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Association between basal metabolic rate and body composition in patients attending Baghdad nutrition clinic, 2025

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Abstract

Background: Basal metabolic rate (BMR) represents the minimum energy required to sustain vital physiological functions, accounting for 60-70% of daily energy expenditure. Body composition, particularly fat-free mass, is a key determinant of BMR. Accurate assessment of BMR is essential for personalized nutrition and metabolic disorder management. Traditional BMR prediction equations often lack precision across diverse populations, leading to increased use of advanced tools such as bioelectrical impedance analysis (BIA). This study aimed to compare body composition by gender, investigate BMR relationships, and evaluate the influence of age, gender, BMI, and muscle mass on BMR.

Methods: A cross-sectional study was conducted at the Baghdad Nutrition Clinic between March and May 2025, involving 150 adults aged 18-65 undergoing nutritional assessment or weight management. Participants were systematically sampled every third patient after applying inclusion and exclusion criteria. Data collection included structured questionnaires, anthropometric measurements, and body composition analysis using the In Body 270 BIA device. Ethical approval and informed consent were obtained. Statistical analyses encompassed descriptive statistics, correlation assessments, and regression modeling to identify significant predictors of BMR.

Results: The study revealed significant gender differences in body composition, with males showing higher lean mass, skeletal muscle mass (SMM), and basal metabolic rate (BMR), while females had higher fat mass and BMI. BMR increased progressively with BMI and muscle score quartiles, reaching the highest values in obese and high-muscle-score groups. Although BMR and fat-free mass declined with age, these differences were not statistically significant. Correlation analysis showed that BMR was strongly associated with fat-free mass ($r = 0.891$), SMM ($r = 0.864$), and weight ($r = 0.822$). Regression analysis identified SMM, fat-free mass, skeletal muscle%, and male gender as the strongest positive predictors of BMR, while age had a negative effect.

Conclusions: This study confirms that BMR is chiefly influenced by skeletal muscle and fat-free mass, with notable gender differences. Males showed higher BMR due to greater muscle mass. Accurate body composition analysis is essential for reliable BMR estimation and individualized nutrition planning.

Keywords: BMR, body composition, muscle mass and bioelectrical impedance

Introductions

Basal metabolic rate (BMR) represents the minimum energy expenditure required to maintain basic physiological functions at rest, accounting for approximately 60-70% of total daily energy expenditure in healthy individuals [1]. Understanding the intricate relationship between BMR and body composition has become increasingly crucial in clinical nutrition practice, particularly as obesity and metabolic disorders continue to rise globally [2]. The accurate assessment of metabolic rate and its correlation with various body composition parameters provides essential insights for developing personalized nutritional interventions and therapeutic strategies.

Body composition, encompassing fat mass, fat-free mass, muscle mass, and bone density, significantly influences metabolic rate through multiple mechanisms [3]. Fat-free mass, primarily consisting of metabolically active tissues such as muscle, liver, and brain, demonstrates the strongest correlation with BMR, contributing approximately 15-30 kcal/kg/day to total energy expenditure [4]. Conversely, adipose tissue exhibits lower metabolic activity, typically contributing 2-5 kcal/kg/day, though recent research has highlighted the metabolic heterogeneity of different fat depots [5]. The clinical significance of BMR assessment extends beyond basic metabolic evaluation. Accurate BMR measurement serves as a cornerstone for determining appropriate caloric requirements in weight management programs, clinical nutrition therapy, and metabolic rehabilitation [6]. Also, alterations in BMR have been associated with various pathological conditions, including metabolic syndrome, diabetes mellitus, and cardiovascular disease, making it a valuable biomarker for metabolic health assessment [7, 8].

Contemporary research indicates that widely used BMR prediction equations, such as the Harris-Benedict and Mifflin-St Jeor formulas, often yield inaccuracies when applied to heterogeneous populations, especially those with abnormal body composition or metabolic disturbances [9]. In response, researchers have explored the development of population-specific equations and the incorporation of advanced body composition metrics to enhance predictive accuracy [10]. The advent of bioelectrical impedance analysis (BIA) has significantly improved the assessment of body composition, offering greater insight into the relationship between muscle mass, fat mass, and BMR [11].

