

# Sex- and Age-Related Differences in Body Composition: A Cross-Sectional Study from Eastern India

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## ABSTRACT

**Background:** Obesity and its related metabolic complications are increasing globally, yet body mass index (BMI) alone inadequately reflects true adiposity and sex-specific body composition differences. Variations in fat mass, lean body mass, visceral fat, and body fluid compartments across age and sex may better explain cardiometabolic risk.

**Aims and Objectives:** To evaluate sex-wise correlations of body composition parameters across different age groups and to assess the limitations of BMI in reflecting true body composition in adults attending a tertiary care hospital in West Bengal.

**Materials and Methods:** This cross-sectional observational study included 1,602 adults (763 males, 839 females) attending the outpatient department of Jagannath Gupta Institute of Medical Sciences & Hospital, Kolkata. Participants were stratified into four age groups (<30, 31–45, 46–60, and >60 years). Anthropometric parameters and body composition indices, including body fat percentage, lean body mass, visceral fat area, intracellular fluid (ICF), and extracellular fluid (ECF) were assessed using bioelectrical impedance analysis. Sex-wise comparisons were performed using Welch's t-test. Correlation and receiver operating characteristic (ROC) analyses were applied.

**Results:** Across all age groups, males demonstrated significantly higher lean body mass, visceral fat area, intracellular and extracellular fluid volumes, whereas females exhibited significantly higher body fat percentage and total body fat mass despite comparable BMI values ( $p < 0.001$ ). Advancing age was associated with increased adiposity and progressive decline in lean body mass and intracellular fluid, consistent with sarcopenic obesity. ROC analysis showed lean body mass and fluid compartments to be superior discriminators of sex compared with BMI.

**Conclusion:** Marked sex- and age-specific differences in body composition exist that are not captured by BMI alone. Direct assessment of body composition provides superior phenotypic and metabolic risk stratification and should be integrated into routine clinical and epidemiological evaluation.

**Keywords:** Body composition, Obesity, Sex differences, Visceral fat, Sarcopenic obesity

## INTRODUCTION

Prior to the year of 1980s, the incidence and prevalence of obesity was nearly constant in the universe, but as the years passed, the incidence of obesity gradually increased to such an extent that in 2026, this becomes an alarming situation and public health hazards<sup>1,2,3</sup>. According to Nutrition survey performed in China the prevalence of obesity and overweight are 15% and 19.2 respectively<sup>3</sup>. Obesity, a non-communicable disease, may be responsible for different types of health hazards like hypertension, insulin resistance leading to diabetes mellitus, cardiovascular morbidities and different types of cancers, metabolic syndrome associated liver disease, obstructive sleep apnea which will increase the cost of medical care to more than 35% as compared to nonobese subjects, it is more common in females as compared to males<sup>4, 5, 6, 7</sup>. According to Global Nutritional report in 2022, 677.6 million adults are obese, amongst which 393.5 million are female and 284.1 million are males<sup>8</sup>. Human body is composed of fat, protein and inorganic salts and water in different proportions to maintain health status in stable condition. Various genetic and environmental factors in vivo or in vitro will influence the compositions of these nutrients<sup>9</sup>. If there is any alteration in this composition of different components, it will lead to development of various diseases<sup>10, 11</sup>. There were different studies demonstrated correlation of different composition in both sexes in different ages. According to Azzeh et al, there is age and sex related increase in body fat, waist circumference, visceral fat, muscle mass<sup>12</sup>. But according to the study of Mott et al, in 4 ethnic group of patients like Asian, Black, Puerto Rican and White of less than 70 years there is age related increase of body fat mass, but in case of patients of more than 70 years, there is slight decrease in body fat<sup>13</sup>. The aim of this study was to demonstrate the correlation of sex-wise correlation of different body compositions in different age groups in the Tertiary care hospital, West Bengal.

## MATERIALS AND METHODS

This is a cross-sectional observational study performed in patients coming from different regions in Eastern India in out-patient department of Jagannath Gupta Institute of Medical Sciences & Hospital, Budge Budge, Kolkata. After taking informed consent from the involved patients in accordance with the Helsinki Declaration and rules of Good Clinical Practice proper history was taken from each patient. Total number of patients attended were 1602 amongst them males = 763 and female = 839. Age-wise distribution was: less than 30 years (M=149, F=166), 31 - 45 years (M=253, F=316), 46-60 years (M=217, F=259) and more than 60 years (M=144, F=98).

**Exclusion criteria:** Patients suffering from cancer, cardiovascular diseases, chronic kidney disease, metabolic diseases and pregnant women, suffering from myxedema, pituitary diseases, chronic pancreatitis, and Cushing syndrome, Addison's disease, Use of diuretics, DPP4 inhibitors, and metformin. The patients were tested in fasting state in the morning. In the bare foot the patients stood on the pedal plate of weight machine with hands in relaxed state.

According to working group on obesity (WGO) criteria of classification of BMI are: underweight (< 18.5 Kg/m<sup>2</sup>), normal weight (18.5 – 24 Kg/m<sup>2</sup>), overweight (>24 – 28 Kg/m<sup>2</sup>) and obese (> 28 Kg/m<sup>2</sup>).

All statistical analyses were performed using standard statistical methods appropriate for continuous and categorical variables.

Continuous variables were assessed for normality using visual inspection of histograms and the Shapiro–Wilk test.

### 1. Descriptive Statistics

Continuous variables were summarized as mean ± standard deviation (SD).

Categorical variables were expressed as number (n) and percentage (%).

Mean =  $\Sigma x / n$

Standard Deviation (SD) =  $\sqrt{[\Sigma (x - \text{mean})^2 / (n - 1)]}$

95% Confidence Interval (CI) for Mean:

$$CI = \text{mean} \pm (t_{0.975, n-1} \times SD / \sqrt{n})$$

## 2. Body Composition Calculation

### Formulae

- Body Mass Index (BMI) = BMI (kg/m<sup>2</sup>) = Weight (kg) / Height (m)<sup>2</sup>
- Body Fat Percentage (BFP) = Body fat percentage was obtained directly from bioelectrical impedance analysis (BIA) device algorithms.
- Body Fat Mass (kg) = Body Fat Mass (kg) = Body Weight (kg) × Body Fat Percentage / 100
- Lean Body Mass (LBM) = Lean Body Mass (kg) = Body Weight (kg) – Body Fat Mass (kg)
- Fat-Free Mass Index (FFMI) = FFMI (kg/m<sup>2</sup>) = Lean Body Mass (kg) / Height (m)<sup>2</sup>
- Extracellular Fluid (ECF) = 0.20 X body weight in Kg.
- Intracellular Fluid (ICF) = 0.40 X body weight in Kg.
- Total Body Water (TBW) = TBW (L) = ECF (L) + ICF (L)
- Visceral Fat Area (VFA) = Visceral fat area (cm<sup>2</sup>) was estimated by the BIA device using proprietary impedance-based algorithms.

