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A novel equation synthesis for estimating resting energy expenditure in prostate cancer patients

Nilüfer Acar Tek^{1,2*} , Tevfik Koçak^{1,2*} , Süleyman Yeşil³ and Tevfik Sinan Sözen³

Abstract

Background An accurate calculation of energy expenditure (REE) is necessary for estimating energy needs in malign prostate cancer. The purpose of this research was to evaluate the accuracy of the established novel equation for predicting REE in malign and benign prostate patients versus the accuracy of the previously used predictive equations based on REE measured by indirect calorimetry.

Methods The study was conducted as a cross-sectional case-control study and between December 2020 and May 2021 with 40 individuals over the age of 40 who applied to the Urology Clinic of Gazi University Faculty of Medicine. Subjects with 41 malign prostate and 42 benign prostate patients were both over the age of 40 (65.3 ± 6.30 years) and recruited for the study. Cosmed-FitMate GS Indirect Calorimetry with Canopyhood (Rome, Italy) was used to measure REE. A full body composition analysis and anthropometric measurements were taken. Clinical trial number: Not applicable.

Results Malign prostate group PSA Total and measured REE values (4.93 ± 5.44 ng/ml, 1722.9 ± 272.69 kcal/d, respectively) were statistically significantly higher than benign group (1.76 ± 0.73 ng/ml, 1670.5 ± 266.76 kcal/d, respectively) ($p = 0.022$). Malign prostate group (MPG) and benign prostate group (BPG) have the highest percentage of the accurate prediction value of Eq. 80.9% (novel equation MPG) and 64.2% (novel equation BPG). The bias of the equations varied from -36.5% (Barcellos II Equation) to 19.2% (Mifflin-St. Jeor equation) for the malign prostate group and varied from -41.1% (Barcellos II Equation) to 17.7% (Mifflin-St. Jeor equation) in the benign prostate group. The smallest root mean squared error (RMSE) values in the malign and benign prostate groups were novel equation MPG (149 kcal/d) and novel equation BPG (202 kcal/d). The new specific equation for malign prostate cancer: $REE = 3192,258 + (208,326 * \text{body weight (WT)}) - (20,285 * \text{height (HT)}) - (187,549 * \text{fat free mass (FFM)}) - (203,214 * \text{fat mass (FM)}) + (4,194 * \text{prostate specific antigen total (PSAT)})$. The new specific equation for the benign prostate group is $REE = 615,922 + (13,094 * \text{WT})$. Bland-Altman plots reveal an equally random distribution of novel equations in the malign and benign prostate groups.

Conclusions Previously established prediction equations for REE may be inconsistent. Utilising the PSAT parameter, we formulated novel energy prediction equations specific to prostate cancer. In any case, the novel predictive equations enable clinicians to estimate REE in people with malign and benign prostate groups with sufficient and most acceptable accuracy.

Keywords Prostate cancer, Resting energy expenditure, Indirect calorimetry, Novel predictive equations

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Background

An increased risk of prostate cancer is discussed in relation to an excessive energy intake in comparison to energy expenditure [1]. Total energy expenditure is defined as the sum of all energy consumed by an organism over the course of a day [2]. The majority of energy needs are met by basal/resting metabolic rate (BMR/REE), which accounts for roughly 60–70% of total energy expenditure [3]. Researchers have linked inaccurate estimates of total energy requirements to reduced physical performance and metabolic response, fatigue, increased inflammation, weight loss, malnutrition, and even obesity [4]. Prostate cancer patients may experience metabolic changes that alter their overall energy expenditure depending on the stage and type of the disease. The significance of resting energy expenditure in an individual's total energy expenditure is increased by the advanced age and declining physical activity of cancer patients [5].

For the patients' survival and mobilization, it was critical to receive adequate and balanced nutrition tailored to their particular cancer [6]. The accuracy of using predictive equations to estimate the energy requirements of patients with various cancer types may be low due to their fluctuating energy metabolism and metabolic variations [7]. As a result, whenever possible, the primary strategy should be to evaluate each patient individually while measuring energy expenditure via indirect calorimetry. It will be more accurate to plan a unique nutrition therapy program by measuring REE with indirect calorimetry for the patient's treatment and essential comfort in order to prevent negative energy balance in those

with prostate cancer [8]. Since the 1980's, researchers have developed equations to predict REE across all age groups. Researchers have developed several REE prediction equations for both healthy and clinical use, such as the Harrise-Benedict (1919), Schofield (1985), Ireton Jones (2002), Mifflin-St. Jeor (1990), Barcellos Equation II (2020), Cunningham (1991), Owen (1986), Wang (2000), IOM (2004), Henry (2004), and 21 kcal/kg/d Silver (2013) models. Many studies have evaluated the accuracy of the resting energy expenditure prediction equations in different patient groups [9, 10]. This study discussed the use of previous predictive equations shown in Table 1 in the malign and benign prostate groups. The gold standard for measuring energy expenditure via pulmonary gas exchanges is indirect calorimetry (IC). It's a non-invasive method that improves clinical outcomes by tailoring nutritional support prescriptions to patients' individual metabolic requirements [11]. Indirect calorimetric methods are more challenging to implement on a large scale due to the higher cost of measurement equipment and the need for trained personnel [12]. Other indirect measuring devices were difficult for cancer patients to use because of their mouthpieces and nasal designs. Portable indirect measurement tools, such as those with a Canopyhood rather than a face mask, are ideal when it comes to comfort and ease of measurement [13]. Indirect calorimetric measurement values were the dependent variable, while demographics (age, gender, ethnicity), anthropometrics (weight, height), and body composition are the independent variables in these equations (adipose tissue, lean tissue). Similar to the regression analysis-based equations,

