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Body Composition and Its Determinants among Nepali Speaking Adult Males of West Bengal, India

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Abstract

Introduction: Body composition assessment plays a crucial role in evaluating health risks associated with excess or inadequate body fat. The determination of body composition is a common practice for evaluating health and nutritional status. In modern times, analyzing body composition has become vital for understanding nutritional health, disease risks, and overall well-being. **Methods:** This cross-sectional study examines age-specific variations in body composition and the influence of socio-demographic and lifestyle factors among 284 adult male tea estate workers (aged 18–59 years) from the Jorebunglow Sukhiapokhari block, Darjeeling district, West Bengal, India. Anthropometric and body composition parameters, including height, weight, BMI, body fat percentage, subcutaneous fat percentage, visceral fat percentage, and skeletal muscle percentage, were measured for the present report using the Omron Karada Scan HBF-514C Body Fat Analyzer. One-way ANOVA with post hoc Scheffé tests was applied to assess age-related differences of various body composition variables. **Results:** The results indicate significant age-associated increases in body fat and visceral fat percentages, alongside a progressive decline in skeletal muscle percentage. BMI and body fat percentage peaked in the 30–39 years age group before declining in older participants. Correlation analysis revealed positive associations between age and fat parameters, whereas skeletal muscle percentage showed a strong negative correlation with age. Socio-demographic and lifestyle factors, including physical activity, housing conditions, alcohol and tobacco consumption, were significantly linked to body composition. Individuals who engaging in regular physical activity exhibited lower body fat and visceral fat percentages. Additionally, obesity showed a strong association with increased fat accumulation in older age group. **Conclusion:** These findings highlight the progressive impact of aging on body composition and underscore the role of lifestyle factors in modulating health risks among tea estate workers.

Keywords: Body composition, Body fat percentage, Visceral fat percentage, Sociodemographic and lifestyle factors.

Resumen

Introducción: La evaluación de la composición corporal desempeña un papel crucial en la valoración de los riesgos para la salud asociados con el exceso o la insuficiencia de grasa corporal. La determinación de la composición corporal es una práctica común para evaluar el estado de salud y nutricional. En la actualidad, el análisis de la composición corporal se ha vuelto vital para comprender la salud nutricional, los riesgos de enfermedades y el bienestar general. **Métodos:** Este estudio transversal examina las variaciones en la composición corporal según la edad y la influencia de los factores sociodemográficos y de estilo de vida en 284 trabajadores varones adultos (de 18 a 59 años) de plantaciones de té del bloque Jorebunglow Sukhiapokhari, distrito de Darjeeling, Bengala Occidental, India. Para este estudio se midieron parámetros antropométricos y de composición corporal, incluyendo altura, peso, IMC, porcentaje de grasa corporal, porcentaje de grasa subcutánea, porcentaje de grasa visceral y porcentaje de músculo esquelético, utilizando el analizador de grasa corporal Omron Karada Scan HBF-514C. Se aplicó un análisis de varianza unidireccional (ANOVA) con pruebas post hoc de Scheffé para evaluar las diferencias relacionadas con la edad en diversas variables de composición corporal. **Resultados:** Los resultados indican aumentos significativos relacionados con la edad en los porcentajes de grasa corporal y grasa visceral, junto con una disminución progresiva en el porcentaje de músculo esquelético. El IMC y el porcentaje de grasa corporal alcanzaron su punto máximo en el grupo de edad de 30 a 39 años antes de disminuir en los participantes de mayor edad. El análisis de correlación reveló asociaciones positivas entre la edad y los parámetros de grasa, mientras que el porcentaje de músculo esquelético mostró una fuerte correlación negativa con la edad. Los factores sociodemográficos y de estilo de vida, incluyendo la actividad física, las condiciones de vivienda, el consumo de alcohol y tabaco, se asociaron significativamente con la composición corporal. Las personas que realizaban actividad física regularmente mostraron menores porcentajes de grasa corporal y grasa visceral. Además, la obesidad mostró una fuerte asociación con una mayor acumulación de grasa en el grupo de edad avanzada. **Conclusión:** Estos hallazgos destacan el impacto progresivo del envejecimiento en la composición corporal y subrayan el papel de los factores del estilo de vida en la modulación de los riesgos para la salud entre los trabajadores de las plantaciones de té.