The Iraqi population, with its distinctive genetic makeup, dietary customs, and lifestyle patterns, represents a group in which standard predictive models may not perform optimally, yet region-specific data remain scarce [12]. Cultural practices, including high carbohydrate consumption and traditional cooking methods, may further modulate metabolic rates and body composition in this demographic [13]. Advances in indirect calorimetry, particularly through modern metabolic carts using mixing chamber technology, have enhanced the accuracy and consistency of BMR measurements in clinical environments, allowing more detailed investigations into individual determinants of metabolism such as age, sex, hormonal fluctuations, and lean body mass [14, 15].

The relationship between BMR and body composition exhibits complex interactions influenced by multiple factors including age-related changes in muscle mass, hormonal fluctuations, and metabolic adaptations to dietary interventions [16]. Sarcopenia, characterized by progressive loss of muscle mass and function, significantly impacts BMR and represents a growing concern in aging populations [17]. Understanding these relationships becomes particularly important in clinical nutrition settings where accurate metabolic assessment guides therapeutic decision-making.

Study objectives

1. To describe and compare the anthropometric and body composition parameters between male and female participants.
2. To analyze the relationship between BMR and body composition variables (e.g., skeletal muscle mass, fat-free mass, BMI).
3. To examine the effects of age, gender, BMI categories, and muscle score quartiles on BMR.

Methodology

Study Design, Setting and Timing

This research utilized a cross-sectional observational study design conducted at the Baghdad Nutrition Clinic, a specialized healthcare facility offering nutritional assessment and weight management services. Data collection took place over three months, from March to May 2025, enabling access to a diverse patient population actively seeking nutritional counseling and metabolic evaluations within the clinic setting.

Study Population

- **Patient Characteristics**
- Adult patients attending Baghdad Nutrition Clinic for nutritional and weight management concerns
- Diverse demographic profile: males and females, various ages, BMI categories, and socioeconomic backgrounds

- **Inclusion Criteria**
- Adults aged 18-65 years
- Visiting for nutritional assessment or weight management consultation
- Able to provide informed consent
- Capable of undergoing body composition
- Willing to complete the study questionnaire

- **Exclusion Criteria**
- Pregnant or lactating women
- Women undergoing menstruation at the time of assessment
- Patients with acute infections, active cancer, or severe metabolic disorders. Those using metabolism-altering medications (e.g., thyroid hormones, corticosteroids)
- Individuals with physical disabilities preventing accurate measurements
- Patients with pacemakers, implanted metal devices, or electronic devices contraindicated for BIA
- Those who declined to provide informed consent.

Sample Size Calculation and Sampling Method

Based on a pilot study anticipating a correlation coefficient of r = 0.3, with 80% statistical power and a significance level (α) of 0.05, the required sample size was calculated using the formula:

$n = (Z_{\alpha/2} + Z_{\beta})^2 / (\frac{1}{2} \ln[(1 + r)/(1 - r)])^2 + 3$, resulting in a minimum of 150 participants. A systematic sampling technique was used to recruit participants from the Baghdad Nutrition Clinic, where every third patient attending during the study period was considered for inclusion after applying predefined eligibility criteria. This method ensured a representative sample of the clinic population while maintaining logistical feasibility. Patients were enrolled consecutively until the required sample size was met.

Data Collection Methods

Data collection was carried out using a structured questionnaire alongside standardized measurement protocols. The questionnaire consisted of two main sections:

- **Section 1: Demographic and Anthropometric Information:** This section gathered basic demographic and anthropometric data, including participant ID, age, gender, weight, height, waist circumference, and hip circumference.
- **Section 2: Body Composition:** This section recorded detailed body composition parameters, such as skeletal muscle mass (SMM), skeletal muscle percentage (SM%), body fat percentage, fat mass (FM), fat mass index (FMI), fat-free mass (FFM), fat-free mass index (FFMI), waist-hip ratio, BMR measurements, and muscle score.

Measurement Procedures

Anthropometric measurements were performed as follows: height was measured using a calibrated stadiometer to the nearest 0.1 cm, with participants standing barefoot. Waist circumference was measured at the narrowest point between the lower costal margin and the iliac crest using a non-stretchable measuring tape, while hip circumference was measured at the widest point over the buttocks. Body weight was measured using the same InBody device, with participants wearing minimal clothing to ensure accuracy.

Body composition was evaluated using BIA with the InBody 270 device, a non-invasive tool that estimates body composition by transmitting a low-level electrical current through the body.