Table 1 Predictive equations for REE in malign and benign prostate group used in the present study

Author and Year	Gender	Age (years)	Predictive Equation for REE	Note
HarriseBenedict, 1919	Male	-	$\text{kcal/d: } 66.4730 + (13.7516\text{WT}) + (5.0033 \text{ HT}) - (6.7550 \text{ AGE})$	WT: kg, HT: cm, AGE: years
Schofield, 1985	Male	30–60	$\text{kcal/d: } ((0.048 * \text{WT} + 3.653) * 239)$	WT: kg,
IretoneJones, 2002	All	-	$\text{kcal/d: } 1784 - (11 \text{ AGE}) + (5 \text{ WT}) + (244 \text{ SEX}) + (239\text{T}) + (804\text{B})$	WT: kg AGE: years SEX: Male:0, Female:1 T: trauma (absence : 0 and presence : 1) B: burnt (absence : 0 and presence : 1)
Mifflin-St.Jeor, 1990	Male	-	$\text{kcal/d: } (10 * \text{WT}) + (6.25 * \text{HT}) - (5 * \text{AGE}) + 5$	WT: kg, HT: cm, AGE: years
Barcellos Equation II, 2020	All	-	$\text{kcal/d: } 58(\text{MUAC}) + 621.4(\text{SEX}) - 425(\text{O}) - 19$	MUAC: mid-upper arm circumference SEX: Male:0, Female:1 O: obesity (0: BMI < 30 and 1: BMI ≥ 30 kg/m ²).
Cunningham1, 1991	All	18–65	$\text{kcal/d: } 370 + 21.6 * \text{FM}$	FM: kg
Owen, 1986	Male	18–65	$\text{kcal/d: } 879 + 10.2 * \text{WT}$	WT: kg,
Wang, 2000	All	18–65	$\text{kcal/d: } 24.6 * \text{FFM} + 175$	FFM: kg
IOM, 2004	Male	-	$\text{kcal/d: } 293 - (3.8 * \text{AGE}) + (456.4 * \text{HT}) + (10.12 * \text{WT})$	WT: kg, HT: cm, AGE: years
Henry, 2004	Male	30–60	$\text{kcal/d: Men age } 30\text{--}60 \text{ years: } 11.4 \times \text{WT} + 541 \times \text{HT} - 137$	HT: meters
height and weight		> 60	$\text{kcal/d: Men age } > 60 \text{ years: } 11.4 \times \text{WT} + 541 \times \text{HT} - 256$	
21 kcal/kg/d Silver, 2013	All	-	$\text{kcal/d: } 21 \times \text{WT}$	WT: kg

WT Weight, HT Height, FM Fat mass

these equations were developed using data collected from the population of healthy people at large to provide fast and easy solutions and the use of predictive equations in REE predictions has become widespread [14].

In conclusion researchers developed a number of equations in healthy cancer populations to determine REE for cancer patients. But there was still no agreement on what the best equation was for determining REE for different types of cancer [9, 10, 15]. Some studies examining the accuracy of REE prediction equations have concluded that current equations are not providing valid and accurate predictions in cancer patients [9, 16, 17]. The aim of the present study was to establish a novel REE equation for comparison with previous prediction equations in patients with malign and benign prostate disease using resting energy expenditure (REE) measured with the gold standard indirect calorimetry model (FitMate GS with canopyhood).

Methods

Ethical Standards

The Gazi University Faculty of Medicine Clinical Research Ethics Committee issued decision number 4 on 7 April 2020, approving the study. All patients signed informed consent, and the Declaration of Helsinki guided the conduct of this study.

The study's design and participants

The study was conducted between December 2020 and May 2021 with 40 individuals over the age of 40 who applied to the Urology Clinic of Gazi University Faculty of Medicine, with new diagnosis malign prostate cancer according to the pathology result and new diagnosis benign prostate cancer in the pathology result. In order to measure REE in individuals with malign and benign prostate cancer by the indirect calorimetry method, compare with REE values estimated by equations and develop the most appropriate equation for this group. The study recruited 83 volunteers aged over 40 (65.3 ± 6.30 years) (41 malign prostate cancer and 42 benign prostate cancer).

The inclusion criteria were being over the age of 40, male, having pathology results indicating either prostate cancer (malign prostate tissue) or benign prostate tissue (without prostate cancer), and not having undergone surgical intervention. The exclusion criteria included having endocrine and metabolic disorders; chronic kidney and liver disease; sleep disorders; psychiatric and cognitive disorders; heart failure; respiratory diseases such as asthma, influenza, and colds; regular medication; and having received chemotherapy and radiation during all measurements. The flow chart of the study is presented in Fig. 1.

Anthropometric measurements and body composition analysis

Anthropometric measurements and body composition analysis were performed by the researcher, who is a specialist dietitian, in the early morning hours after at least 8 h of night fasting. The researcher used the TANITA BC 601 to measure body weight and analyse body composition, including fat mass, percentage fat, and fat-free mass (FFM). The scale's specifications include a frequency measurement range of 50 kHz, a current measurement range of 100 μ A, and a voltage measurement range of 150–1200 $^{\circ}$ C. We measured the height (cm) with the feet close together and the head at the Frankfort plane using a 0.1 cm sensitive portable stadiometer. We recorded an individual's waist circumference (in centimetres) to the nearest 0.1 centimetre by placing a nonelastic tape measure midway between the lowest rib border margin and the iliac crest at the end of a normal expiration, ensuring the tape did not compress the skin.