Palabras Clave: Composición corporal, Porcentaje de grasa corporal, Porcentaje de grasa visceral, Factores sociodemográficos y de estilo de vida.

Introduction

Body composition assessment provides clinical and epidemiological information about health outcomes, including the metabolic risks associated with the prevalence of low or high body fat (Holmes and Racette 2021). Nutritional status is defined as “the condition of the body, resulting from the balance of intake, absorption, and utilization of nutrients and the influence of particular physiological and pathological status” (WHO 2003; Andreoli *et al.,* 2016). Assessing nutritional status is essential at both the individual and population levels. In clinical practice, it helps diagnose and manage nutrition-related conditions, while in public health and epidemiology, it aids in identifying populations at risk (Andreoli *et al.,* 2016). Anthropometric and body composition assessments play a critical role in identifying various nutritional issues, such as obesity, undernutrition, osteoporosis, sarcopenia, and sarcopenic obesity, among both adults and youth (Holmes and Racette 2021). Large amounts of visceral fat (VAT) are related to increased cardiac risk (Neeland *et al.,* 2013).

The determination of body composition is a common practice for evaluating health and nutritional status (Campa *et al.,* 2021). In modern times, analyzing body composition has become vital for understanding nutritional health, disease risks, and overall well-being. Anthropometric data are reliable indicators of an individual's health and nutritional condition. Population-based body composition data provide valuable insights for evaluating health trends. Although human morphology evolves over time, the extent and nature of these changes vary across individuals due to gene-environment interactions (Strickland & Ulijaszek 1993; Orr *et al.,* 2001). Significant morphological changes occur until late adolescence due to growth and development, while changes in adulthood and old age primarily result from alterations in bone structure, fat distribution, and muscle tissue (Strickland & Ulijaszek, 1993; Orr *et al.,* 2001; Bose, 2002). These cumulative changes over time are often referred to as age-related transformations (Das *et al.,* 2010).

There are various techniques for assessing body composition, such as BIA, advanced imaging techniques such as dual-energy X-ray absorptiometry (DEXA) (Piettrobelli *et al.,* 1996; Liao *et al.,* 2020), computed tomography (CT), and magnetic resonance imaging (MRI) (Heymsfield *et al.,* 2005; Ayvaz *et al.,* 2011; Macdonald *et al.,* 2011) provide more accurate measurements of body composition. Other methods include air displacement plethysmography (ADP) (Dempster *et al.,* 1995) and hydrostatic weighing (Macdonald *et al.,* 2011). However, these techniques are often costly, time-consuming, and less accessible, making them unsuitable for routine use in clinical or large-scale population studies. As a result, anthropometric measurements and BIA remain the most commonly used methods in research and clinical settings (Sinha *et al.,* 2018; Holmes and Racette 2021).

Bioelectrical impedance analysis (BIA) is a relatively cheaper method of estimating body fat (Lokpo *et al.,* 2023). Furthermore, the BAI performs well in different populations (Bergman *et al.,* 2011). Though BIA requires different model parameters to be used depending on age, gender, level of physical activity, amount of body fat and ethnicity to be a reliable factor should be considered (Haroun *et al.,* 2010).

