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Analysis of body composition parameters: Associations with gender, age, and adiposity indices in adults

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ABSTRACT

Background: Height-independent body composition parameters such as fat free mass index (FFMI) and body fat mass index (BFMI) allow height-independent interpretation of nutrition status and putatively provide a better assessment of body fat. **Aims and Objectives:** This study was undertaken to investigate the relationships between body composition parameters and their associations with gender, age, and adiposity indices in adults using bioelectrical impedance analysis (BIA). **Materials and Methods:** A cross-sectional study was conducted on 120 participants (60 males, 60 females) aged 18 years and older. Body composition parameters including body mass index (BMI), BFMI, FFMI, total body water (TBW), intracellular water (ICW), and extracellular water (ECW) were measured using BIA. Participants were stratified by age and gender for comparative analyses. **Results:** Significant gender differences were observed across all parameters. Females showed higher BMI (26.75 vs. 24.38 kg/m^2) and BFMI (9.755 vs. 5.85 kg/m^2), while males demonstrated higher FFMI (17.63 vs. 16.50 kg/m^2) and TBW (60.59% vs. 50.95%). Among age groups, only BMI showed significant differences ($P=0.024$), with the highest values in the 40–59 years group. Strong positive correlations were found between BFMI and BMI ($r=0.776$, $P<0.01$) and TBW with ICW ($r=0.962$, $P<0.01$). Strong negative correlations were observed between TBW and BFMI ($r=-0.830$, $P<0.01$). Age showed no significant correlations with any body composition parameters. **Conclusions:** The study demonstrates significant gender-based differences in body composition parameters and reveals that BMI correlates strongly with FM but only moderately with fat-free mass. Most body composition parameters remain relatively stable across age groups. These findings emphasize the importance of gender-specific approaches in body composition assessment and suggest the need for more comprehensive evaluation methods beyond traditional BMI measurements.

Key words: Body composition; Body mass index; Body fat mass index; Fat-free mass index; Adiposity

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INTRODUCTION

Non-communicable diseases (NCDs) now are the main cause of morbidity and mortality worldwide. The major risk factors implicated for the development of NCDs are dietary pattern, harmful behavioral patterns such as alcohol consumption, smoking and lack of physical activity, and obesity.[1,2] Obesity is one of the most important risk factors for NCDs.[3,4] According to the World Health Organization, in 2022, 2.5 billion adults (18 years and older) were overweight. Of these, 890 million were living with obesity.[5] The cost of medical care for obese patients is 30% higher

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than that of the normal weight peers.[6] Body mass index (BMI) is widely used to identify excess adiposity, both in adults and in adolescents.[7] However, it is not increased body weight that is crucial for the development of such diseases, but excessive body fat.[8] BMI as a sole measure of obesity can lead to misclassification, because actual body fat is not measured in BMI and fat mass (FM) cannot be distinguished from lean mass.[9] Height-independent body composition parameters such as fat free mass index (FFMI) and body FM index (BFMI) allow height-independent interpretation of nutrition status and putatively provides a better assessment of body fat. Moreover, variations in these parameters with regards to gender and age warrant different considerations.

In this study, we study the body composition of participants including BFMI, FFMI, intracellular water (ICW), extracellular water (ECW), total body water (TBW), and lean body mass (LBW) and explore correlation among these indices. Changes in these indices with the increase of age and gender differences are also studied. Therefore, the main purpose of this study is to explore the relationship between human body composition with respect to gender, age and adiposity.

MATERIALS AND METHODS

Study design

This was a cross-sectional design to assess the body composition of participants and explore its relationship with age, gender, and adiposity. The study was conducted in accordance with ethical guidelines and approved by the Institutional Ethics Committee (D/249/FM/JNMCH dated May 11, 2019).

Study population

Inclusion criteria included individuals aged 18 years and older, while exclusion criteria were individuals with severe systemic diseases, pregnancy, or conditions affecting body fluid balance. Eligible participants were recruited by means of systematic random method.

Data collection procedures

Data collection took place in a controlled clinical setting. Anthropometric measurements were performed following standardized protocols, and body composition indices were assessed using bioelectrical impedance analysis (BIA), a validated non-invasive method.

Anthropometric measurements

- Height was measured using a stadiometer to the nearest 0.1 cm
- Weight was recorded using a digital scale to the nearest 0.1 kg
- BMI was calculated as weight (kg) divided by height squared (m^2).