Resting energy expenditure

The Fitmate GS measures VO_2 consumption and calculates the RMR by estimating VCO_2 production from a fixed RQ of 0.85 based on the abbreviated Weir equation, as it does not contain a VCO_2 sensor [18]. Resting energy expenditure measurements were made by using the Cosmed-FitMate GS Indirect Calorimetry with Canopyhood (It is an advanced metabolic measurement system option) (Rome, Italy). FitMate is a reliable and valid system for measuring RMR in many studies [19, 20]. In healthy adults and outpatients, Fitmate GS with Canopyhood has been validated against the gold standard device DELTATRAC and Douglas bag [21–23]. Routine procedures for measuring RMR were followed. Calibration was carried out before each measurement in accordance with the manufacturer's instructions. A Canopyhood was then placed over the patient's head. When the VO_2 coefficient of variation was less than 10%, a steady state was achieved. After the instrument stabilized for 15 min, RMR readings were taken. During the canopyhood measurement, outpatients were lying in a supine position for 15 min and instructed to limit movement, talk, and avoid sleeping [24]. The measurements were made during the early morning period between 8.00am and 10.00am in the morning after at least 8 h of night hunger. The participant did not engage in heavy exercise and consumed their usual diet in the day leading up to the REE measurement. Specifically, the method developed by Compther et al. (2006) [25].

As a result, FitMate GS with Canopyhood REE (kcal/day), VO_2 (ml/min), Vp (l/min), and FeO_2 (%) measurements were evaluated.

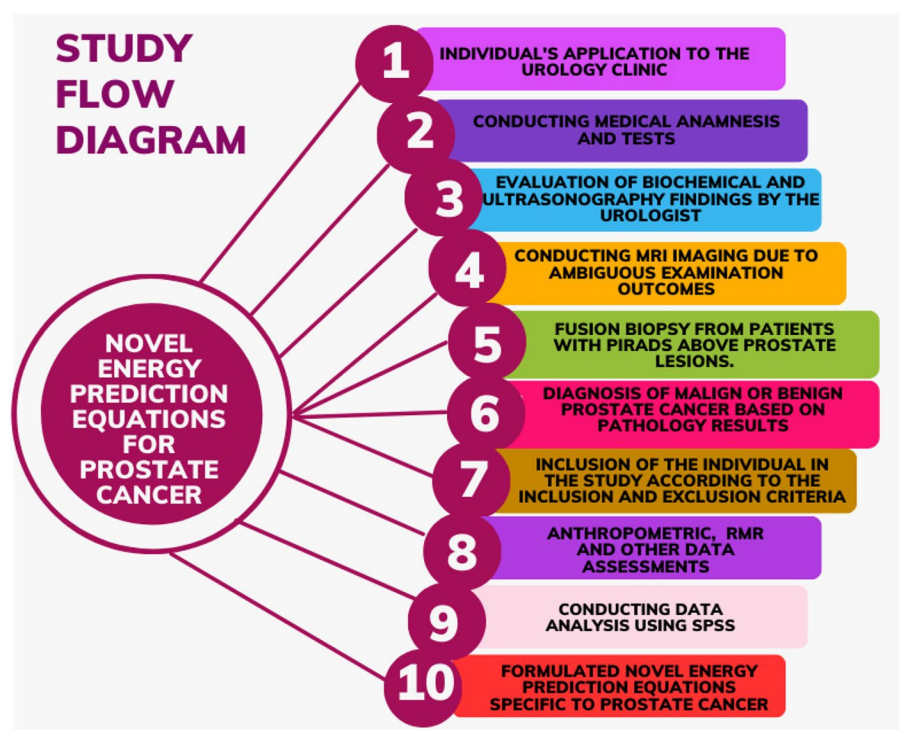


Fig. 1 Flow diagram of the study

Resting energy expenditure prediction equations

Eleven different REE calculation equations were used to evaluate the accuracy of the measured and calculated REE values. The study included these equations: Har-riseBenedict-1919, Schofield-1985, Iretone Jones-2002, Mifflin-St. Jean-1990, Barcellos Equation II-2020, Cunningham-1991, Owen-1986, Wang-2000, Institutes of Medicine (IOM)–2004, Henry-2004, and 21 kcal/kg/day (Table 1).

Statistical Analysis

All statistical analyses were performed using SPSS (The Statistical Package for Social Sciences) Version 22.0 (SPSS Inc., Chicago, IL, USA). Data were presented as mean and standard deviation (SD). We evaluated the normality of the data distribution using the Shapiro-Wilk or tests. We used the two-tailed Student's t-test to compare the mean values of normally distributed variables between the malign and benign prostate groups. We utilized the Mann-Whitney U test to contrast the non-normally distributed malign and benign prostate groups. We statistically analysed the measured REE-related variables using simple linear regression. We used measured REE in a stepwise multiple regression analysis (backward selection technique), integrating all factors with a p value in the simple linear regression analysis of less than 0.20.