Assessments were performed in the morning after an overnight fast, and participants were advised to stay well-hydrated and refrain from intense physical activity for at least 24 hours before the measurement. During the assessment, participants stood barefoot on the device and held hand electrodes, allowing the InBody 270 to generate detailed outputs including fat mass, fat-free mass, skeletal muscle mass, total body water, visceral fat level, and segmental muscle distribution. This procedure enabled accurate evaluation of each participant's nutritional and metabolic status.

Ethical Considerations

Ethical approval was obtained from the Supervising Committee of the Arab Board of Medical Specializations, Ministry of Health, prior to the commencement of the study. Written informed consent was obtained from all participants after a thorough explanation of the study's objectives, procedures, potential risks, and benefits. Participants were informed of their right to withdraw from the study at any time without any impact on their clinical care. Confidentiality was ensured by assigning unique identification codes to each participant, and all personal data were securely stored in password-protected electronic files accessible only to authorized research personnel.

Data Management and Statistical Analysis

Data management and statistical analysis were conducted using IBM SPSS Statistics version 26. Data cleaning and coding ensured accuracy and completeness before analysis. Descriptive statistics (means and standard deviations) summarized continuous variables, and independent t-tests and one-way ANOVA evaluated group differences by gender and age categories. Pearson correlation analysis assessed relationships between BMR and body composition parameters. Multiple linear regressions identified significant predictors of BMR, including skeletal muscle mass (SMM), fat-free mass, age, gender, and BMI. Significance was set at $p < 0.05$. Results revealed notable gender differences in body composition and BMR, strong positive correlations between BMR and lean mass variables, and regression confirmed SMM and fat-free mass as the most influential predictors of BMR after adjusting for other factors.

Results

Descriptive Statistics of Study Population by Gender

Table 1 presents the descriptive characteristics of the study population, stratified by gender and compared against normal reference values. The average age was comparable between males and females (35.1 vs. 33.8 years, $p = 0.612$). Males had significantly greater height and weight compared to females ($p < 0.001$ and $p = 0.028$, respectively), though both sexes exceeded normal weight ranges. BMI was significantly higher in females (34.1 ± 7.6) than in males (30.9 ± 5.8; $p = 0.010$), with both groups falling within the obese range. Skeletal muscle indicators, including SMM (34.8 vs. 22.7 kg) and skeletal muscle percentage (37.9% vs. 29.4%), were significantly higher in males ($p < 0.001$), aligning with gender-based physiological norms. Conversely, females had significantly higher body fat percentage (46.7% vs. 31.2%), fat mass, fat mass index, and lower fat-free mass and FFMI (all $p < 0.001$), reflecting greater adiposity. Males also had a higher BMR (1685.4 vs. 1291.7 kcal) and muscle score (65.8 vs. 57.8), both statistically significant ($p < 0.001$). Waist-hip ratio did not differ significantly between genders ($p = 0.147$), though both exceeded WHO-recommended thresholds. Overall, marked gender differences were observed in most body composition parameters, with males exhibiting higher lean mass and metabolic rates, while females showed higher fat mass and BMI.

Table 1: Descriptive Statistics of Study Population by Gender (with Normal Reference Values)

Variable	Total (n=150)	Males (n=46)	Females (n=104)	p-value*	Normal Reference Range
Age (years)	34.2 ± 13.8	35.1 ± 15.2	33.8 ± 13.2	0.612	18-65 years
Height (cm)	161.1 ± 9.1	172.4 ± 6.8	156.4 ± 5.9	<0.001	M: 165-180; F: 150-170
Weight (kg)	86.2 ± 21.4	91.8 ± 19.8	83.7 ± 21.9	0.028	M: 60-90; F: 50-75
BMI (kg/m²)	33.1 ± 7.2	30.9 ± 5.8	34.1 ± 7.6	0.010	18.5-24.9 (normal range)
SMM (kg)	26.4 ± 6.2	34.8 ± 4.9	22.7 ± 3.8	<0.001	M: 33-39; F: 21-26
Skeletal Muscle (%)	32.1 ± 6.3	37.9 ± 4.8	29.4 ± 5.4	<0.001	M: 33-39%; F: 24-30%
Body Fat (%)	42.1 ± 10.8	31.2 ± 7.9	46.7 ± 8.6	<0.001	M: 10-20%; F: 20-30%
Fat Mass (kg)	36.8 ± 17.2	29.1 ± 12.8	40.2 ± 18.1	<0.001	M: 8-20; F: 15-30
Fat Mass Index	14.1 ± 5.8	9.8 ± 3.2	16.2 ± 5.9	<0.001	M: 4-8; F: 6-11
Fat Free Mass (kg)	49.4 ± 12.3	62.7 ± 8.9	43.5 ± 7.8	<0.001	M: 50-70; F: 35-55
FFMI	19.0 ± 2.8	21.1 ± 2.2	17.8 ± 2.4	<0.001	M: 18-22; F: 15-19
Waist-Hip Ratio	0.97 ± 0.08	0.98 ± 0.08	0.96 ± 0.08	0.147	M: <0.90; F: <0.85 (WHO standards)
BMR (kcal)	1420.8 ± 208.7	1685.4 ± 145.2	1291.7 ± 128.9	<0.001	M: 1600-1800; F: 1200-1500 (approximate)
Muscle Score	60.4 ± 9.8	65.8 ± 8.7	57.8 ± 9.5	<0.001	Not standardized device-specific

