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Gender-specific correlations between body composition and basal metabolic rate in university students: A cross sectional study

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Abstract
Objective: Basal metabolic rate (BMR) and body composition parameters are essential indicators of an individual's health status. This study aimed to (1) compare health parameters between male and female university students and (2) analyze the influence of body composition on BMR in both genders.
Materials and Methods: Forty students (20 males, 20 females) from the Department of Physical Education and Sports Science, University of Rajshahi, Bangladesh, were selected using stratified random sampling. Height and weight were measured to calculate BMI. BMR and body composition parameters, including intracellular water, extracellular water, total body water (TBW), fat mass, fat-free mass (FFM), and protein mass, were assessed using an IN-Body analyzer.
Results: Males had significantly higher BMR, TBW, and FFM than females ($p<0.05$). Pearson correlation analysis showed significant associations between BMR and TBW (males: $r = 0.699$, $p = 0.001$; females: $r = 0.860$, $p < 0.001$), BMR and fat mass (males: $r = 0.678$, $p = 0.001$; females: $r = 0.476$, $p = 0.03$), BMR and FFM (males: $r = 0.610$, $p = 0.004$; females: $r = 0.493$, $p = 0.02$), and BMR and protein mass (males: $r = 0.642$, $p = 0.002$; females: $r = 0.668$, $p = 0.001$). Moreover, BMR was associated with BMI in males ($p=0.03$) but not in females ($p=0.76$).
Conclusion: This study highlights the strong influence of body composition on BMR, with males exhibiting higher metabolic rates than females. These findings can aid in designing personalized health strategies to optimize metabolic health in university students.

Keywords: Basal metabolic rate (BMR), body composition, gender differences, university students

1. Introduction
Obesity represents a worldwide health emergency linked to a variety of severe health issues, such as metabolic disorders, cardiovascular diseases, and type-2 diabetes [1]. By 2014, there were more than 2.1 billion overweight and obese people in worldwide, up from 857 million in 1980 [2]. Recent studies indicate that developing countries like Bangladesh also have a high prevalence of obesity, with 24% of urban adults in Bangladesh being obese [3]. The condition arises primarily due to an imbalance between energy intake and expenditure, where excess calories are stored as fat. This is where the concept of basal metabolic rate (BMR) becomes significant.
Basal Metabolic Rate (BMR) denotes the least amount of energy that the body needs to maintain vital physiological processes, such as breathing, blood circulation, and cellular functions, when in a state of rest [4]. It accounts for roughly 60-75% of the total daily energy expenditure, serving as a crucial element in sustaining energy balance [5] [6]. Individuals who possess a lower BMR may experience a diminished capacity to expend calories, resulting in a heightened risk of fat storage unless their caloric intake is appropriately modified. A research conducted by Roberts *et al*. (1988) suggested that people with a reduced basal metabolic rate (BMR) may have a higher likelihood of experiencing weight gain [7]. Additionally, findings from Astrup *et al*. (1999) suggest that those who have previously experienced obesity often possess basal metabolic rates (BMRs) that are 3-5% lower than the expected values, which could hinder their ability to maintain weight loss or increase the risk of regaining weight [8]. Another study conducted among Chinese obese people concluded that BMR is generally

higher in overweight and obese adults compared to those with normal BMI [9].

However, a number of factors can affect this relationship and may vary the results. While individuals with a higher BMR tend to burn more calories at rest, research indicates that obesity can also lead to a higher BMR because the extra body mass requires more energy to maintain [10]. Additionally, basal metabolic rate (BMR) is affected by various factors such as age, sex, genetic predisposition, hormonal equilibrium, and metabolic adjustments, with body composition identified as the most significant factor [10-12]. As a result, understanding the determinants of BMR has remained a key area of interest among researchers over the years.

The influence of body composition parameters on BMR has been investigated by many researchers to understand the mechanism and develop most efficient procedure of obesity management. For instance, a study among Indian adults showed that fat-free mass, total body water, and fat percentage all have significant correlation with BMR [13]. Similar study was also investigated among postmenopausal women in the Indian context [14]. Moreover, studies regarding this topic are also available for Caucasian and Pima Indian subjects [15], as well as for Korean and African-American populations [16][17]. However, no prior research has explored this concept in the context of Bangladesh. Therefore, in this study we aimed to investigate the correlation between Basal Metabolic Rate (BMR) and body composition parameters among Bangladeshi university students.