We determined the accuracy of the predictive equations for both individuals and the entire population. We determined the accuracy at the group level by calculating the average percentage difference between the predicted and measured REE. We evaluated individual accuracy by calculating the proportion of patients whose predicted REE fell within less than 10% of their measured REE. We determined that accurate predictions ranged from 90 to 110% of the measured REE, classifying values below 90% as an underprediction and values above 110% as a verprediction. We calculated this model's RMSE to find a more accurate representation of its prediction in our data set. Furthermore, we calculated the bias (mean difference and standard deviation of the differences), along with the 95% confidence intervals, to assess the level of agreement between indirect calorimetry and the 11 equations of interest. In this study, we used a Bland-Altman plot and analysis to compare patients with malign and benign prostate cancer who measured their REE using an indirect calorimeter with those who calculated their REE using different predictive equations. We displayed the mean difference and the limits of agreement as horizontal lines in Bland-Altman plots of individuals with cancerous and noncancerous prostates. We determined the limits of agreement by taking the mean difference plus or minus two times the standard deviation of the differences. We

Table 2 The main characteristics of subjects

Variables	Malign prostate patient group (n:41)	Benign prostate patient group (n:42)
	Mean ± SD	Mean ± SD
Age (year)	66.0±6.64	64.5±5.94
Weight (kg)	82.0±12.50	80.5±12.72
Height (cm)	170.0±5.12	168.2±5.24
BMI (kg/m ²)	28.3±3.99	28.5±4.44
Percent of body fat (%)	26.8±4.97	26.7±6.27
FM (kg)	22.3±6.80	22.0±7.86
FFM (kg)	56.8±6.67	55.6±6.80
PSA Total (ng/ml)**	4.93±5.44	1.76±0.73
Measured REE (kcal/day) **	1722.9±272.65	1670.7±266.76
VO ₂ (ml/min)	250.2±40.70	240.4±40.92
Vp (l/min)	32.5±5.37	33.0±6.50
FeO ₂ (%)	19.8±0.13	19.9±0.13
Tumor Grade (%)		
1	9 (22,0)	-
2	6 (14,5)	-
3	9 (22,0)	-
4	13 (31,7)	-
5	4 (9,8)	-
D'Amico risk classification (%)		
Low Risk	10 (24,4)	-
Medium Risk	14 (34,1)	-
High Risk	17 (41,5)	-

BMI Body Mass Index, FM Fat Mass, FFM Fat Free Mass, PSA Prostate Specific Antigen, REE Resting Energy Expenditure

** The difference between male and female groups were found statistically significant ($p < 0.05$)

determined significance in all cases using a two-tailed p value of less than 0.05.

Results

The primary characteristics of the prostate subjects are shown in Table 2. The mean age, body weight, BMI, fat percentage, body fat mass, and FFM were not significantly different between the two groups ($p > 0.05$). It was found that the PSA Total (PSAT) and measured REE values for the malign prostate patient group were significantly higher than those for the benign group (1.76 ± 0.73 ng/ml and 1670.5 ± 266.76 kcal/d, respectively) ($p < 0.05$).

Two standard deviations (SDs) above and below the mean are shown by the dashed lines (limits of agreement).

Table 3 shows measured and calculated REE values of malign and benign prostate groups. In our comparison of the Canopy hood measurement with the REE prediction equations for the malign and benign prostate

cancer groups the Novel Equation demonstrated superior results in predicting REE, as evidenced by the variables: predicted-measured REE kcal/d, standard deviation, accuracy percentage, under-prediction percentage, over-prediction percentage, bias percentage, maximum negative error percentage, maximum positive error percentage, and root mean square error. (Table 3).

Most equations showed a drift, indicating a systematic error: the larger range of the measured values, the greater discrepancy between the highest and lowest values (Tables 3 and 4). Differences, as well as lower and upper equalisation limits and malign and benign prostate group values calculated with different equations and measures using the direct calorimetric method, are shown in Bland-Altman plots (Figs. 1 and 2, respectively). Only the Owen equation of 21 kcal/kg/day and the novel equation-MPG were found to have a normally distributed sample of malignant prostate cancer subjects and were therefore approved for use based on Bland-Altman plots. However, only the equation of 21 kcal/kg/day and the Novel Equation-BPG showed a random distribution in prostate benign cancer subjects, so the other equations were deemed unsuitable for use in REE estimation (Fig. 3).

Development and Validation of the Novel REE Predictive Equations

At first, we treated REE as the dependent variable and each of the other variables listed in Table 4 as the independent variables, running a univariate regression for each independent variable on its own. Univariate regression analysis revealed that all factors, besides groups, were statistically significant.

Modelling and multiple regression analysis were performed on all relevant variables. The analysis variables were selected using the backwards method. In the end, the model included both body weight (WT), height (HT), fat-free mass (FFM), fat mass (FM), and prostate-specific antigen total (PSAT) as independent variables. Table 5 shows the outcomes of a multiple regression analysis.

We present the equation and results from Table V below.

Novel prediction equation for malign prostate patient

$$\begin{aligned}
 REE = & 3192,258 + (208,326 * WT) \\
 & - (20,285 * HT) - (187,549 * FFM) \\
 & - (203,214 * FM) + (4,194 * PSAT)
 \end{aligned}$$

Table 3 Evaluation of measured REE with different predictive equations malign and benign prostate group based on differences predicted-measured, SD of predictive REE, percentage of accuracy, under-prediction, over-prediction, bias, maximum negative error, maximum positive error, and RMSE