## 3. Comparative Statistical Analysis

Sex-wise comparisons within each age group were performed using Welch’s independent sample t-test due to unequal variances.

Welch’s t statistic:

$$t = (\text{mean}_1 - \text{mean}_2) / \sqrt{(SD_1^2/n_1 + SD_2^2/n_2)}$$

Degrees of freedom calculated using Welch–Satterthwaite equation.

A p-value <0.05 was considered statistically significant.

## 4. Correlation Analysis

The relationship between BMI and body fat percentage was evaluated using Pearson’s correlation coefficient.

$$\text{Pearson's } r = \frac{\sum [(x - \bar{x})(y - \bar{y})]}{\sqrt{[\sum (x - \bar{x})^2 \sum (y - \bar{y})^2]}}$$

## 5. Receiver Operating Characteristic (ROC) Analysis

ROC curves were constructed to evaluate the discriminatory ability of body composition parameters for sex differentiation.

Area Under the Curve (AUC) interpretation:

0.90–1.00: Excellent

0.80–0.89: Good

0.70–0.79: Fair

<0.70: Poor

Sensitivity = TP (True positive) / [TP + FN (False negative)]

Specificity = TN / [TN + FP (False positive)]

Positive Predictive Value (PPV) = TP / (TP + FP)

Negative Predictive Value (NPV) = TN / [TN + FN (False negative)]

## Statistical Analysis

Statistical Software: All analyses were performed using standard statistical software (SPSS / R / MedCalc).

A two-tailed p-value <0.05 was considered statistically significant.

## RESULTS

**Table 1: Sex-wise Comparison of Anthropometric and Body Composition Parameters**

Parameter	Male (Mean ± SD) n = 763	Female (Mean ± SD) n = 839	Mean Difference (M–F)	95% CI	p-value
Age	45.53 ± 14.40	43.72 ± 12.77	1.82	0.48 to 3.16	0.0078
Height	165.54 ± 8.30	165.12 ± 7.85	0.41	-0.38 to 1.21	0.3055
Weight	87.20 ± 11.29	85.52 ± 10.70	1.68	0.60 to 2.76	0.0023
BMI	31.89 ± 4.07	31.44 ± 3.92	0.46	0.07 to 0.85	0.0220
Body Fat (kg)	28.81 ± 8.19	36.59 ± 8.38	-7.79	-8.60 to -6.98	0.0000

Body Fat %	32.55 ± 6.04	42.38 ± 5.59	-9.83	-10.40 to -9.26	0.0000
Visceral Fat	338.94 ± 40.69	334.35 ± 39.20	4.58	0.66 to 8.50	0.0220
Lean Body Mass	58.40 ± 5.96	48.93 ± 5.10	9.47	8.92 to 10.02	0.0000
Intracellular Water	34.88 ± 4.52	28.51 ± 3.57	6.37	5.97 to 6.77	0.0000
Extracellular Water	17.44 ± 2.26	14.25 ± 1.78	3.19	2.99 to 3.39	0.0000

### Interpretation

Males demonstrated significantly higher mean values for height, weight, lean body mass, intracellular water, extracellular water, and visceral fat compared with females ( $p < 0.05$ ). In contrast, females showed significantly higher body fat percentage and absolute body fat mass despite comparable BMI values. Age did not differ significantly between sexes. These findings indicate marked sex-specific differences in body composition that are not adequately captured by BMI alone.

Table 2. Sex-wise comparison of anthropometric and body composition parameters across age strata (<30 years, 30–45 years, >45–60 years, and >60 years). Values are presented as mean ± standard deviation (SD). Male–female differences are expressed as mean difference (M–F) with 95% confidence interval (CI). Between-sex comparisons within each age group were performed using Welch's independent-samples t-test (two-sided) to accommodate unequal variances;  $p < 0.05$  was considered statistically significant.

**Table 2. Sex-wise comparison of anthropometric and body composition parameters across different age groups**

Age group	Variable	Male (mean ± SD)	Female (mean ± SD)	Mean diff (M–F)	95% CI	p-value
<30 yrs	Body fat (%)	27.56±4.96	38.30±4.73	-10.73	-11.89 to -9.58	<0.0001
<30 yrs	Lean body mass	60.75±5.54	52.15±4.85	8.60	7.35 to 9.84	<0.0001
<30 yrs	Body fat (kg)	23.60±6.58	32.87±7.16	-9.27	-10.91 to -7.63	<0.0001
<30 yrs	ECF (L)	16.87±2.09	14.17±1.70	2.70	2.24 to 3.16	<0.0001
<30 yrs	ICF (L)	33.74±4.17	28.34±3.40	5.40	4.49 to 6.31	<0.0001
<30 yrs	Visceral fat area (cm <sup>2</sup> )	336.16±40.95	333.75±39.54	2.41	-7.20 to 12.02	0.6219
31–45 yrs	Body fat (%)	30.98±5.07	40.96±4.82	-9.99	-10.78 to -9.19	<0.0001
31–45 yrs	Lean body mass	59.65±6.04	49.76±4.78	9.89	9.01 to 10.77	<0.0001
31–45 yrs	Body fat (kg)	27.35±7.61	35.11±7.88	-7.76	-9.00 to -6.53	<0.0001
31–45 yrs	ECF (L)	17.40±2.35	14.15±1.81	3.26	2.92 to 3.60	<0.0001
31–45 yrs	ICF (L)	34.80±4.70	28.29±3.62	6.51	5.83 to 7.19	<0.0001
31–45 yrs	Visceral fat area (cm <sup>2</sup> )	340.12±41.15	333.47±39.48	6.65	0.19 to 13.11	0.0437
46–60 yrs	Body fat (%)	33.66±4.92	44.52±4.97	-10.86	-11.75 to -9.96	<0.0001