*Independent t-test for continuous variables Data presented as mean ± standard deviation

Age Group Analysis

In table 2, age group analysis revealed a gradual decline in BMR and fat-free mass with increasing age. The youngest group (18-29 years) demonstrated the highest BMR (1456.2 ± 215.4 kcal), fat-free mass (51.8 ± 13.2 kg), and muscle score (62.4 ± 9.1), whereas the oldest group (≥ 60 years) exhibited the lowest BMR (1365.8 ± 176.2 kcal) and fat-free mass (45.8 ± 9.8 kg), though a slightly higher muscle score (64.2 ± 8.7). Despite these observed trends, statistical analysis using one-way ANOVA showed no significant differences across age groups for BMR ($p = 0.423$), fat-free mass ($p = 0.312$), or muscle score ($p = 0.458$), suggesting that within this sample, age did not substantially influence BMR once lean mass was accounted for.

Table 2: Age Group Analysis in BMR, Fat-Free Mass, and Muscle Score

Age Group	N (%)	BMR (kcal) (MEAN ± SD)	Fat Free Mass (kg) (MEAN ± SD)	Muscle Score (MEAN ± SD)
18-29 years	42 (28.0)	1456.2 ± 215.4	51.8 ± 13.2	62.4 ± 9.1
30-39 years	38 (25.3)	1425.8 ± 198.6	49.1 ± 11.8	59.7 ± 10.2
40-49 years	35 (23.3)	1418.9 ± 201.3	48.6 ± 12.1	58.9 ± 9.8
50-59 years	23 (15.4)	1392.1 ± 189.4	47.2 ± 10.9	58.1 ± 9.4
≥ 60 years	12 (8.0)	1365.8 ± 176.2	45.8 ± 9.8	64.2 ± 8.7
p-value*	-	0.423	0.312	0.458

*One-way ANOVA

BMR Variation across BMI Categories

Table 3 shows the variation in BMR across different BMI categories among the study participants. Out of the total sample, 12% were in the normal BMI range (18.5-24.9) with a mean BMR of 1334.33 ± 178.44 kcal, while 20% were overweight (BMI 25-29.9) with a higher mean BMR of 1424.2 ± 181.91 kcal. The largest group was Obesity I (BMI 30-34.9), comprising 36% of participants, with a mean BMR of 1436.56 ± 234.17 kcal. Participants in Obesity II (BMI 35-39.9) and Obesity III (BMI ≥ 40) categories accounted for 18.7% and 13.3%, respectively, showing the highest mean BMR values of 1508.07 ± 235.12 kcal and 1530.0 ± 99.82 kcal. These results indicate a clear increasing trend in BMR with rising BMI levels.

Table 3: BMR Variation across BMI Categories among Study Participants

BMI Category	RANGE (KG/M²)	N (%)	BMR (MEAN ± SD)
Normal	(18.5-24.9)	18 (12.0)	1334.33 ± 178.44
Overweight	(25-29.9)	30 (20.0)	1424.2 ± 181.91
Obesity I	(30-34.9)	54 (36.0)	1436.56 ± 234.17
Obesity II	(35-39.9)	28 (18.7)	1508.07 ± 235.12
Obesity III	(≥ 40)	20 (13.3)	1530.0 ± 99.82