2. Materials and Methods

2.1 Study design and participants

A total of 20 male and 20 female participants, aged 19 to 24 years, from the Department of Physical Education and Sports Science, University of Rajshahi, Bangladesh, were recruited for this cross-sectional investigation. Participants were selected using a stratified random sampling technique. They were invited to the Human Performance and Kinanthropometry Laboratory, University of Rajshahi, between 10:00 AM and 12:00 PM for two consecutive days. After obtaining written consent, they completed a self-administered questionnaire to provide demographic information and then underwent the necessary assessments.

2.2 Inclusion and exclusion criteria

Participants for this study were selected based on specific inclusion and exclusion criteria. The inclusion criteria required participants to be undergraduate students from the Department of Physical Education and Sports Science, University of Rajshahi, who were in good health and willing to undergo the necessary assessments.

Exclusion criteria included postgraduate students, students from other departments, individuals with a history of cardiovascular or any chronic diseases, pregnant individuals, and smokers.

2.3 Measuring parameters and procedures

Anthropometric measures—including height, weight, and BMI—were designated as independent variables. A SECA (Germany) digital column scale equipped with a stadiometer was used to determine height, and to the closest 0.1 kg, body weight was measured without shoes. Using the formula BMI = weight (kg) / height (m^2), where weight is measured in kilograms and height is measured in meters squared, the BMI was determined. Additionally, an IN-F500 Body Composition Analyzer (InBody Co., Seoul, South Korea) was utilized to assess body composition parameters, such as intracellular water, extracellular water, total body water, fat mass, fat free mass, and protein content, which were also treated as independent variables. Basal metabolic rate (BMR) was measured as a dependent variable according to the analyzer's manufacturer protocol. To ensure accurate findings, all participants were advised to refrain from any prolonged physical activity prior to testing and to maintain adequate hydration on the test day.

2.4 Statistical analysis

Statistical analyses were conducted using SPSS version 20, with all data expressed as mean ± standard deviation (SD). Pearson correlation coefficients were computed to assess the association between BMR and each independent variable, and independent sample t-tests were used to compare mean values between male and female participants. A p-value of less than 0.05 was considered statistically significant.

3. Results

In this cross-sectional investigation, data from 40 participants were analyzed, and the corresponding mean values and standard deviations for key parameters are summarized in Table 1. The male cohort exhibited a higher mean BMI (23.44 ± 3.13) compared to females (19.33 ± 1.86), whereas female participants had a slightly higher mean age (22 ± 1.41) than males (21.27 ± 2.73). Notably, total body water was significantly elevated in male students (36.78 ± 2.79) relative to female students (25.13 ± 2.36), as detailed in Table 2 ($p < 0.001$). Similarly, the mean basal metabolic rate (BMR) was markedly higher in males (1544.75 ± 145.27) than in females (1078.05 ± 92.17) ($p < 0.001$). Additionally, fat-free mass was substantially greater in males (52.36 ± 3.14) than in females (34.40 ± 3.03) ($p < 0.001$), reflecting greater muscle mass in males. These statistically significant differences in total body water, BMR, and fat-free mass between male and female participants are further illustrated in Figure 1.

Table 1: Demographic parameters of the study participants

Variables	Male Participants (mean ± SD)	Female Participants (mean ± SD)
Age (years)	21.27 ± 2.73	22 ± 1.41
Height (cm)	166.87 ± 6.09	155.61 ± 6.72
Weight (kg)	65.54 ± 6.9	46.69 ± 4.68
BMI (kg/m^2)	23.44 ± 3.13	19.33 ± 1.86
ICW (liter)	24.56 ± 1.97	16.72 ± 1.6
ECW (liter)	12.22 ± 0.91	8.41 ± 0.77
TBW (liter)	36.78 ± 2.79	25.13 ± 2.36
Fat mass (kg)	13.17 ± 4.88	12.28 ± 3.85
FFM (kg)	52.36 ± 3.14	34.40 ± 3.03
Protein (kg)	13.83 ± 1.35	8.53 ± 1.23
BMR (kcal)	1544.75 ± 145.27	1078.05 ± 92.17
Note: BMI = Body Mass Index, ICW = Intra Cellular Water, ECW = Extra Cellular Water, TBW = Total Body Water, FFM = Fat Free Mass, BMR = Basal Metabolic Rate		