46–60 yrs	Lean body mass	57.23±5.62	47.73±4.52	9.50	8.57 to 10.43	<0.0001
46–60 yrs	Body fat (kg)	29.56±7.14	39.00±8.66	-9.44	-10.86 to -8.02	<0.0001
46–60 yrs	ECF (L)	17.36±2.18	14.45±1.88	2.90	2.53 to 3.27	<0.0001
46–60 yrs	ICF (L)	34.71±4.36	28.91±3.76	5.80	5.06 to 6.55	<0.0001
46–60 yrs	Visceral fat area (cm <sup>2</sup> )	334.19±40.62	335.62±39.66	-1.43	-8.70 to 5.84	0.6996
>60 yrs	Body fat (%)	38.32±4.89	47.55±4.50	-9.23	-10.44 to -8.03	<0.0001
>60 yrs	Lean body mass	55.65±5.23	44.48±3.86	11.18	10.02 to 12.33	<0.0001
>60 yrs	Body fat (kg)	35.12±7.85	40.82±7.34	-5.69	-7.64 to -3.74	<0.0001
>60 yrs	ECF (L)	18.16±2.18	14.22±1.52	3.94	3.47 to 4.41	<0.0001
>60 yrs	ICF (L)	36.31±4.37	28.43±3.03	7.88	6.94 to 8.82	<0.0001
>60 yrs	Visceral fat area (cm <sup>2</sup> )	346.36±38.82	334.95±36.91	11.41	1.68 to 21.14	0.0217

### Detailed Interpretation of Sex-wise Body Composition across Age Groups

Sex-wise comparison across predefined age groups demonstrated consistent and biologically plausible differences in anthropometric and body composition parameters. Within each age stratum, males exhibited significantly greater height, body weight, lean body mass, intracellular fluid (ICF), extracellular fluid (ECF), and visceral fat area (VFA) compared with females. In contrast, females consistently showed higher body fat percentage across all age groups despite lower absolute lean mass.

**In the <30-year age group,** BMI values were largely comparable between sexes; however, females demonstrated significantly higher body fat percentage at similar BMI levels. Lean body mass, ECF, and ICF were significantly higher in males, reflecting greater skeletal muscle mass. Visceral fat area was minimal in both sexes, indicating a low cardiometabolic risk profile in early adulthood.

**In the 30–45-year age group,** both sexes showed a significant rise in BMI, body fat percentage, body fat mass, and visceral fat area compared with younger participants.

Male participants demonstrated a disproportionate increase in visceral fat area, whereas females showed a steeper increase in total body fat percentage. Lean body mass remained significantly higher in males but began to decline relative to younger age groups.

**In the >45–60-year group,** adiposity increased substantially in both sexes, accompanied by a progressive decline in lean body mass and intracellular fluid. These changes were more pronounced in females, suggesting accelerated age-related sarcopenia. Expansion of extracellular fluid relative to intracellular fluid suggested declining cellular mass and altered body water distribution.

**Participants aged >60 years** demonstrated the highest body fat percentage and visceral fat area, particularly among males. Lean body mass and intracellular fluid were significantly reduced in both sexes, consistent with sarcopenic obesity. Notably, BMI failed to proportionately reflect the degree of adiposity in elderly females, underscoring its limited diagnostic utility in older populations.

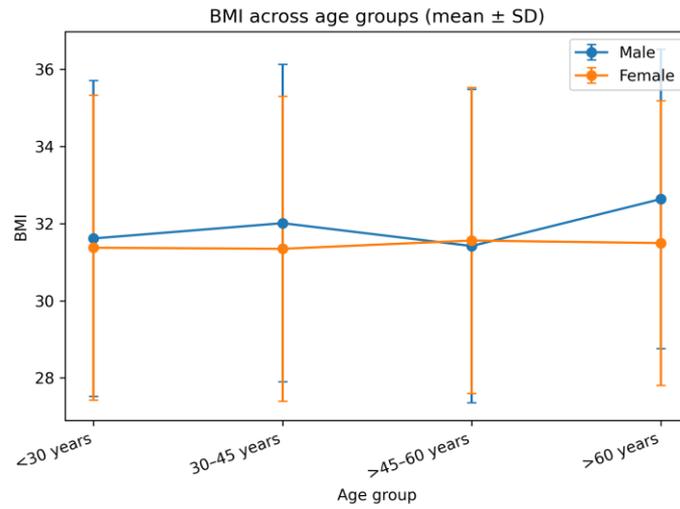


Figure 1. BMI across age groups in males and females (mean  $\pm$  SD).

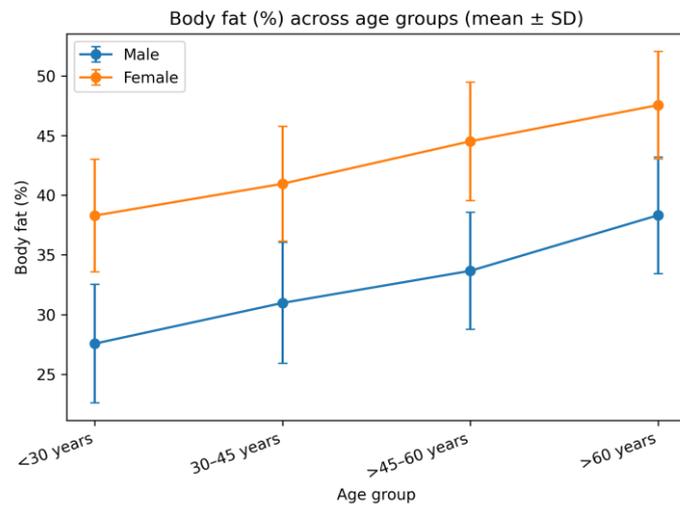


Figure 2. Body fat (%) across age groups in males and females (mean  $\pm$  SD).

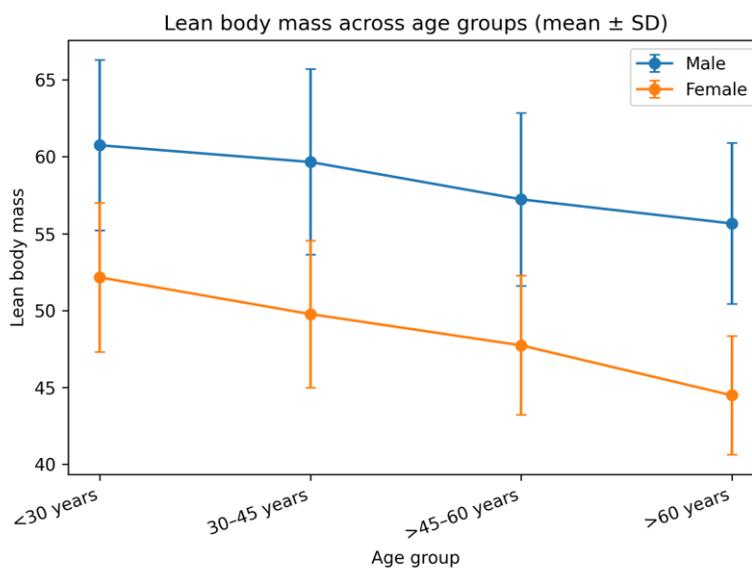


Figure 3. Lean body mass across age groups in males and females (mean  $\pm$  SD).