REE predictive equations	Difference predicted-measured REE kcal/d	SD	Accurate-prediction %	Under-prediction %	Over-prediction %	BIAS %	Maximum negative Error %	Maximum positive Error %	RMSE*
Malign prostate group (MPG)									
Harris Benedict	123	192	43.9	36.3	9.8	7.1	−16.6	22.3	226
Schofield	−91	194	60.9	2.4	36.7	−5.3	−43.0	13.8	212
IretoneJones	11	235	48.8	26.8	24.4	−0.6	−47.4	21.0	233
Mifflin-St.Jeor	330	198	26.8	-	73.2	19.2	−0.3	33.6	384
Barcellos Equation II	−630	288	7.3	-	92.7	−36.5	−103.2	4.4	691
Cunningham	125	196	56.1	39.0	4.9	7.2	−26.3	21.9	231
Owen,	11	199	58.5	19.5	22.0	−0.6	−36.8	18.9	197
Wang,	93	196	56.1	31.7	12.2	5.4	−29.5	20.6	215
IOM	74	197	53.7	31.7	14.6	4.3	−23.6	22.0	208
Henry	100	213	43.9	39.0	17.1	5.8	−21.5	23.8	234
21 kcal/kg/d	0.9	196	58.5	17.1	24.4	0.0	−28.2	15.5	194
New Equation MPG	0.6	151	80.9	7.0	12.1	0.0	−28.0	11.7	149
Benign prostate group (BPG)									
Harris Benedict	90	214	50.0	33.3	16.7	5.4	−31.7	27.2	230
Schofield	−126	209	57.1	4.8	38.1	−7.5	−66.8	12.2	242
IretoneJones	−49	234	54.8	14.2	31.0	−2.9	−66.6	15.2	237
Mifflin-St.Jeor	297	213	14.2	4.8	81.0	17.7	−18.2	35.4	364
Barcellos Equation II	−687	261	2.4	-	97.6	−41.1	−131.7	3.1	734
Cunningham	99	212	42.9	40.5	16.7	5.9	−45.5	20.7	231
Owen,	−25	211	61.9	14.3	23.8	−1.5	−58.8	17.3	210
Wang,	67	212	46.7	35.7	16.7	4.0	−49.0	18.8	220
IOM	39	211	59.5	23.8	16.7	2.3	−47.2	21.0	213
Henry	69	217	43.9	39.0	17.1	4.1	−39.8	24.9	226
21 kcal/kg/d	−21	231	50.0	23.8	26.2	−1.2	−34.2	22.4	229
New Equation BPG	−12	208	64.2	19.0	16.8	0.0	−49.0	19.9	202

REE Resting Energy Expenditure and BIAS: mean difference between measured and predicted, BPG Benign Prostate Group, MPG Malign prostate cancer group, IOM Institute of Medicine

*RMSE (kcal/d): Root mean squared error

Novel prediction equation for benign prostate patient

$$REE = 615,922 + (13,094 * WT)$$

Discussion

An accurate calculation of energy expenditure REE is necessary for estimating energy needs in prostate cancer. The purpose of this research was to evaluate the accuracy of the established novel equation for predicting REE in malign and benign prostate patients versus the accuracy of the previously used predictive equations based on REE measured by indirect calorimetry. In the present study, findings demonstrated that the previous equations used to predict the REEs of adults with prostate cancer (over

the age of 40) show a large disparity between the two, contain a large number of errors, and frequently result in over- or underestimating REE.

Cancer-induced metabolic alterations can influence both REE and energy intake, potentially resulting in either a negative or positive energy balance. Due to the challenges in directly measuring TEE, REE the predominant component of TEE, is frequently assessed to estimate energy consumption [26]. Resting energy expenditure is varied in cancer and may be affected by alterations in tumour burden, systemic inflammation, and body composition. The tumor's energetic requirement can significantly influence energy metabolism, particularly in the context of metastases [27]. In cancer patients, additional energy expenditure is estimated to be 100–1400 kcal/day,