Table 2: Comparison of parameters between male and female participants

Parameters	Male Participants	Female Participants	p-value (2-tailed)
TBW (liter)	36.78 ± 2.79	25.13 ± 2.36	<0.001*
BMR (kcal)	1544.75 ± 145.27	1078.05 ± 92.17	<0.001*
FFM (kg)	52.36 ± 3.14	34.40 ± 3.03	<0.001*
*indicates significant at p<0.05			

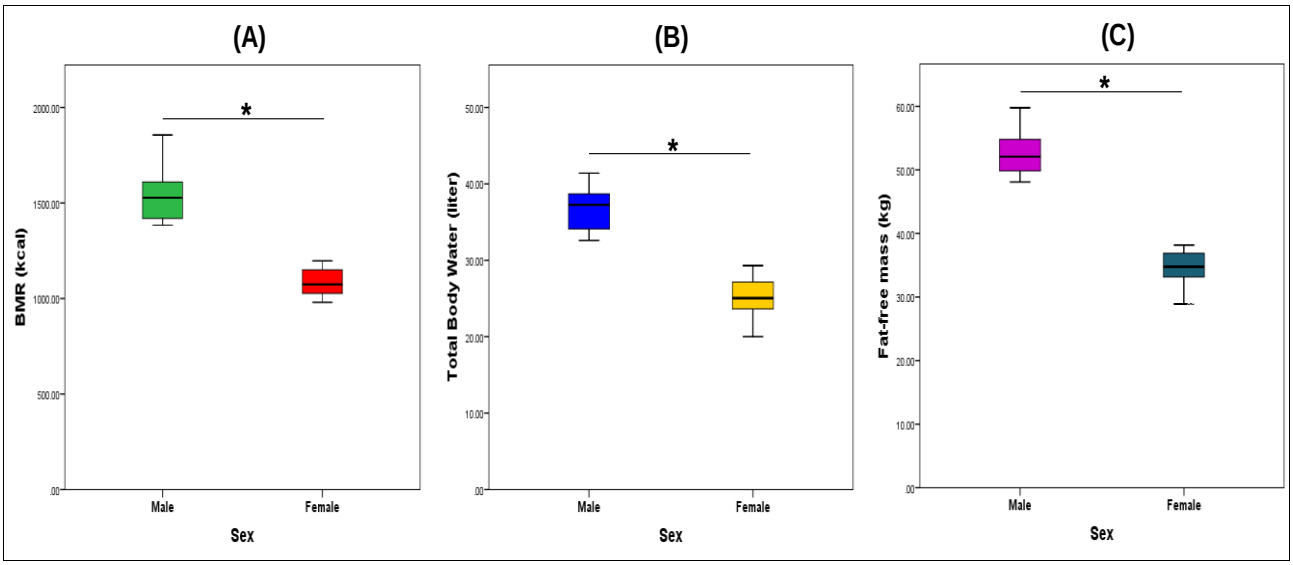

Fig 1: Gender-specific differences in (A) BMR, (B) Total Body Water, and (C) Fat-free mass. * Indicates significant difference between male and female at p<0.05.

In this study, the primary objective was to examine the correlation between basal metabolic rate (BMR) and key body composition parameters, including BMI, total body water (TBW), fat mass, fat-free mass and protein content, in both male and female participants. The findings, summarized in Table 3, highlight distinct gender-based variations. Pearson's correlation analysis identified a significant positive correlation between BMR and BMI in males (r = 0.470, p = 0.03), whereas no significant association was found in females (r = 0.073, p = 0.76) (Figure 2). However, BMR was strongly correlated with TBW in both males (r = 0.699, p = 0.001) and females (r = 0.860, p < 0.001), as illustrated in Figure 3. A significant positive correlation was also observed between BMR and fat mass (males: r = 0.678, p = 0.001; females: r = 0.476, p = 0.03), as well as with protein content (males: r = 0.642, p = 0.002; females: r = 0.668, p = 0.001). Additionally, the relationship between BMR and fat-free mass was significant for both genders (males: r = 0.610, p = 0.004; females: r = 0.493, p = 0.02), as shown in Figure 4, indicating an increased fat-free mass is associated with an increase BMR value.