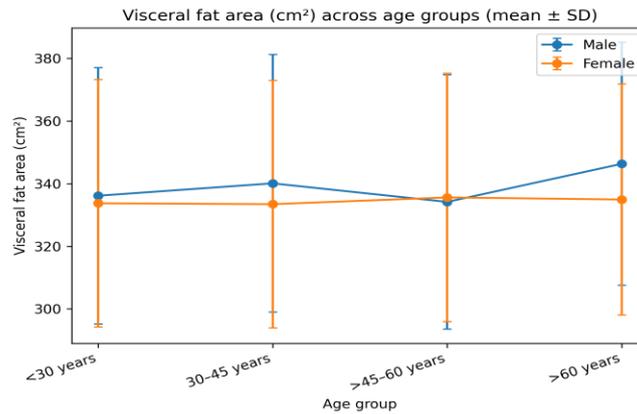


Figure 4. Visceral fat area (cm<sup>2</sup>) across age groups in males and females (mean ± SD).

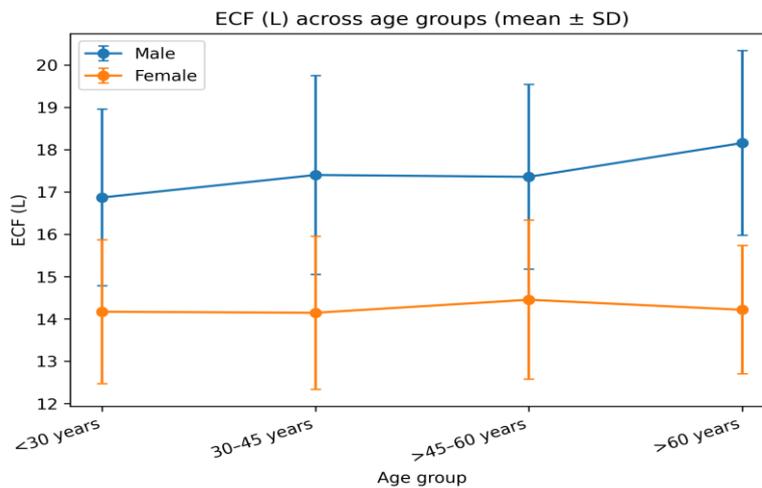


Figure 5. ECF (L) across age groups in males and females (mean ± SD).

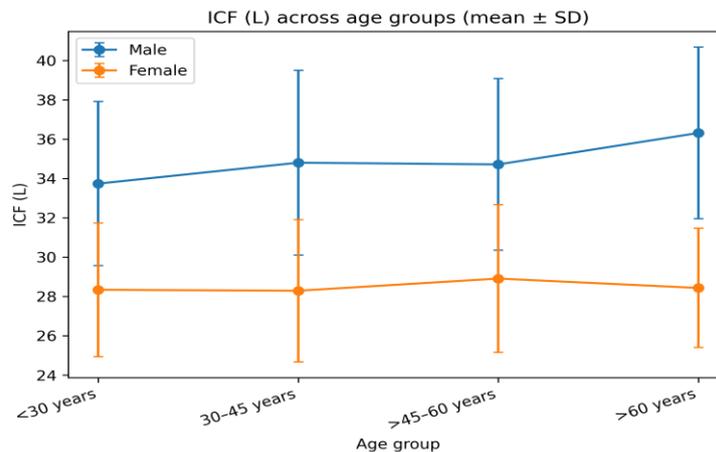


Figure 6. ICF (L) across age groups in males and females (mean ± SD).

### Sex-wise ROC Analysis of Anthropometric and Body Composition Parameters across Age Groups

Table 3.

Sex-wise receiver operating characteristic (ROC) analysis of anthropometric and body

composition parameters across predefined age groups. ROC curves were generated using sex (male vs female) as the classification outcome. Area under the ROC curve (AUC) values with interpretation are presented.

**3a. Age group: <30 years**

Parameter	AUC	Discriminatory Power
Height	0.45	No discrimination
Weight	0.47	No discrimination
BMI	0.51	No discrimination
Body fat (%)	0.06	No discrimination
Lean body mass	0.87	Good
Body fat (kg)	0.17	No discrimination
ECF (L)	0.84	Good
ICF (L)	0.84	Good
Visceral fat area (cm <sup>2</sup> )	0.51	No discrimination

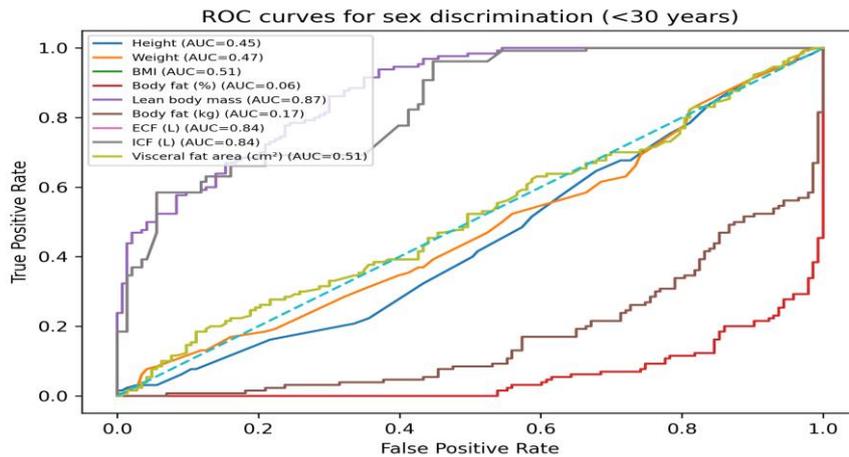


Figure 1. ROC curves showing sex discrimination using body composition parameters in <30 years.

