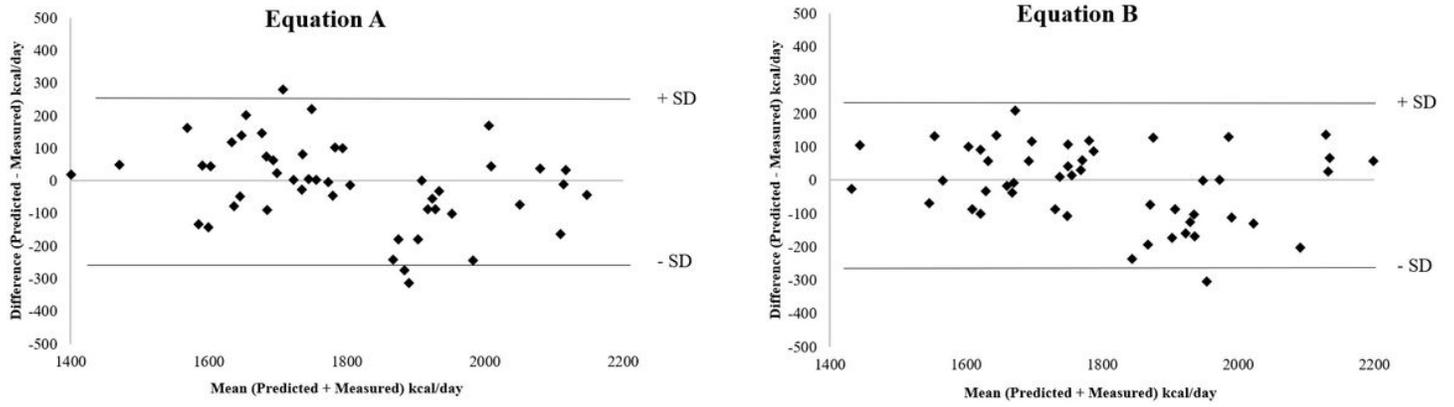


Figure 2

Bland - Altman plots between differences and mean predicted-measured resting energy expenditure using new equations