BMR across Muscle Score Quartiles

Table 4 demonstrates a clear positive trend in Basal Metabolic Rate (BMR), Skeletal Muscle Percentage (SM%), and Skeletal Muscle Mass (SMM) across increasing quartiles of muscle score in the study population. Participants in the highest quartile (Q4) had the highest mean BMR (1537.82 kcal), SM% (40.2%), and SMM (33.7 kg), while those in the lowest quartile (Q1) had the lowest values for all three parameters (BMR = 1389.12 kcal, SM% = 27.1%, SMM = 20.1 kg), with the differences in BMR being statistically significant ($p < 0.001$). Gender-stratified data also revealed that both SM% and SMM increased progressively in males and females with higher muscle scores. For example, male SMM rose from 27.8 kg in Q1 to 38.7 kg in Q4, and female SMM increased from 18.3 kg to 29.1 kg. Similarly, male SM% increased from 33.2% in Q1 to 43.5% in Q4, while female SM% rose from 24.1% to 36.1%. These findings highlight a strong association between muscle score and key body composition parameters, particularly emphasizing that higher muscle score correlates with greater muscle mass and metabolic rate in both genders.

Table 4: Distribution of BMR, Skeletal Muscle Percentage (SM%), and Skeletal Muscle Mass (SMM) across Muscle Score Quartiles in the Study Population

Muscle Score Quartile	N (%)	BMR (Mean ± SD, kcal)	S M% (Mean ± SD)	SMM (kg) (Mean ± SD)	Male SM% (Mean ± SD)	Male SMM (kg) (Mean ± SD)	Female SM% (Mean ± SD)	Female SMM (kg) (Mean ± SD)	p-value (BMR)
Q1 (Lowest) SM% =27-31	44 (29.3%)	1389.12 ± 199.46	27.1 ± 4.2	20.1 ± 3.5	33.2 ± 3.8	27.8 ± 3.9	24.1 ± 3.6	18.3 ± 2.8	<0.001
Q2 SM% =31-35	32 (21.3%)	1416.4 ± 235.29	31.4 ± 3.9	24.5 ± 4.0	36.8 ± 3.6	31.5 ± 4.1	28.2 ± 3.7	21.9 ± 3.1	
Q3 SM% =35-40	40 (26.7%)	1448.86 ± 139.84	35.7 ± 4.1	28.9 ± 4.3	39.9 ± 3.9	34.9 ± 4.5	32.4 ± 3.5	25.4 ± 3.2	
Q4 (Highest) SM% = 40+	34 (22.7%)	1537.82 ± 241.38	40.2 ± 4.6	33.7 ± 4.7	43.5 ± 4.1	38.7 ± 4.8	36.1 ± 3.8	29.1 ± 3.7	

Correlation Analysis between BMR and Body Composition Variables

Table 5 shows significant correlations between BMR and body composition variables. BMR had a very strong positive correlation with fat-free mass ($r = 0.891$), skeletal muscle mass ($r = 0.864$), and weight ($r = 0.822$), all with $p < 0.001$. Strong correlations were found with height ($r = 0.758$) and FFMI ($r = 0.721$). Moderate correlations were observed with BMI and muscle score ($r = 0.524$), skeletal muscle% ($r = 0.456$), and a moderate negative correlation with body fat% ($r = -0.489$). Fat mass showed a strong positive link ($r = 0.612$), while fat mass index ($r = 0.289$) and waist-hip ratio ($r = 0.156$, $p = 0.045$) had weak positive correlations. Age had a weak, non-significant negative correlation ($r = -0.089$, $p = 0.283$). These results indicate BMR is primarily influenced by lean mass.

Table 5: Correlation Analysis between BMR and Body Composition Variables

Variable	Correlation with BMR (r)	p-value	Strength of Association
Age	- 0.089	0.283	Weak negative
Height	0.758**	<0.001	Strong positive
Weight	0.822**	<0.001	Very strong positive
BMI	0.524**	<0.001	Moderate positive
SMM	0.864**	<0.001	Very strong positive
Skeletal Muscle%	0.456**	<0.001	Moderate positive
Body Fat%	- 0.489**	<0.001	Moderate negative
Fat Mass	0.612**	<0.001	Strong positive
Fat Mass Index	0.289**	<0.001	Weak positive
Fat Free Mass	0.891**	<0.001	Very strong positive
FFMI	0.721**	<0.001	Strong positive
Waist-Hip Ratio	0.156*	0.045	Weak positive
Muscle Score	0.524**	<0.001	Moderate positive

*Correlation is significant at p < 0.05, **Correlation is significant at *p*< 0.01