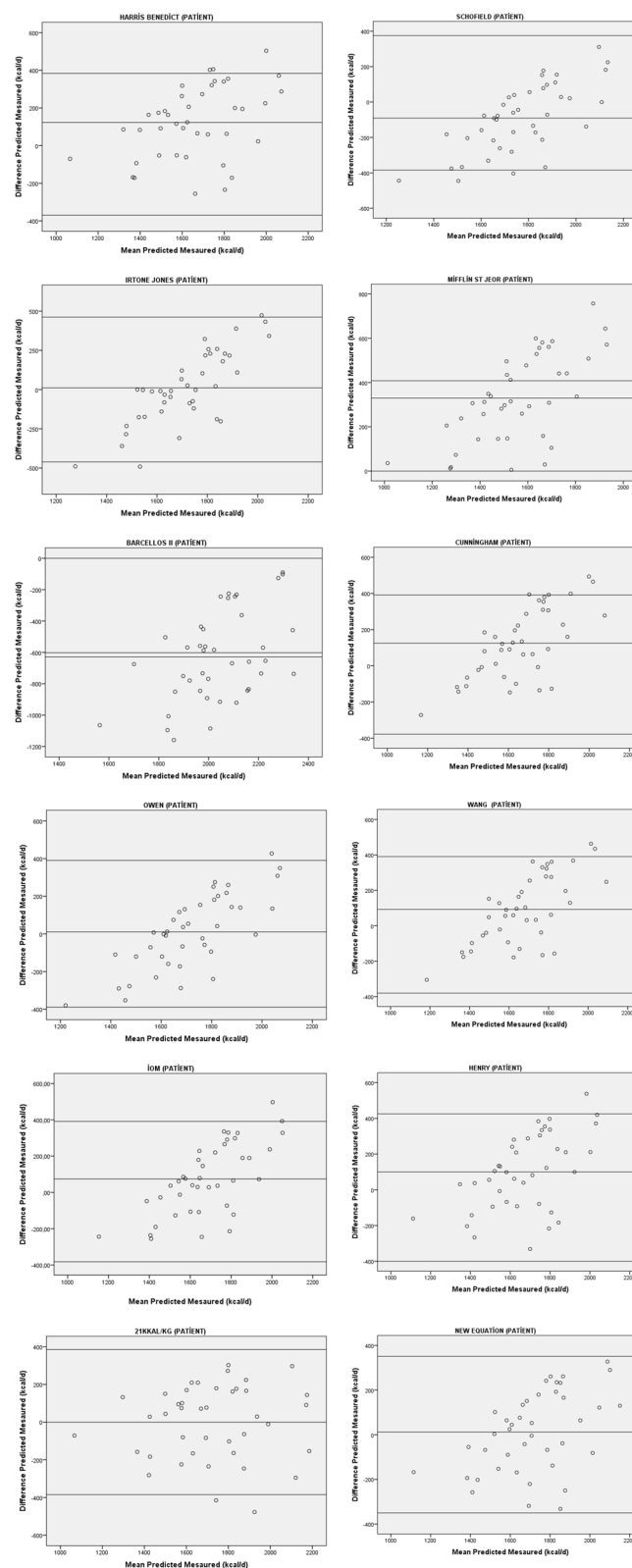


Fig. 2 Bland-Altman a scatter plot comparing the 11 different predictive equations for REE using data from a group of prostate cancer patients who were measured using an indirect calorimeter with a canopy. Two standard deviations (SDs) above and below the mean are shown by the dashed lines (limits of agreement)

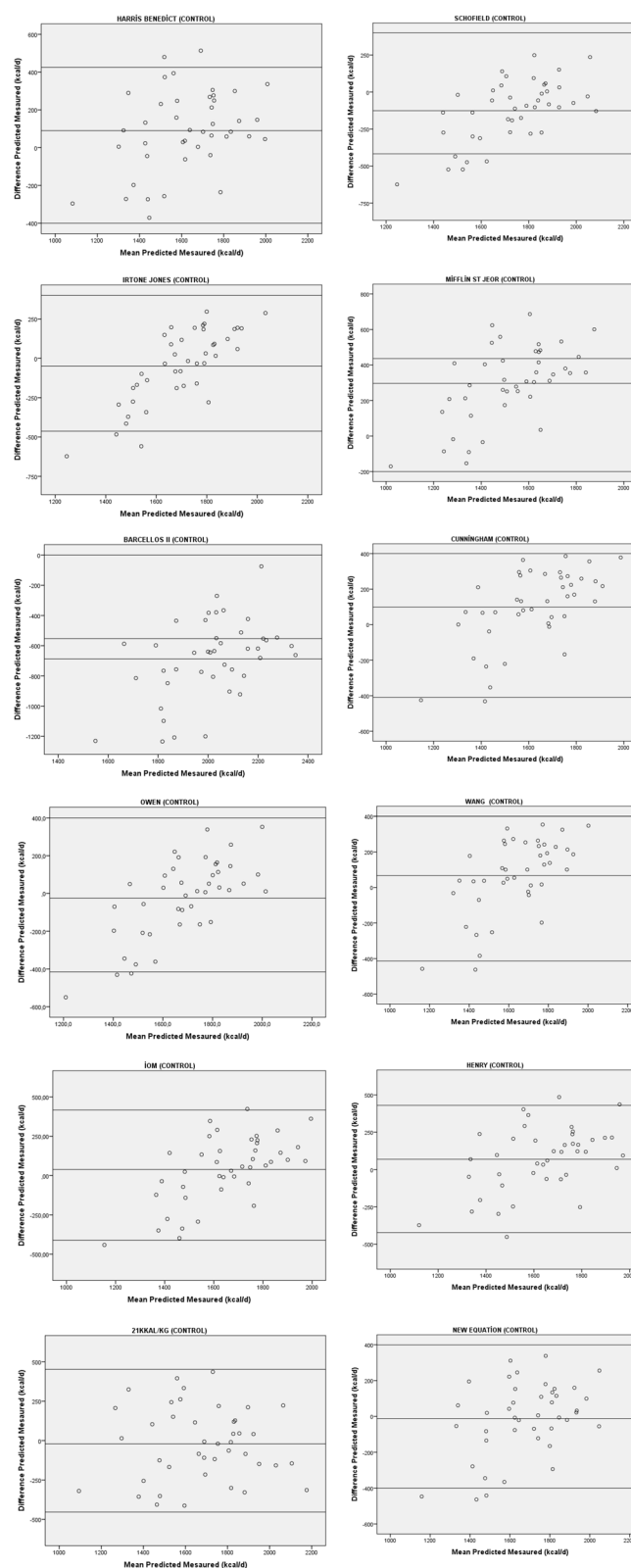


Fig. 3 Bland-Altman a scatter plot comparing the 11 different predictive equations for REE using data from a group of prostate cancer control group who were measured using an indirect calorimeter with a canopy. Two standard deviations (SDs) above and below the mean are shown by the dashed lines (limits of agreement)

Table 4 Result of malign and benign prostate group univariate regression analysis