Body composition assessment

The following parameters were measured using a multifrequency BIA device:

- BFMI
- FFMI
- ICW
- ECW
- TBW
- LBM.

All measurements were taken under standardized conditions, including fasting state, hydration status, and minimal physical activity before the assessment.

Data analysis

Descriptive statistics

- Continuous variables were summarized using mean±standard deviation
- Categorical variables were expressed as frequencies and percentages.

Correlation analysis

- Pearson's or Spearman's correlation coefficients (as applicable) were used to determine relationships between body composition indices.

Comparative analysis

- Age-based differences in body composition were analyzed using one-way Analysis of Variance or Kruskal–Wallis tests as applicable
- Gender differences were examined using independent t-tests or Mann–Whitney U tests as applicable.

Ethical considerations

- Approval from Institutional Ethics Committee was obtained
- Informed consent was obtained from all participants before enrollment
- The study adhered to the principles of the Declaration of Helsinki
- Data confidentiality and participant anonymity were maintained throughout the study.

RESULTS

A total of 120 participants were enrolled in the study. Half (n=60) of the participants were males and half (n=60) were females. Table 1 presents the summary statistics of the study participants:

Table 1: Descriptive statistics of study variables

S. No.	Variable	Mean±standard deviation
1.	Age	47.1±9.91 years
2.	Body mass index	25.6±4.31 kg/m^2
3.	Body fat mass index	7.8±3.34 kg/m^2
4.	Fat free mass index	17.1±2.61 kg/m^2
5.	Fat (in %)	29.9±9.58%
6.	Total body water	55.8±8.47%
7.	Intracellular water	31.1±5.94
8.	Extracellular water	24.7±3.19

Our study population had a mean age of 47.1±9.91 years, indicating a middle-aged sample.

Regarding body composition metrics:

- The mean BMI was 25.6±4.31 kg/m^2
- The BFMI (FFMI) averaged 7.8±3.34 kg/m^2, while the FFMI was 17.1±2.61 kg/m^2
- The mean body fat percentage was 29.9±9.58%, which is relatively high and shows considerable variation among participants.

The hydration status indicators show:

- TBW averaged 55.8±8.47% of body weight
- The distribution between ICW (31.1±5.94) and ECW (24.7±3.19) appears to maintain a roughly normal ratio.

Gender-based differences

The mean age of males was 48.22±10.34 years and of females was 45.97±9.42 years (P=0.215).

Table 2 presents a gender-based comparison of body composition metrics with their statistical significance.

BMI

Females showed higher BMI (26.75±4.58) compared to males (24.38±3.69). This difference is statistically significant (P=0.002).

Body fat metrics

Females had significantly higher BFMI (9.755±3.23 vs. 5.85±2.10 in males, P<0.001). Body fat percentage shows a marked gender difference (36.05%±8.18% in females vs. 23.70%±6.36% in males, P<0.001). Conversely, FFMI was higher in males (17.63±2.46 vs. 16.50±2.65 in females, P=0.018).

Water content

Males showed higher TBW (60.59%±7.30% vs. 50.95%±6.63% in females, P<0.001). Both ICW and ECW were significantly higher in males (ICW: 34.58±5.01 in males vs. 27.49±4.52 in females; ECW: 25.71±3.41 in males vs. 23.67±2.61 in females). All water-related differences were highly significant (P<0.001).

Table 2: Comparison of body composition metrics with regards to gender

Variable	Male	Female	Significance
BMI	24.38±3.69	26.75±4.58	P=0.002
Body fat mass index (BFMI)	5.85±2.10	9.755±3.23	P<0.001
Fat free mass index (FFMI)	17.63±2.46	16.50±2.65	P=0.018
Fat (in %)	23.70±6.36	36.05±8.18	P<0.001
Dry lean weight	10.99±7.63	8.16±3.15	P=0.009
Total body water	60.59±7.30	50.95±6.63	P<0.001
Intracellular water (ICW)	34.58±5.01	27.49±4.52	P<0.001
Extracellular water (ECW)	25.71±3.41	23.67±2.61	P<0.001

BMI: Body mass index

Dry lean weight

Males had higher dry lean weight (10.99±7.63 vs. 8.16±3.15 in females, P=0.009). These findings align with established physiological differences between males and females, particularly regarding body fat distribution, muscle mass, and water content.