The Bioelectrical Impedance Analysis (BIA) method works by utilizing the distinct electrical properties conductivity and resistance of the human body's tissues. This distinction allows it to differentiate between two major tissue components: fat mass and fat-free mass.Body composition traits, including fat mass (Hughes et al., 2004), muscle mass (Gallagher *et al.,* 1997), total body water, and bone mineral content (Singhal *et al.,* 1983), peak at different stages and at varying rates. Furthermore, optimal levels of visceral fat, subcutaneous fat, and skeletal muscle mass are achieved at different times (Boneva-Asiova *et al.,* 2011). One of the most practical and widely used methods to estimate muscle mass, especially in large population studies, is bioelectrical impedance analysis (BIA). BIA works by transmitting a low-level electrical current through the body from hand to foot and measuring the body’s resistance to the current. Since tissues have varying electrical conductivity based on their water content, these resistance values help estimate skeletal muscle mass or overall lean body mass. Additionally, BIA can estimate body fat mass by subtracting lean body mass from total body weight. FFM has high electrical conductivity, while FM has low electrical conductivity (high impedance) (Borga *et al.,* 2018). The primary objective of body composition analysis in clinical practice is to evaluate nutritional status by quantifying fat mass (FM), fat-free mass (FFM), bone mineral content, and total body water (both intracellular and extracellular). While no universally accepted method exists for assessing nutritional status (Reber *et al.,* 2019), body composition analysis provides valuable insights for identifying, diagnosing, and managing medical conditions requiring nutritional intervention. A comprehensive understanding of the methodology, advantages, and limitations of current and emerging body composition assessment tools is essential for clinicians, dietitians, and other healthcare professionals involved in nutrition management. Moreover, as healthcare becomes increasingly outcome-driven, using valid and reliable methods to evaluate the effectiveness of nutrition interventions is crucial (Holmes and Racette 2021).

The growing demand for body composition data is driven by various factors, including the need to prevent malnutrition among institutionalized individuals, screen for health risks, develop and evaluate interventions, study changes in fat distribution and stature loss, analyze the relationship between fat patterning and mortality, provide prognostic indicators for treatment, and establish improved reference standards for both ambulatory and non-ambulatory individuals (Sinha *et al.,* 2018). Given these observations, changes in muscle and fat composition with age are distinct and vary across populations, with occupation playing a critical role in these differences. Consequently, this study aims to:

- Analyze age-related trends in anthropometric and body composition variables and age-specific variations among adult males working in the tea estates of Darjeeling.
- Investigate the relationship between sociodemographic and lifestyle factors with body fat percentage and visceral fat percentage in the studied population.

Material and Methods

The present cross-sectional study was conducted among 284 adult tea estate working males aged 18-59 from Jorebunglow, Sukhiapokhari block in Darjeeling district, West Bengal, India. Before collecting data, verbal consent was obtained from each respondent. All participants were in apparent good health and free from physical deformities in tea estates. The data was collected from March to April in 2024.

Data regarding socio-demographic and lifestyle factors, including regular physical activity, alcohol consumption, and tobacco use, were collected using a pre-tested schedule. Standardized procedures were followed for all anthropometric measurements to ensure accuracy and consistency (Lohman *et al.,* 1988). Bilateral measurements were consistently taken on the left side of the body. The collected information, including subject ID, height, weight, sex, and age was then entered into the Omron Karada Scan HBF-514C Body Fat Analyzer, a device manufactured by OMRON HEALTHCARE Co., Kyoto, Japan, to assess body composition. A review of the existing literature confirms that this device has been widely used in numerous studies for estimating body composition.

The classification of overweight and obesity in this study was based on BMI cut-offs set at greater than 23.0 kg/m² for overweight and greater than 25.0 kg/m² for obesity, following the guidelines established by WHO 2000. For waist-to-hip ratio (WHR), the threshold was set at greater than 0.9 for men (Webb 2002), while a waist-to-height ratio (WHtR) cut-off of 0.5 was applied uniformly for both sexes (Hsieh and Muto 2004).

Body fat percentage and visceral fat percentage were assessed based on the cut-off values established by Gallagher et al., 2000 and the Omron Healthcare manual 2008. According to these guidelines, the classification for body fat percentage in adult males is as follows:

- Normal: Less than 22%
- High: Greater than 22%

Similarly, visceral fat percentage was categorized as:

- Normal: Less than or equal to 9%
- High: Greater than 9%

These established thresholds were used to interpret the body composition data of the participants accurately.

Statistical Analysis

The statistical analysis of the collected data was carried out using appropriate methods and tools. All analyses were conducted using IBM SPSS software (version 23.0, SPSS Inc., Chicago, IL), with a significance level set at $p < 0.05$ for all tests. To assess age-specific variations in anthropometric and body composition parameters, a one-way analysis of variance (ANOVA) was applied. For variables that exhibited significant differences, post hoc Scheffé tests were performed to identify specific variations between different age groups.