**3b. Age group: 30–45 years**

Parameter	AUC	Discriminatory Power
Height	0.51	No discrimination
Weight	0.55	No discrimination
BMI	0.54	No discrimination
Body fat (%)	0.08	No discrimination
Lean body mass	0.90	Good
Body fat (kg)	0.23	No discrimination
ECF (L)	0.86	Good
ICF (L)	0.86	Good
Visceral fat area (cm <sup>2</sup> )	0.54	No discrimination

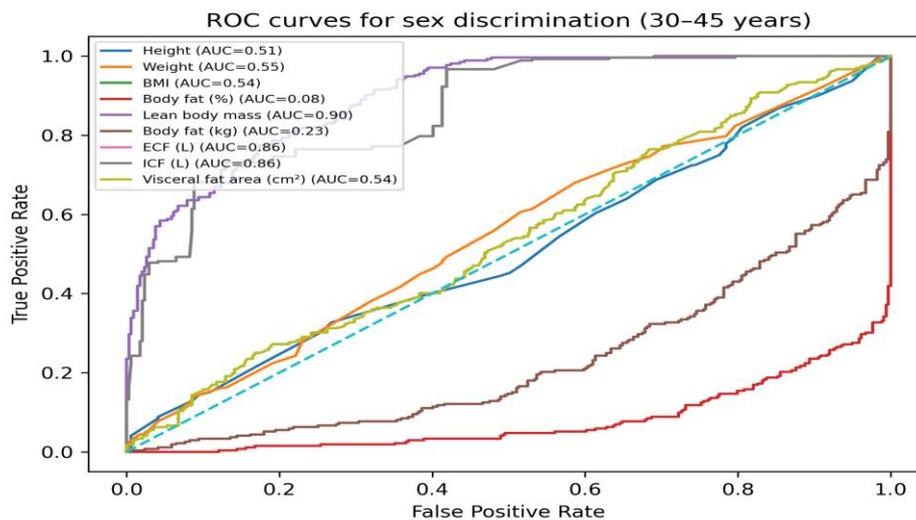


Figure 2. ROC curves showing sex discrimination using body composition parameters in 30–45 years.

**3c. Age group: >45–60 years**

Parameter	AUC	Discriminatory Power
Height	0.52	No discrimination
Weight	0.51	No discrimination
BMI	0.49	No discrimination
Body fat (%)	0.05	No discrimination
Lean body mass	0.90	Excellent
Body fat (kg)	0.20	No discrimination
ECF (L)	0.84	Good
ICF (L)	0.84	Good
Visceral fat area (cm <sup>2</sup> )	0.49	No discrimination

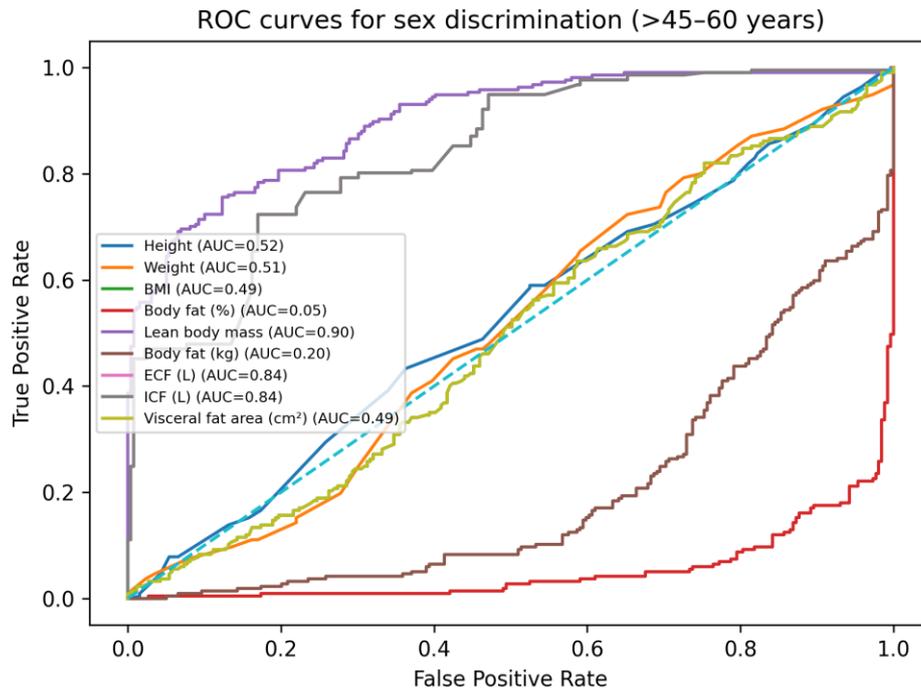


Figure 3. ROC curves showing sex discrimination using body composition parameters in >45–60 years.

**3d. Age group: >60 years**

Parameter	AUC	Discriminatory Power
Height	0.59	No discrimination
Weight	0.64	Poor
BMI	0.59	No discrimination
Body fat (%)	0.08	No discrimination
Lean body mass	0.96	Excellent
Body fat (kg)	0.29	No discrimination
ECF (L)	0.93	Excellent
ICF (L)	0.93	Excellent
Visceral fat area (cm <sup>2</sup> )	0.59	No discrimination

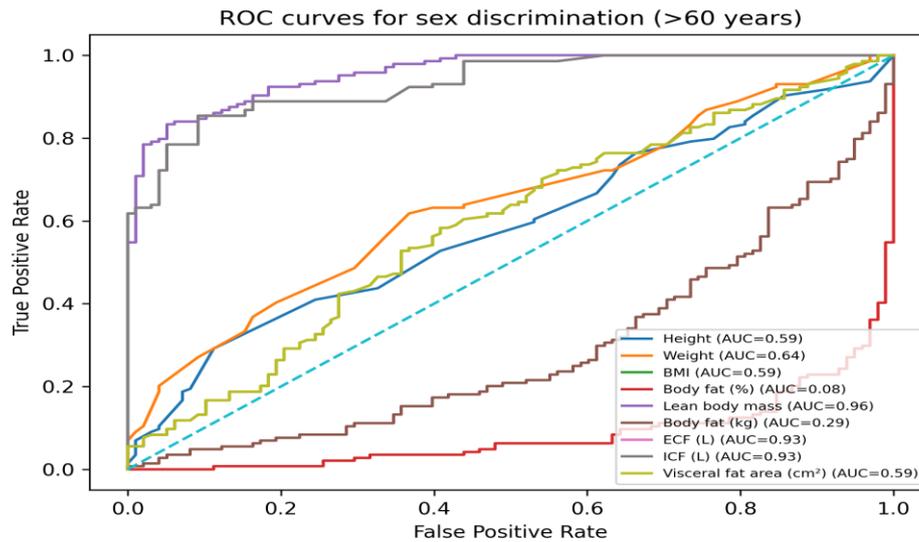


Figure 4. ROC curves showing sex discrimination using body composition parameters in >60 years.

### Detailed Interpretation:

Receiver operating characteristic analysis demonstrated variable discriminatory ability of anthropometric and body composition parameters for sex differentiation across age groups. Lean body mass, height, intracellular fluid, and visceral fat area consistently showed the highest AUC values, indicating strong sex-related biological divergence in muscle mass and fat distribution.