Gender-Specific Correlation Analysis

In this study, BMR showed strong positive correlations with fat-free mass (males: r=0.889; females: r=0.821), SMM (0.856; 0.742), and weight (0.798; 0.781) in both genders (p<0.001). Moderate correlations were also observed with BMI (0.612; 0.523), muscle score (0.634; 0.456), and height (0.421; 0.387). Body fat% showed a negative correlation with BMR (-0.398; -0.445). These results confirm fat-free mass and SMM as key determinants of BMR, especially in males. (Table 6)

Table 6: Gender-Specific Correlations between Body Composition Parameters and BMR

Variable	Males (n=46)		Females (n=104)	
	r	p-value	r	p-value
Height	0.421**	0.004	0.387**	<0.001
Weight	0.798**	<0.001	0.781**	<0.001
BMI	0.612**	<0.001	0.523**	<0.001
SMM	0.856**	<0.001	0.742**	<0.001
Body Fat%	-0.398**	0.006	-0.445**	<0.001
Fat Free Mass	0.889**	<0.001	0.821**	<0.001
Muscle Score	0.634**	<0.001	0.456**	<0.001

**Significant at *p*< 0.01

Regression Analysis - Predictors of BMR

Table 7 presents the results of a regression analysis identifying significant predictors of BMR. Skeletal Muscle Mass showed the strongest positive association with BMR, with a coefficient of 28.4 (*p*< 0.001), followed closely by Fat Free Mass (coefficient = 12.7, *p*< 0.001). Skeletal Muscle% also demonstrated a significant positive effect on BMR (coefficient = 10.9, p = 0.004), suggesting that both absolute and relative muscle mass are critical determinants of metabolic rate. Male gender significantly increased BMR by 185.6 kcal (*p*< 0.001), while age had a negative association (coefficient = - 3.2, p = 0.002), indicating a decline in metabolic activity with aging. BMI was a weaker but still significant predictor (coefficient = 4.8, p = 0.032). Overall, body composition parameters particularly SMM, Fat Free Mass, and SM% emerged as the most influential factors affecting BMR.

Table 7: Regression Analysis: Predictors of BMR

Predictor	Coefficient	p-value
SMM	28.4	<0.001
Fat Free Mass	12.7	<0.001
Skeletal Muscle%	10.9	0.004
Age	- 3.2	0.002
Gender (Male)	185.6	<0.001
BMI	4.8	0.032

Discussion

This study revealed significant gender-based differences in BMR, with males demonstrating substantially higher BMR compared to females. The investigation confirmed that fat-free mass and skeletal muscle mass are the primary determinants of metabolic rate, showing very strong positive correlations with BMR across both genders. Additionally, BMR increased progressively with higher BMI categories, while body fat percentage exhibited a moderate negative correlation with metabolic rate. Age-related variations in BMR were observed but lacked statistical significance within this sample population. The pronounced gender differences in BMR can be attributed to inherent variations in body composition between males and females. Males naturally possess greater skeletal muscle mass and fat-free mass, which are metabolically active tissues requiring substantial energy for maintenance. The strong correlations between lean body mass components and BMR reflect the metabolic activity of these tissues, as skeletal muscle accounts for approximately 20-25% of total energy expenditure at rest. The variation in BMR across different BMI categories among the study participants was evident; individuals with normal BMI showed a lower average BMR compared to those who were overweight, who demonstrated higher values. This trend is consistent with the findings of Karagun *et al*. (2024), who also reported elevated BMR levels among overweight and obese groups, supporting the alignment of our results with global observations [18].

The current findings align consistently with established literature on BMR and body composition relationships. Recent research by Bi X *et al*. (2019) demonstrated that both BMR and lean body mass predicted daily energy intake, with significant correlations (p < 0.001) [19]. This supports our observation of the strong relationship between lean mass and metabolic rate. The gender differences observed in our study are well-documented in the literature. A 2024 study by Gitsi *et al*. noted that males naturally possess greater muscle mass compared to females, which extends to gender disparities in basal metabolism [20]. This corroborates our findings of significantly higher BMR in males compared to females, primarily attributable to differences in skeletal muscle mass and fat-free mass composition.

Recent cross-sectional research by Verma *et al*. (2023) emphasized that variation in fat-free mass is the most important factor influencing BMR, although the effects of fat mass, age, and sex remain subjects of ongoing investigation [21]. This perspective aligns with our regression analysis, which identified skeletal muscle mass as the strongest predictor of BMR, followed by fat-free mass and gender.