Table 3 presents body composition metrics across three age groups: <40 years, 40–59 years, and ≥60 years.

Sample distribution:

- <40 years: 32 participants
- 40–59 years: 69 participants (largest group)
- ≥60 years: 19 participants.

1. BMI
   The only statistically significant difference among all metrics was BMI (P=0.024) which was highest in the middle age group (40–59 years): 26.43±4.25 and similar values in younger (<40 years: 24.27±4.50) and older groups (≥60 years: 24.58±3.55).
2. Body fat metrics
   BFMI showed a trend (P=0.076) but did not reach statistical significance. It was highest in middle age (8.39±3.45). Fat percentage also showed highest values in middle age (31.26%±9.67%) but was not statistically significant (P=0.158). FFMI remained remarkably stable across age groups (P=0.916).
3. Water content:
   TBW showed slight variations but was not statistically significant (P=0.418). Interestingly, the ≥60 years group had the highest TBW (58.21%±9.22%). Neither ICW (P=0.368) nor ECW (P=0.598) showed significant age-related differences. ECW showed a slight increasing trend with age (24.24→24.79→25.10).
4. Dry lean weight:
   No significant differences between age groups (P=0.806). It was slightly lower in the ≥60 years group (8.67±3.87 kg).

Table 3: Body Composition metrics in different Age groups

Age group	BMI	BFMI	FFMI	Fat %	Dry lean wt (in kg)	TBW (in %)	ICW (in %)	ECW (in %)
<40 years								
Mean	24.27	6.81	17.02	26.90	9.44	56.02	31.39	24.24
SD	4.50	3.20	2.26	9.25	3.84	8.16	5.62	3.51
40–59 years								
Mean	26.43	8.39	17.11	31.26	9.88	54.99	30.38	24.79
SD	4.25	3.45	2.78	9.67	7.18	8.38	5.76	3.10
≥60 years								
Mean	24.58	7.34	16.98	29.85	8.67	58.21	32.84	25.10
SD	3.55	2.83	2.66	9.05	3.87	9.22	6.94	3.05
Significance	P=0.024	P=0.076	P=0.916	P=0.158	P=0.806	P=0.418	P-0.368	P=0.598

BMI: Body mass index, BFMI: Body fat mass index, FFMI: Fat free mass index, TBW: Total body water, ICW: Intracellular water, ECW: Extracellular water

Notable observations:
1. Most body composition parameters do not show statistically significant changes with age, except BMI
2. The middle-age group (40–59 years) tends to have higher values for BMI and fat-related metrics
3. The stability of FFMI across age groups is particularly interesting
4. The relatively high water content in the ≥60 years group is unexpected and might warrant further investigation.

Correlation analysis of study variables

This is presented in Table 4.

Strong positive correlations (r>0.7):
1. BFMI shows strong positive correlations with:
   - BMI (r=0.776, P<0.01)
   - Fat percentage (r=0.910, P<0.01).
2. TBW shows strong positive correlations with:
   - ICW (r=0.962, P<0.01)
   - ECW (r=0.812, P<0.01).

Strong negative correlations (r<−0.7):
1. TBW shows strong negative correlations with:
   - BFMI (r=−0.830, P<0.01)
   - Fat percentage (r=−0.780, P<0.01).
2. ICW shows strong negative correlations with:
   - BFMI (r=−0.830, P<0.01)
   - Fat percentage (r=−0.829, P<0.01).

Moderate correlations:
1. FFMI shows moderate positive correlations with:
   - BMI (r=0.549, P<0.01)
   - Dry lean weight (r=0.534, P<0.01).
2. ECW shows moderate to strong negative correlations with:
   - BMI (r=−0.643, P<0.01)
   - BFMI (r=−0.614, P<0.01).

Important observations:
1. Age shows no significant correlations with any body composition parameters
2. BMI correlates strongly significantly with BFMI but only moderately with FFMI
3. The inverse relationship between fat metrics and water content is clearly demonstrated.

Dry lean weight shows relatively weak correlations with most parameters except FFMI.

DISCUSSION

This cross-sectional study investigated body composition parameters and their relationships with age, gender, and adiposity in 120 participants. Several noteworthy findings emerged that warrant detailed discussion in the context of current scientific understanding.