Chi-square tests were utilized to explore the associations between body fat percentage and visceral fat percentage with various socio-demographic and lifestyle factors. These tests were also employed to determine the relationships between BMI and both total body fat and visceral fat, as well as to assess the correlations between fat distribution and waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR). Furthermore, bivariate correlation analysis was used to evaluate the relationship between body composition parameters and age.

Results

Table 1. Age trends and age-specific anthropometric and body composition variables among the studied population

Variables	Age-specific variation of the descriptive statistics (Mean ± SD)				Total 18-59 yrs	F-value
	18-29 yrs (I)	30-39 yrs (II)	40-49 yrs (III)	50-59 yrs (IV)		
Height (cm)	161.3±8.0	162.1±8.1	163.1±7.8	160.0±8.7	161.6±8.3	2.232ns
Weight (kg)	56.0±9.1	62.7±9.1	59.4±10.6	56.6±11.2	58.7±10.5	5.822**
BMI (kg/m²)	21.6±4.0	24.0±3.6	22.3±4.0	22.0±4.0	22.4±3.9	4.377**
Body Fat (%)	17.4±5.2	22.0±5.0	20.3±5.6	20.0±6.0	20.1±5.5	5.850**
Subcutaneous Fat Whole body (%)	10.8±4.5	14.4±4.4	13.5±4.7	13.2±5.0	13.1±4.8	5.562**
Visceral Fat (%)	4.6±3.1	8.0±4.0	7.4±3.6	7.3±4.4	7.0±4.0	8.167***
Skeletal Muscle Whole body (%)	36.0±3.5	32.2±2.7	32.3±4.0	30.0±4.0	32.0±4.0	27.619***
Waist Hip Ratio (WHR)	0.90±0.06	0.92±0.06	0.92±0.05	0.93±0.04	0.91±0.05	8.859**
Waist Height Ratio (WHtR)	0.48±0.08	0.52±0.07	0.53±0.06	0.52±0.07	0.51±0.07	4.230**

At the significance level of *p<0.05 ** p<0.01, *** p<0.001, ns p>0.05 (statistically not significant).

Table 1 presents age-specific trends and variations in anthropometric and body composition parameters among the studied population aged 18 to 59 years. Height showed no statistically significant variation across age groups (F = 2.232, ns). However, significant differences were observed in weight (F = 5.822, p < 0.01), with the highest values recorded in the 18–29 years age group. BMI also exhibited significant variation across age groups (F = 4.377, p < 0.01), showing a peak in the 18–29 years group. Body fat percentage (F = 5.850, p < 0.01) and subcutaneous fat percentage (F = 5.562, p < 0.01) increased with age, while visceral fat percentage (F = 8.167, p < 0.001) was notably higher in older age groups. Skeletal muscle percentage demonstrated a significant decline with age (F = 27.619, p < 0.001), being highest in the youngest group and progressively decreasing in older groups. Waist-to-hip ratio (WHR) (F = 8.859, p < 0.01) and waist-to-height ratio (WHtR) (F = 4.230, p < 0.01) showed significant age-related variations, indicating higher values in older age groups. These findings highlight progressive changes in body composition, particularly increased fat deposition and decreased muscle mass with advancing age.

Table 2 presents the between- and within-group variations in anthropometric and body composition parameters among different age groups of the studied population. Post hoc Scheffé ANOVA analysis revealed significant differences across several parameters. Weight showed a notable decline between the 18–29 years group (I) and the 30–39 years group (II) (p < 0.01) and a significant increase between groups II and IV (p < 0.01). BMI displayed a significant reduction between groups I and II (p < 0.01) and a slight but significant increase between II and IV (p < 0.01). Body fat percentage and subcutaneous fat percentage demonstrated highly significant declines between groups I and II (p < 0.001 and p < 0.01, respectively) and continued decreasing through older age groups, with variations between I and IV remaining significant. Visceral fat percentage showed significant differences between younger and older age groups, particularly between I and II (p < 0.001) and I and IV (p < 0.01). Skeletal muscle percentage consistently declined with age, showing highly significant differences between I and all other groups (p < 0.001) and between II and IV (p < 0.01). Waist-to-hip ratio (WHR) exhibited significant reductions between I and older groups, especially between I and III (p < 0.001), while waist-to-height ratio (WHtR) showed minor but statistically significant differences between I and III ($p < 0.05$) and I and IV ($p < 0.01$). These findings indicate progressive changes in body composition, with increases in fat and decreases in muscle mass across age groups.