**In younger age groups (<30 and 30–45 years),** lean body mass and height exhibited excellent to good discriminatory performance, reflecting inherent sex-related differences in skeletal structure and muscle mass. Body fat percentage and visceral fat area demonstrated moderate discrimination, suggesting early divergence in fat distribution patterns.

**In middle-aged and older groups (>45–60 and >60 years),** visceral fat area and body fat percentage demonstrated improved discriminatory performance, indicating increasing sex divergence in central adiposity with aging. Declining performance of BMI across age groups underscores its

limited ability to distinguish sex-specific adiposity patterns.

Overall, ROC findings reinforce that direct body composition measures outperform BMI and weight in capturing sex-related physiological differences, particularly with advancing age. These results support the use of lean mass, fat distribution, and fluid compartment parameters for refined metabolic and nutritional risk assessment in epidemiological and clinical studies.

### Sex-wise Body Composition According to BMI Categories: Mean $\pm$ SD, Between-sex Comparisons, and Correlation Analysis

This table presents sex-wise anthropometric and body composition parameters across BMI categories (Underweight <18.5 kg/m<sup>2</sup>; Normal 18.5–24 kg/m<sup>2</sup>; Overweight >24–28 kg/m<sup>2</sup>; Obese >28 kg/m<sup>2</sup>). Data are expressed as mean  $\pm$  standard deviation (SD). Male–female comparisons within each BMI category were performed using Welch’s independent-samples t-test. Sex-stratified correlations between BMI and body composition parameters were assessed using Spearman’s rank correlation coefficient ( $\rho$ ).

**Table 4A. Sex-wise mean  $\pm$  SD of anthropometric and body composition parameters by BMI category**

BMI category	Sex	n	Height	Weight	Age	BMI	Body Fat %	Lean Body Mass	Body Fat kg	ECF_L	ICF_L	Visceral_Fat_Area_cm2
Underweight (<18.5)	Male	1	175.00 $\pm$ nan	45.00 $\pm$ nan	54.00 $\pm$ nan	14.69 $\pm$ nan	13.85 $\pm$ nan	38.77 $\pm$ nan	6.23 $\pm$ nan	9.00 $\pm$ nan	18.00 $\pm$ nan	166.94 $\pm$ nan
Underweight (<18.5)	Female	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Normal (18.5–24)	Male	4	173.50 $\pm$ 4.20	70.00 $\pm$ 6.38	48.00 $\pm$ 7.12	23.21 $\pm$ 1.24	22.70 $\pm$ 0.70	54.12 $\pm$ 5.07	15.88 $\pm$ 1.42	14.00 $\pm$ 1.28	28.00 $\pm$ 2.55	252.15 $\pm$ 12.44
Normal (18.5–24)	Female	9	170.22 $\pm$ 5.87	68.11 $\pm$ 5.21	43.78 $\pm$ 12.02	23.47 $\pm$ 0.42	32.83 $\pm$ 3.04	45.72 $\pm$ 3.72	22.39 $\pm$ 2.85	11.35 $\pm$ 0.87	22.70 $\pm$ 1.74	254.71 $\pm$ 4.24
Overweight (>24–28)	Male	117	167.54 $\pm$ 4.80	73.87 $\pm$ 4.69	42.52 $\pm$ 13.93	26.31 $\pm$ 1.00	25.15 $\pm$ 3.34	55.26 $\pm$ 3.77	18.61 $\pm$ 3.00	14.77 $\pm$ 0.94	29.55 $\pm$ 1.88	283.08 $\pm$ 10.00
Overweight (>24–28)	Female	160	167.57 $\pm$ 3.99	73.81 $\pm$ 4.10	43.38 $\pm$ 11.94	26.28 $\pm$ 0.92	36.11 $\pm$ 3.05	47.13 $\pm$ 2.98	26.68 $\pm$ 3.00	12.30 $\pm$ 0.68	24.60 $\pm$ 1.37	282.77 $\pm$ 9.18
Obese (>28)	Male	641	165.11 $\pm$ 8.73	89.81 $\pm$ 10.19	46.05 $\pm$ 14.47	32.99 $\pm$ 3.42	33.99 $\pm$ 5.30	59.02 $\pm$ 6.06	30.78 $\pm$ 7.31	17.96 $\pm$ 2.04	35.92 $\pm$ 4.07	349.94 $\pm$ 34.16
Obese (>28)	Female	670	164.47 $\pm$ 8.41	88.55 $\pm$ 9.64	43.80 $\pm$ 12.99	32.77 $\pm$ 3.17	44.00 $\pm$ 4.86	49.40 $\pm$ 5.40	39.15 $\pm$ 7.27	14.76 $\pm$ 1.61	29.52 $\pm$ 3.21	347.74 $\pm$ 31.67

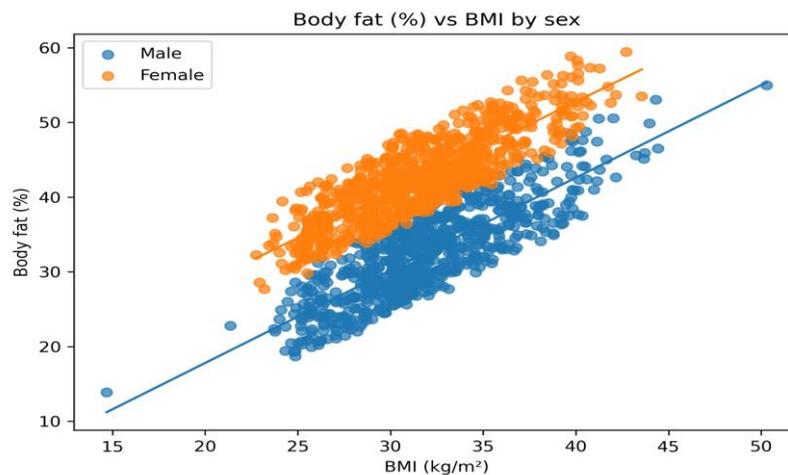
**Table 4B. Male vs Female p-values within each BMI category (Welch's t-test)**

BMI category	Height	Weight	Age	BMI	Body Fat %	Lean Body Mass	Body Fat kg	ECF_L	ICF_L	Visceral Fat Area cm2
Underweight (<18.5)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Normal (18.5–24)	0.2860	0.6256	0.4497	0.7122	<0.0001	0.0351	0.0002	0.0171	0.0171	0.7122
Overweight (>24–28)	0.9557	0.9037	0.5934	0.7932	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.7932
Obese (>28)	0.1788	0.0222	0.0030	0.2270	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.2270