Gender-based differences in body composition

Our study revealed significant gender-based differences in all measured body composition parameters. Females demonstrated higher BMI (26.75 vs. 24.38 kg/m^2) and substantially higher body fat metrics (FMI: 9.755 vs. 5.85 kg/m^2; Fat%: 36.05% vs. 23.70%) compared to males. These findings align with established physiological differences between genders and reflect the natural sexual dimorphism in body composition, as reported in previous studies.[10,11] The higher FM in females can be attributed to evolutionary and hormonal factors, particularly the influence of estrogen on fat deposition and distribution.[12] This sexual dimorphism develops during puberty and is maintained throughout adult life, serving important reproductive and metabolic functions.

Conversely, males exhibited higher FFMI (17.63 vs. 16.50 kg/m^2) and TBW content (60.59% vs. 50.95%),

Table 4: Correlation matrix for different study variables

Study variables	Age	Body mass index	Body fat mass index	Fat free mass index	FAT %	Dry lean wt (in kg)	Total body water (in %)	Intracellular water (in %)	Extracellular water (in %)
Age									
Correlation coefficient	1	−0.018	0.093	−0.106	0.169	−0.121	0.104	0.060	0.155
Sig. (2-tailed)		0.846	0.310	0.248	0.065	0.186	0.260	0.513	0.091
Body mass index									
Correlation coefficient	−0.018	1	0.776**	0.549**	0.499**	0.228*	−0.678**	−0.586**	−0.643**
Sig. (2-tailed)	0.846		0.000	0.000	0.000	0.012	0.000	0.000	0.000
Body fat mass index									
Correlation coefficient	0.093	0.776**	1	0.039	0.910**	−0.100	−0.830**	−0.830**	−0.614**
Sig. (2-tailed)	0.310	0.000		0.671	0.000	0.278	0.000	0.000	0.000
Fat free mass index									
Correlation coefficient	−0.106	0.549**	0.039	1	−0.278**	0.534**	−0.138	0.014	−0.347**
Sig. (2-tailed)	0.248	0.000	0.671		0.002	0.000	0.134	0.877	0.000
FAT %									
Correlation coefficient	0.169	0.499**	0.910**	−0.278**	1	−0.252**	−0.780**	−0.829**	−0.494**
Sig. (2-tailed)	0.065	0.000	0.000	0.002		0.005	0.000	0.000	0.000
Dry lean wt (in kg)									
Correlation coefficient	−0.121	0.228*	−0.100	0.534**	−0.252**	1	−0.108	−0.034	−0.231*
Sig. (2-tailed)	0.186	0.012	0.278	0.000	0.005		0.240	0.713	0.011
Total body water (in %)									
Correlation coefficient	0.104	−0.678**	−0.830**	−0.138	−0.780**	−0.108	1	0.962**	0.812**
Sig. (2-tailed)	0.260	0.000	0.000	0.134	0.000	0.240		0.000	0.000
Intracellular water (in %)									
Correlation coefficient	0.060	−0.586**	−0.830**	0.014	−0.829**	−0.034	0.962**	1	0.679**
Sig. (2-tailed)	0.513	0.000	0.000	0.877	0.000	0.713	0.000		0.000
Extracellular water (in %)									
Correlation coefficient	0.155	−0.643**	−0.614**	−0.347**	−0.494**	−0.231*	0.812**	0.679**	1
Sig. (2-tailed)	0.091	0.000	0.000	0.000	0.000	0.011	0.000	0.000	

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed)

reflecting greater muscle mass and lean tissue. This finding is consistent with previous research demonstrating that androgens, particularly testosterone, promote muscle protein synthesis and lean mass development in males.[13] The observed differences in body water content between genders align with established physiological principles, as lean tissue contains more water than adipose tissue. This sexual dimorphism in body composition underscores the importance of gender-specific reference ranges when interpreting body composition parameters in clinical practice.