Variable malign prostate group	Coefficients (95% CI)		Adjusted R ²	p value
Age (years)	−4.650	(−17.860; 8.559)	0.000	0.481
Body Weight (kg)	15.906	(11.098; 20.714)	0.523	< 0.001
Height (cm)	17.248	(0.932; 33.564)	0.082	0.039
Waist circumference (cm)	16.811	(8.618; 25.003)	0.306	< 0.001
BMI (kg/m ²)	45.999	(29.701; 62.298)	0.411	< 0.001
FFM (kg)	29.335	(20.124; 38.546)	0.503	< 0.001
Fat Mass (kg)	21.894	(11.035; 32.752)	0.281	< 0.001
Body Fat Percentage (%)	16.283	(−0.681; 33.247)	0.065	0.059
PSA Total (ng/ml)	−1.405	(−3.691; 0.881)	0.013	0.221
Variable benign prostate group	Coefficients (95% CI)		Adjusted R ²	p value
Age (years)	−6.270	(−20.463; 7.922)	0.000	0.377
Body Weight (kg)	13.094	(7.864; 18.324)	0.376	< 0.001
Height (cm)	9.725	(−6.227; 25.677)	0.012	0.225
Waist circumference (cm)	11.806	(4.644; 18.948)	0.218	0.002
BMI (kg/m ²)	33.961	(18.169; 49.761)	0.304	< 0.001
FFM (kg)	23.902	(13.964; 33.839)	0.356	< 0.001
Fat Mass (kg)	15.516	(5.870; 25.162)	0.189	0.002
Body Fat Percentage (%)	11.971	(−1.070; 25.012)	0.056	0.071
PSA Total (ng/ml)	9.112	(−8.284; 26.508)	0.003	0.296

Table 5 Result of malign and benign prostate group canopy multiple regression analysis

Variable malign prostate group	Coefficients (95% CI)		p value
Constant	3192,258	(909,754; 5474,671)	0.007
WT	208,326	(103,911; 312,741)	< 0.001
HT	−20,285	(−35,329; 5,042)	0.011
FFM	−187,549	(−295,044; 80,754)	0.001
FM	−203,241	(−309,408; 97,074)	< 0.001
PSAT	4,194	(1,654; 6,818)	0.003
Variable benign prostate group	Coefficients (95% CI)		p value
Constant	615,922	(189,491; 1042,353)	0.006
WT	13,094	(7,864; 18,324)	< 0.001

WT Body Weight, FM Fat Mass, HT Height and PSAT PSA Total

Adjusted R² for the model malign prostate cancer patient: 0.548

Adjusted R² for the model benign prostate cancer patient: 0.375

depending on tumor burden [26]. The factors of fat-free mass (FFM), body size, age, gender, and body fat, among others, are the most important in determining resting metabolic rate [28]. In another study, study emphasised the importance of total body fat mass, fat-free mass, and abdominal adiposity in determining RMR [29]. The modified metabolic processes induced by a high-calorie diet and a sedentary lifestyle can result in obesity, diabetes, dyslipidaemia, hypertension, and perhaps MetS, accompanied by alterations in REE and TEE expenditure, which may correlate with an elevated risk of PCa diagnosis and

severity [30]. Emerging research indicates that adipocytes generated from escalating obesity serve as a lipid reservoir for neighbouring prostate cancer cells [31]. In our study, people were classified as overweight based on their BMI results, and their body fat percentages above typical thresholds. While it is believed that elevated fat mass influences resting energy expenditure (REE), the recently diagnosed status of the patients and their low tumour risk and stage classifications are considered to have a negligible impact on REE. Table 2 presents the subjects' primary characteristics, but no statistical significance was found.

This situation was thought to be related to the homogeneous distribution of the groups.

Metabolic anomalies that could lead to inaccuracies in the measurement of resting energy expenditure (REE) in cancer patients may influence the efficacy of REE estimation Eqs. [32–34]. When making nutritional recommendations for cancer patients, it is important to first determine whether or not their metabolism and energy expenditure have been altered [35]. With so many equations involved in estimating energy expenditure, it's easy to see how mistakes can add up over time, which can reduce the impact of the intervention. Consequently, the best equation for estimating REE has not yet been determined [36, 37]. Evaluation of FitMate GS with Canopyhood REE with different predictive equations in malign and benign prostate group values was presented in Table 3. An accurate prediction was defined as one that fell between 90% and 110% of the actual REE. Underprediction was defined as a prediction of less than 90%, and overprediction was defined as a prediction of more than 110%. It was found that the percentage of adult hospital patients whose REE were correctly predicted was low, ranging from 8 to 49% across all equations in a study [37]. Another study found that the accuracy of correctly predicted REE varied between 9.6% and 62% across all equations [38]. The study revealed that the REE measured by IC exhibited lower average discrepancies of +59 and +52 kcal when compared to Barcellos I and II, respectively; however, it also demonstrated broad limitations of agreement ranging from +1542 to -1424 kcal and +1429 to -1326 kcal, respectively [39]. In the present study (Tables 3 and 4) Upon comparing the unique energy predicting equation we derived with prior REE estimation equations, we believe that its validity and reliability are substantial.

Bias was calculated as the percentage disparity between the predicted and measured REE. It was found in a study that the REE from FitMate GS exhibited a fanning effect, with smaller REE values exhibiting a narrower spread of biases and a positive proportional bias being present. The FitMate GS showed little individual variation and high group precision because of its low bias [19]. As one study found in a sample of cancer patients, just over half had their REE predicted correctly using the Harris-Benedict, Owen et al., Mifflin et al., or 21 kcal/kg methods. Spread of bias was clearly visible for the group of cancer patients, with increasing REE values between measured REE and REE predicted by the equations of Cunningham et al. and Wang et al. The observed bias with REE predicted by the equation of Schofield showed a tendency toward underestimating measured REE with increasing REE values, but this trend was not statistically significant [35]. Using classical equations (Harris Benedict, Schofield, Ireton Jones, and Mifflin-St. Jeor), researchers found that the

mean of the measured REE was greater than the classical equations in a study of patients with digestive cancer [10]. Upon comparing the unique energy estimation equation we derived with the BIAS value and existing REE estimation equations, we conclude that the REE estimate demonstrates its optimality.