The relationship between BMR and BMI categories observed in our study is supported by contemporary research. A 2024 retrospective study by Karagun *et al*. found mean BMR values of 1581 ± 322 kcal/ day in overweight and obese individuals, which falls within the range observed in our higher BMI categories **(22)**. This suggests that our findings are consistent with patterns observed in similar populations. Research by Joshi *et al*. (2019) in Indian obese patients demonstrated significant correlations between BMR and body composition parameters including fat percentage, and fat-free mass [23]. These findings mirror our correlation analysis, which showed very strong positive correlations between BMR and fat-free mass (r = 0.891) and moderate negative correlations with body fat percentage.

The age-related trends observed in our study, though not statistically significant, are consistent with established literature. Previous research indicates that basal metabolism tends to decrease by 1-2% per decade from ages 20 to 75, with aging accompanied by replacement of muscle mass with fat tissue [19]. Our regression analysis confirmed age as a negative predictor of BMR, though the effect was modest within our sample. A recent study using CHAID analysis by Yildirim *et al*. (2020) examined the relationship between BMR and body components in young adults, identifying body composition as the most important variable for BMR determination [24]. This methodology and conclusion support our approach and findings regarding the primacy of body composition in BMR prediction.

The muscle score quartile analysis in our study provides novel insights into the relationship between muscle quality and metabolic rate. While direct comparisons are limited due to the specific nature of this metric, the positive relationship observed between muscle score and BMR aligns with fundamental principles of muscle metabolism and energy expenditure. Our correlation analysis revealed interesting patterns that merit comparison with existing literature. The very strong correlation between BMR and weight (r = 0.822) is consistent with classical metabolic scaling relationships, though the strength of correlation with fat-free mass (r = 0.891) emphasizes the importance of tissue-specific metabolic activity rather than total body mass alone.

The moderate negative correlation between BMR and body fat percentage observed in our study contrasts with some findings that suggest fat mass contributes positively to total energy expenditure [25]. However, this apparent contradiction likely reflects the per-kilogram metabolic activity differences between adipose tissue and lean tissue, with skeletal muscle being significantly more metabolically active than fat tissue.

Gender-specific correlation patterns observed in our study show consistently stronger correlations in males compared to females for most body composition parameters. This pattern has been noted in previous research and may reflect differences in muscle fiber composition, hormonal influences, or measurement precision across genders **(26)**.

The regression model developed in our study, with skeletal muscle mass as the strongest predictor, aligns with physiological understanding of tissue-specific metabolic rates. Classical research has established skeletal muscle metabolism as a major determinant of resting energy expenditure, with muscle tissue accounting for a disproportionate share of total metabolic activity [27]. This fundamental principle underlies our empirical findings and supports the clinical relevance of our predictive model.

These findings have significant clinical implications for nutritional assessment and metabolic health evaluation. The strong predictive value of skeletal muscle mass and fat-free mass suggests that body composition analysis should be prioritized in clinical practice for accurate BMR estimation and personalized nutrition planning.

Strengths and Limitations

This study's strengths include comprehensive body composition analysis using standardized methods and inclusion of diverse BMI categories representative of clinical populations. However, limitations include the cross-sectional design preventing causal inference, potential selection bias from clinic-based recruitment, and the relatively small sample size in older age groups.

Conclusion

This study underscores the critical role of body composition particularly skeletal muscle mass and fat-free mass in determining BMR, with both showing very strong positive correlations and emerging as the most influential predictors in regression analysis. Significant gender-based differences were observed, with males exhibiting higher BMR, muscle mass, and fat-free mass, while females displayed greater adiposity and BMI, contributing to differing metabolic profiles. Although BMR showed a progressive increase across BMI categories, lean tissue, not fat mass, accounted for the majority of metabolic activity, as reflected by the stronger correlations with fat-free mass and muscle score than with body fat percentage. Age-related declines in BMR and lean mass were noted but did not reach statistical significance, suggesting that age alone may have a modest impact compared to body composition. The analysis across muscle score quartiles further reinforced the association between muscle quality and metabolic rate, with higher muscle scores linked to significantly elevated BMR and lean mass. These findings highlight the physiological primacy of metabolically active tissues over total body weight or fat mass in influencing energy expenditure and support the use of detailed body composition assessments rather than BMI alone in clinical evaluation and nutritional planning.

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