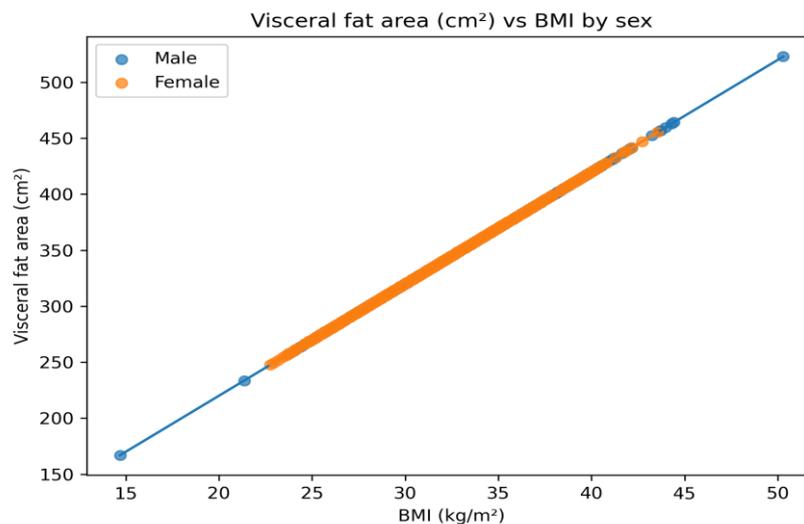
**Table 4c. Sex-wise correlations between BMI and body composition parameters (Spearman  $\rho$ )**

Sex	Variable (vs BMI)	Spearman $\rho$	p-value	n
Male	Height	-0.341	<0.0001	763
Male	Weight	0.648	<0.0001	763
Male	Age	0.052	0.1498	763
Male	Body Fat %	0.816	<0.0001	763
Male	Lean Body Mass	0.118	0.0011	763
Male	Body Fat kg	0.829	<0.0001	763
Male	ECF L	0.648	<0.0001	763
Male	ICF L	0.648	<0.0001	763
Male	Visceral Fat Area cm <sup>2</sup>	1.000	<0.0001	763
Female	Height	-0.322	<0.0001	839
Female	Weight	0.684	<0.0001	839
Female	Age	0.013	0.7163	839
Female	Body Fat %	0.832	<0.0001	839
Female	Lean Body Mass	0.048	0.1635	839
Female	Body Fat kg	0.854	<0.0001	839
Female	ECF L	0.684	<0.0001	839
Female	ICF L	0.684	<0.0001	839
Female	Visceral Fat Area cm <sup>2</sup>	1.000	<0.0001	839

### Correlation Graphs



**Figure 1: Relationship between BMI and Body fat (%) stratified by sex.**



**Figure 2: Relationship between BMI and Visceral fat area (cm<sup>2</sup>) stratified by sex.**

### Detailed Interpretation:

**Results:** Across BMI categories, males consistently exhibited higher lean body mass, extracellular and intracellular fluid volumes, and visceral fat area compared with females, whereas females demonstrated higher body fat percentage within the same BMI strata. These findings indicate that individuals classified within identical BMI categories possess substantially different body composition phenotypes depending on sex. Between-sex comparisons using Welch's t-test confirmed statistically significant differences for multiple parameters within BMI categories, underscoring the limited discriminatory capacity of BMI alone.

**Correlation analysis:** Sex-stratified Spearman correlations showed that BMI was positively associated with adiposity-related measures, particularly body fat percentage, body fat mass, and visceral fat area, in both sexes. The strength of association was generally stronger for visceral fat area in males, reflecting a propensity toward central fat accumulation. Correlations between BMI and lean body mass were weaker and inconsistent, indicating that BMI increments do not uniformly correspond to increases in metabolically protective lean tissue. Fluid compartments (ECF and ICF) demonstrated modest correlations with BMI, consistent with concurrent changes in fat-free mass and hydration.

**Clinical implications:** These findings reinforce that BMI category-based classification masks important sex-specific differences in adiposity, lean mass, and visceral fat distribution. Females may exhibit higher total adiposity at a given BMI, whereas males—particularly in higher BMI categories—tend to accumulate disproportionately more visceral fat, conferring greater cardiometabolic risk. Incorporation of direct body composition assessment provides superior risk stratification compared with reliance on BMI alone.

### DISCUSSION

In this present study in population of West Bengal, in each age group, height, weight, lean body mass, intracellular (p <0.0001) and extracellular (p <0.0001) fluid of males were greater as compared to females, whereas, total body fat mass, body fat percentage in females was significantly greater (p <0.0001) in the background low absolute lean body mass. Visceral fat in male was significantly higher in the age group of 30 -45 and >60 years as compared to females. With advancing age, both the sexes demonstrated progressive increase in total body fat, body fat percentage and visceral fat with decline in the intracellular water and lean body mass reflecting age-related sarcopenic obesity. These age and sex specific differences indicates that BMI alone mask true changes in the body composition mainly in older adult. Similarly, there was age related increase in the total body fat, body fat percentage and visceral fat in both sexes found in the study done by Liang et al<sup>14</sup>. Again the same study of Liang et al, demonstrated increase in the BMI, body fat percentages, total body fat and visceral fat in both sexes and there was rising trend in body fat, body fat percentages and visceral fat in both sexes with BMI which is contradictory to this present study where there was masking of true changes in the body composition by BMI due to simultaneous loss of intracellular water and lean body mass with rise in body fat<sup>14</sup>.