Numerous studies have verified the Schofield Eq. (1985), making it one of the most widely used equations to date. When applied to critically ill patients and the majority of patients overall, it was deemed inadequate for estimating REEs [40, 41]. Although not statistically significant, the bias observed with REE predicted from the equation of Schofield showed a tendency toward underestimation of measured REE with increasing REE values in a study on the determination of resting energy expenditure in patients receiving anticancer treatment [35]. Except for men over the age of 60, Henry and equations gave lower values than Schofield equations. Henry's equations were the most reliable in males [42]. One study highlighted the fact that the Schofield equation is most suitable for adults [43]. The relevance of measuring REE by indirect calorimetry in order to better adequately provide nutritional support to cancer patients is supported by the Barcellos equations, allowing for less predictive and more accurate mean REE estimation in cancer patients [10]. The results of this research showed that the Barcellos II equation is more accurate than the existing equations for estimating REEs. Patients in hospitals were less likely to develop malnutrition when REE was accurately estimated and used to guide nutritional intervention [44]. Cunningham proposed an alternative equation that takes into account the correlation between RMR and FFM. In a study involving both normal-weight and obese male subjects, served as the basis in equation [45]. In the study, Cunningham equation gave the last one in the estimation of REE of male individuals [46]. Similarly, the IOM equation, used for predicting the REEs was found to have low accuracy and high bias and RMSE values [14]. The result, related to the all equation, was presented in Tables 3 and 4. This is widely assumed to have its RMSE in racial and genetic predispositions. Many studies, have recommended that individual societies adopt the equations that have been tailored to their needs. We assert that the newly derived energy estimation equation will demonstrate a strong and significant correlation with all variables pertinent to the synthesis of rare earth element (REE) estimation, thereby yielding optimal REE results in individuals with prostate cancer (PCa) by incorporating disease-specific variables. Subsequent research utilising the unique energy equation will validate this concept.

Since none of the existing prediction equations were appropriate for a population of men with prostate cancer, in this study was developed a novel prediction equation.

Consistent with expectations, the novel equation found that WT, height, FFM, FM and PSA Total were the strongest predictors of REE, accounting for R^2 :54,8% of the variance in REE among men with malign prostate group and accounting for R^2 :37,5% of the variance in REE among men with benign prostate group in Table 5. The findings here corroborate those of other studies. This study's findings were consistent with those of a previous one, which also found that FM was a major factor in determining adults' REEs [47]. Genetics may also account for the variation in REE between populations, which is known to be linked to FM and WT. Since body composition equations are usually population-specific, they should be more appropriate for use as predictive equations for REE [48]. In our opinion, the information we gleaned from the outcomes of the malign and benign prostate group FitMate GS with Canopyhood multiple regression analysis will provide us with more precision in predicting the REE particular to this group of PSAT values, which is incorporated into the malign prostate group equation.

This study had some strengths and limitations. This is the first research to examine the REEs of patients with benign and malign prostate cancer as determined by indirect calorimetry. The current study is the initial step in evaluating REE using novel predictive equations in these groups. Our study shown strength through the strong association between age, body weight, height, BMI, percentage of fat mass and fat-free mass, tumour grade and stage, and PSAT, all of which were utilised in the RMR assessment of malign and benign prostate cancer patients and indicated significant correlations with changes in REE. Furthermore, the PSAT parameter, utilised in regression analysis, delineated the novel REE prediction equation. Furthermore, the utilisation of the gold standard for assessing energy expenditure, specifically the indirect calorimetry model (FitMate GS with canopy hood), in evaluating the resting metabolic rate of patients with malign and benign prostate cancer is another strength of our study. Notwithstanding these strengths, the G Power analysis indicated a low number of malign and benign patients, as assessed by the reviewer. The findings are representative of this sample population, and it would be advantageous to apply the equations created for prostate cancer patients in studies with larger samples. Furthermore, the absence of an advanced bioelectrical impedance device in our study precluded the acquisition of phase angle and body composition data, yet this limitation did not compromise the accuracy of the novel REE prediction equation. This could represent a limitation of our study.

Conclusion and future directions

In conclusion, this study demonstrated that there was substantial variation in REE estimation precision across the predictive equations. As a result, estimating REEs is necessary to optimize treatment and survival rates for people with prostate cancer. Our research was the first to synthesise a large number of REE predictive equations and use FitMate GS with Canopyhood to create a novel prediction equation specifically for malign and benign prostate cancer patients. When indirect calorimetry was unavailable, we recommended a novel prediction equation to accurately predict the REEs of prostate cancer. It would be practical to determine the energy requirement for treating malign and benign prostate cancer by using the novel developed equations in the prediction of REE in the clinic.

Abbreviations

BMR	Basal Metabolic Rate
FFM	Fat Free Mass
IOM	Institutes of Medicine
REE	Resting Energy Expenditure
RMSE	The root mean squared error
SD	Strandard Deviation
PSAT	Prostate Specific Antigen Total

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Authors' contributions

T.K.; investigation, conceptualization, data curation, formal analysis, methodology, writing - review & editing. N.A.T.; investigation, conceptualization, methodology, supervision, project administration. S.Y. and T.S.S.; supervision, review, and editing. All authors have read and agreed to the published version of the manuscript.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Gazi University Ethic Committie with decision number 4 on 7 April 2020. Clear explanations were provided for the parents with regard to the purpose of the study, after which written informed consent was obtained from all the parents in accordance with the Declaration of Helsinki (World Medical Association).

Consent for publication

Not applicable.

Competing interests

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