Table 3: Correlational analysis between BMR and body composition parameters

Parameters	Male Participants	Female Participants
	r p	r p
BMI (kg/m^2)	0.470 0.03*	0.073 0.76
TBW (liter)	0.699 0.001*	0.860 <0.001*
Fat Mass (kg)	0.678 0.001*	0.476 0.03*
FFM (kg)	0.610 0.004*	0.493 0.02*
Protein (kg)	0.642 0.002*	0.668 0.001*
*indicates significant at p<0.05		

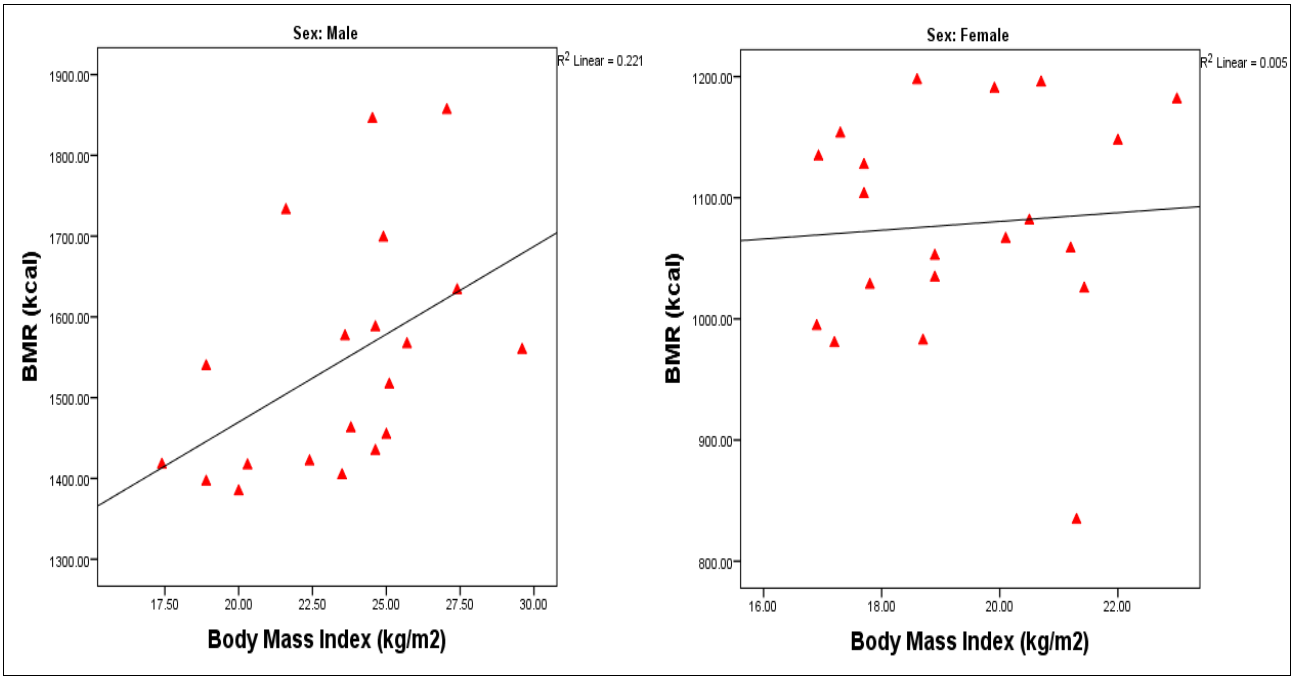

Fig 2: Gender-specific scatterplots representation of BMR and BMI correlation

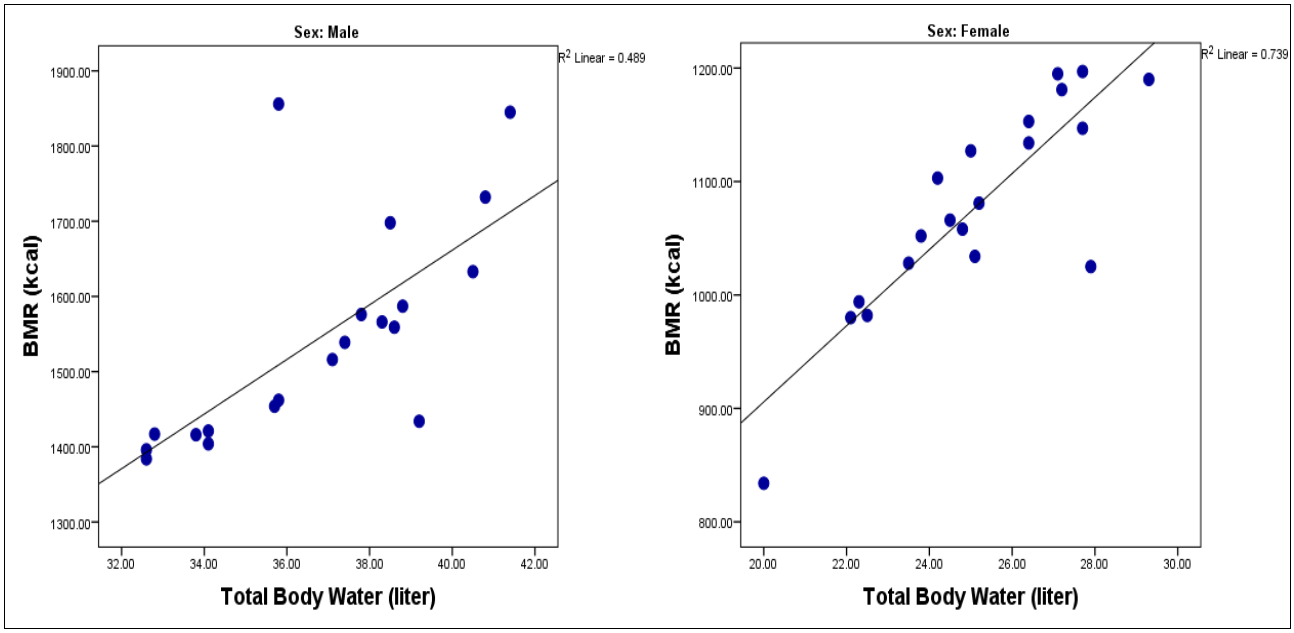

Fig 3: Gender-specific scatterplots representation of BMR and TBW correlation

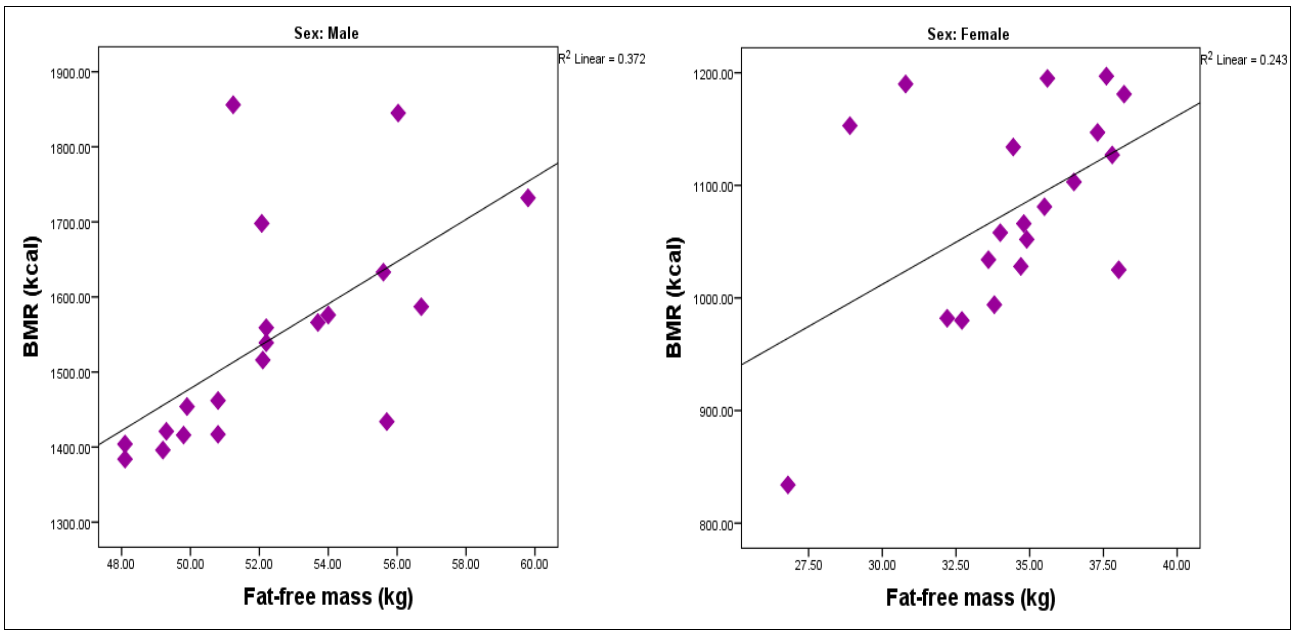

Fig 4: Gender-specific scatterplots representation of BMR and FFM correlation

4. Discussion

The present study explored the correlation between basal metabolic rate (BMR) and body composition parameters among Bangladeshi university students while also comparing key metrics between male and female participants to assess gender-based differences. The findings indicate that males generally exhibit higher BMR, total body water (TBW), and fat-free mass than females. This aligns with previous research showing that males have significantly greater TBW, intracellular water (ICW), and extracellular water (ECW) than females [18, 19]. However, females tend to have a higher ECW/ICW ratio and a greater proportion of body water relative to body weight, as reported by G. Ruggieri *et al.* [18]. Additionally, Ferraro *et al.