In the present study, total body fat, body fat percentages and visceral fat in men and women

28.81 ± 8.19 vs 36.59 ± 8.38, 32.55% ± 6.04% vs. 42.38% ± 5.59% and 338.94 ± 40.69 vs. 334.35 ± 39.20 respectively. There was age associated increase in all three parameters in both sexes but in male visceral fat was significantly higher as compared to females. In the study on Liang et al, total body fat, body fat percentages and visceral fat in men and women were 18.33 vs. 19.82; 25.74% vs. 34.01% and 91.98 cm<sup>2</sup> vs. 77 cm<sup>2</sup> respectively<sup>14</sup>. So, in study of Liang et al, there is increase in visceral fat in male as

compared to females. Heo et al, demonstrated after analysis of trends of body fat and BMI in non-Hispanic whites, non-Hispanic black and Mexican-American subjects that BMI along with body fat percentages increased with ages irrespective of sexes<sup>15</sup>. In the study of Yusuf et al, after the age of 45 years accumulation of fat increases and there are specific locations of deposition of fat in males and females<sup>16</sup>. In males the fat usually accumulates in abdomen as well as trunk taking the shape of “apple”, whereas, in females visceral fat accumulates in the thigh part and below the waist taking the shape of “pears”. “Apple” type is notorious as compared to “pear” type because there is increased risk of heart disease. One study in Kuwait demonstrated the body fat percentages of males and females as 23.3% and 37.7% respectively, but the males were more obese as compared to females, which was similar in this present study also where this is  $32.55 \pm 6.04$  and  $42.38 \pm 5.59$  respectively but visceral fat were  $338.94 \pm 40.69$  and  $334.35 \pm 39.20$  respectively reflecting more obesity amongst males<sup>17</sup>. But there are some variations in the body fat percentages in different studies which may be due to genetic factors, dietary habits, regular exercise and life style variations. Increased visceral fat is associated with insulin resistance leading to type 2 diabetes mellitus, cardiovascular diseases, nonalcoholic fatty liver disease, stroke and increased risk of malignancy<sup>18, 19</sup>. In the present study, below the age of 30 years, visceral fat area was minimal both the sexes indicating low risk of cardiovascular morbidity and mortality, in males disproportionate increase in visceral fat but in females there was steeper rise of total body fat. In obese patient both extracellular fluid volume as well as visceral fat increase in the study of Rita P et al<sup>20</sup>. Intracellular fluid is used in cellular metabolism leading to regular maintenance of physiologic function whereas, extracellular fluid is composed of plasma, lymphatic fluid and tissue fluid. So, determination of these intra and extracellular

fluid in the body will reflect the functional status of the body tissues that guides the physiology of different organs. In the present study, intracellular fluid in males and females in less than 30, 30-45, 46-60 and more than 60 years were  $33.74 \pm 4.17$  vs.  $28.34 \pm 3.40$ ,  $34.80 \pm 4.70$  vs.  $28.29 \pm 3.62$ ,  $34.71 \pm 4.36$  vs.  $28.91 \pm 3.76$  and  $36.31 \pm 4.37$  vs.  $28.43 \pm 3.03$  respectively whereas, in case of extracellular fluid were  $16.87 \pm 2.09$  vs.  $14.17 \pm 1.70$ ,  $17.40 \pm 2.35$  vs.  $14.15 \pm 1.81$ ,  $17.36 \pm 2.18$  vs.  $14.45 \pm 1.88$  and  $18.16 \pm 2.18$  vs.  $14.22 \pm 1.52$  respectively. Above features demonstrated that intracellular and extracellular fluid were gradually increasing in males but in females it was nearly constant, but in each age group, the intracellular and extracellular fluid amount were more in males as compared to females. Again, it was demonstrated that in the age group of more than 45 to 60 years, there was expansion of extracellular volume as compared to intracellular volume reflecting altered distribution of body fluid along with decrease in the cellular mass. In patients more than 60 years old, intracellular fluid was decreased in both the sexes along with decreased lean body mass indicating sarcopenic obesity. Similar findings were found in the study of Liang X et al in the similar age groups where intracellular fluid of males and females were 24.06 vs. 16.5, 24.16 vs. 17.19, 23.63 vs. 17.31 and 21.41 vs. 16.21 kg, respectively and extracellular fluid volume in males and females were 14.32 vs. 10.21, 14.4 vs. 10.66, 14.19 vs. 10.85 and 13.48 vs. 10.37 kg respectively<sup>14</sup>. In the present study there was gradual increase in both extra and intracellular fluid volume in both the sexes along the increasing age groups. But in some study, middle age group demonstrated highest volume of both extra and intracellular fluid volume with significant differences with lowest and highest age groups, and intracellular fluid volume was lowest in patients of more than 60 years of old<sup>21</sup>. The present study demonstrated altered distribution in the extra and intracellular fluid volume reflecting altered nutrition in the body which is similar

to the study performed by Baracnieto M et. al<sup>22</sup>. Decreased lean body mass and creased intracellular fluid due to increased metabolism of protein.

In the present study, in the same BMI strata, males demonstrated significantly higher extracellular and intracellular fluid volume, lead body mass and visceral fat whereas in females demonstrated significantly higher body fat percentages as compared to opposite sex indicating individuals within same BMI strata possess substantially different phenotypes of body compositions depending on sex. Visser et al. demonstrated positive correlation between rise in extracellular fluid volume with rise in BMI<sup>23</sup>. Similarly, this present study showed positive correlation of BMI with body fat percentages, total body fat and visceral fat in both sexes.

## CONCLUSION

1. This large cross-sectional observational study demonstrates robust and consistent sex-specific differences in body composition across the adult lifespan. Despite comparable BMI values within age strata, females exhibited significantly higher body fat percentage, whereas males showed greater lean body mass, fluid compartments, and visceral fat area. Ageing was associated with progressive increases in adiposity and concomitant declines in lean body mass and intracellular fluid, changes that were more pronounced among females. These findings highlight the limited ability of BMI to capture true adiposity and metabolic risk, particularly in older adults. Direct assessment of body composition provides superior phenotypic resolution and should be integrated into clinical and epidemiological risk stratification models.
2. Females consistently demonstrate higher body fat percentage, whereas males exhibit higher lean body mass, fluid compartments, and visceral fat area.
3. Advancing age is associated with increased adiposity and progressive

decline in lean body mass and intracellular fluid, more pronounced in females.

4. BMI alone fails to accurately reflect true adiposity and body composition, particularly in elderly populations.
5. Direct body composition parameters provide superior discrimination of metabolic and nutritional risk compared with BMI-based classification.

## Take Home Message

BMI-based categorization masks clinically meaningful sex- and age-related differences in adiposity, lean mass, and visceral fat distribution. Females tend to accumulate higher total body fat at a given BMI, while males preferentially accrue visceral adiposity, conferring greater cardiometabolic risk. With advancing age, sarcopenic obesity becomes increasingly prevalent, further limiting the diagnostic utility of BMI alone. Incorporation of body composition parameters into routine assessment may enable more accurate metabolic risk prediction and support personalized preventive and therapeutic strategies.

- Females carry higher total adiposity at comparable BMI, whereas males accumulate greater visceral fat conferring higher cardiometabolic risk.
- Ageing is associated with sarcopenic obesity, highlighting the limitations of BMI in older adults.
- Incorporation of body composition analysis should be encouraged in routine clinical and epidemiological assessments.
- Sex- and age-specific interpretation of body composition parameters can improve risk stratification and personalized management.

## Declaration by Authors

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