Age-related changes and their implications

Interestingly, our age-based analysis revealed that most body composition parameters remained relatively stable across age groups, with BMI being the only parameter showing statistically significant differences (P=0.024). The middle-aged group (40–59 years) demonstrated the highest BMI and fat-related metrics, suggesting a potential mid-life peak in adiposity. This observation aligns with previous longitudinal studies showing increasing adiposity through middle age.[14,15]

The stability of FFMI across age groups is particularly noteworthy and somewhat unexpected, as previous literature often reports age-related decline in lean mass, particularly after the sixth decade.[16] This finding might reflect:

1. Selection bias toward healthier older adults in our study population and relatively smaller number of participants aged >60 years

2. The cross-sectional nature of our study, which may mask longitudinal changes.

The observation of highest TBW content in the ≥60 years group (58.21%) contradicts typical age-related changes reported in literature, where older adults generally show decreased TBW.[17] This unexpected finding might be explained by:
1. The relatively small sample size in the ≥60 years group (n=19)
2. Selection bias toward well-hydrated, healthy older adults.

Correlations and their clinical implications

The correlation analysis revealed several important relationships with potential clinical implications:
1. BMI's limitations: The strong correlation between BMI and BFMI (r=0.776) but only moderate correlation with FFMI (r=0.549) supports the growing criticism of BMI as an imperfect measure of adiposity.[18] This finding reinforces the need for more sophisticated body composition assessment methods in clinical practice, particularly in populations where BMI might be misleading, such as athletes or sarcopenic obesity.[19]
2. Water-fat relationship: The strong negative correlations between TBW and fat metrics (r=−0.830 with BFMI) demonstrate the physiological inverse relationship between adiposity and hydration status. This relationship has important implications for:
   - Fluid management in clinical settings, particularly in obese patients
   - Interpretation of bioelectrical impedance measurements
   - Understanding of metabolic health and fluid homeostasis.
3. Age independence: The absence of significant correlations between age and body composition parameters challenges traditional assumptions about age-related changes in body composition. This finding suggests that:
   - Chronological age alone may not be a strong determinant of body composition
   - Lifestyle factors might have greater influence than previously thought.[20]
4. Water compartments: The strong positive correlation between ICW and ECW (r=0.679) suggests coordinated regulation of fluid compartments, while their differential relationships with other parameters indicate distinct physiological roles. This understanding is crucial for:
   - Clinical assessment of hydration status
   - Management of fluid balance in various medical conditions
   - Interpretation of bioimpedance measurements in research and clinical practice.

Clinical and research implications

These findings have several important implications for clinical practice and research:
1. The significant gender differences in all parameters emphasize the need for:
   - Gender-specific approaches in nutritional and medical assessments
   - Development of gender-specific reference ranges
   - Consideration of hormonal influences in body composition assessment.
2. The limitations of BMI demonstrated by our correlation analysis support:
   - The use of more detailed body composition analysis in clinical practice
   - Development of more sophisticated screening tools for obesity
   - Need for multiple parameters in assessing nutritional status.
3. The stability of several parameters across age groups suggests:
   - Age-based assumptions about body composition may need reconsideration
   - Importance of individual assessment rather than age-based generalizations
   - Need for longitudinal studies to better understand age-related changes.

Limitations of the study

Several limitations should be acknowledged:
1. The cross-sectional design prevents causal inference about age-related changes
2. The sample size, particularly in the ≥60 years group (n=19), may limit the generalizability of age-related findings
3. Potential confounding factors.

CONCLUSION

This cross-sectional study provides comprehensive insights into the relationships between various body composition parameters and their associations with age and gender. Our findings demonstrate significant gender-based differences in all body composition parameters, with females showing higher BMI and FM indices, while males exhibited greater fat-free mass and TBW content. The study revealed that BMI, while widely used, correlates strongly with FM but only moderately with fat-free mass, supporting the need for more comprehensive body composition assessment methods in clinical practice.

Notably, most body composition parameters remained relatively stable across age groups, with only BMI showing significant age-related differences. The strong inverse relationship between body fat and water content metrics, along with the coordinated regulation of intracellular and ECW compartments, enhances our understanding of body composition dynamics. These findings have important implications for clinical practice, particularly in nutritional assessment and fluid management strategies.

Our results emphasize the importance of gender-specific approaches in body composition assessment and highlight the need for more sophisticated evaluation methods beyond traditional BMI measurements. Future longitudinal studies with larger sample sizes are warranted to further elucidate age-related changes in body composition and to develop population-specific reference ranges.

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FH- Conception and design, acquisition of data, analysis and interpretation of data; drafting the article and revising it critically, final approval of the draft;
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