* (1992) found that BMR, daily energy expenditure, and sleeping metabolic rate in males are 5-10% higher than in females, even after adjusting for body composition and age [20]. One possible reason for higher BMR in males might be due to males typically possess a higher muscle mass, leading to an elevated metabolic rate, whereas females tend to have a greater percentage of body fat, which affects water distribution and energy expenditure. In addition, testosterone facilitates muscle development and increases energy expenditure in men, while estrogen aids in fat accumulation and fosters a more energy-efficient metabolism in women [21, 22].

One of the significant aims of the current study was to determine the relationship between BMR and other body composition parameters in two different genders. In this case, age is consistently identified as a key determinant of basal metabolic rate (BMR) across multiple studies [23]. However, the present study didn't focus in age-based difference, as all participants were from same department with similar age. After Pearson's correlational analysis, the results of the current study showed that BMI is significantly correlated with BMR in males, but not in females, whereas fat mass and fat-free mass were significantly correlated with BMR for both groups. This aligns with prior research showing BMI is not always the most accurate predictor of BMR or overall health due to individual variations in body composition, with fat-free mass serving as the primary determinant of BMR, whereas fat

mass significantly influences BMR only in individuals with obesity [10][24]. A study by Lazer *et al*. demonstrated that FFM accounted for about 60% of the variability of BMR in his study populations [25]. Johnstone *et al*. (2005) confirmed that 63% of the variance in BMR was attributable to FFM, with minimal contributions from fat mass and age [10]. These findings are consistent with our results, indicating that fat-free mass is a major determinant of basal metabolic rate.

Additionally, the findings of this study indicate a significant correlation between BMR, total body water (TBW), and protein content in both male and female participants. The observed relationship with TBW underscores the potential influence of hydration status on basal metabolic rate, as adequate water levels are essential for cellular function, nutrient transport, and metabolic reactions. Our findings aligned with the study of Olejníčková *et al*., (2019) [11], who stated that higher TBW is directly associated with increased BMR in working-age Czechs [11]. A study conducted among Korean female showed that both intracellular water and extracellular water are significantly correlated with BMR [16]. These findings indicate that basal metabolic rate (BMR) is influenced by multiple factors rather than a single determinant; with body composition parameters such as fat-free mass and total body water, along with gender differences, playing a significant role in its variability.

5. Conclusion

This study concludes that males generally exhibit higher basal metabolic rate (BMR), total body water (TBW), and fat-free mass compared to females. Moreover, body composition parameters significantly influence BMR in both male and female university students. To the best of our knowledge, this is the first study to investigate these relationships among Bangladeshi university students. Further research with larger sample sizes is recommended to enhance the validity and generalizability of these findings.

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