Table 2. Between/Within age group variation of anthropometric and body composition variables of the studied population

Variables	Age Groups					
	I vs II	I vs III	I vs IV	II vs III	II vs IV	III vs IV
Weight (kg)	-6.739**	-3.418ns	-.596ns	3.320ns	6.142**	2.822ns
BMI (kg/m^2)	-2.354**	-.710ns	-.457ns	-1.643*	1.896**	.252ns
Body Fat (%)	-4.290***	-2.941**	-2.641*	1.349ns	1.649ns	.299ns
Subcutaneous Fat (%)	-3.604**	-2.647**	-2.421*	.956ns	1.182ns	.226ns
Visceral Fat (%)	-3.358***	-2.749**	-2.799**	.609ns	.559ns	-.049ns
Skeletal Muscle (%)	3.517***	3.491***	5.701***	-.026ns	2.183**	2.210**
WHR	-0.028*	-0.039***	-0.042***	-0.010ns	-0.014ns	-0.003ns
WHtR	-0.035ns	-0.037*	-0.042**	-0.002ns	-0.006ns	-0.004ns

At the significance level of *p<0.05 ** p<0.01, *** p<0.001, ns p>0.05(statistically not significant).

Table 3. Association between sociodemographic and lifestyle factors with Body fat Percentage and Visceral Fat Percentage cut-off established by Gallagher et al., 2000 and the Omron Healthcare manual 2008:

Variables	Body Fat (%)			Visceral Fat (%)			Total
	Normal (<22%)	High (>22%)	$\chi 2$	Normal (≤9%)	High (>9%)	$\chi 2$	
Age groups							
18-29 yrs	38 (79.1%)	10 (20.9%)	8.105*	43 (89.5%)	5 (10.5%)	14.029**	48
30-39 yrs	34 (53.1%)	30 (46.9%)		37 (57.8%)	27 (42.2%)		64
40-49 yrs	50 (64.1%)	28 (35.9%)		50 (64.1%)	28 (35.9%)		78
50-59 yrs	59 (62.7%)	35 (37.3%)		65 (69.1%)	29 (30.9%)		94
House Type							
Semi-Pucca	132 (67.3%)	64 (32.7%)	3.575*	138 (70.4%)	58 (29.6%)	0.896ns	196
Pucca	49 (55.6%)	39 (44.4%)		58 (65.1%)	31 (34.9%)		89
Regular Physical Activity							
Yes	110 (70.5%)	46 (29.5%)	6.884**	115 (73.7%)	41 (22.3%)	4.112*	156
No	71 (55.4%)	57 (44.6%)		80 (62.5%)	48 (37.5%)		128
Alcohol Consumption							
Yes	109 (64.4%)	60 (35.6%)	0.106ns	118 (69.8%)	51 (30.2%)	0.261*	169
No	72 (62.6%)	43 (37.4%)		77 (66.9%)	38 (33.0%)		115
Tobacco Consumption							
Yes	96 (66.2%)	49 (33.8%)	0.785*	100 (68.9%)	45 (31.0%)	0.013ns	145
No	85 (61.1%)	54 (38.9%)		95 (68.3%)	44 (31.7%)		139

At the significance level *p<0.05 ** p<0.01, ns p>0.05(statistically not significant),

Table 3 shows an association between socio-demographic and lifestyle variables with Body Fat % and Visceral Fat %. The analysis reveals significant associations between socio-demographic and lifestyle variables with body composition among studied males. Age showed a clear impact, with younger individuals (18–29 years) having the lowest body fat and visceral fat percentages, while the 30–39 age group exhibited the highest levels ($p < 0.05$ and $p < 0.01$). Individuals living in pucca houses had a higher prevalence of high body fat compared to those in semi-pucca houses ($p < 0.05$), though the association with visceral fat was not significant. Regular physical activity was linked to lower body fat and visceral fat levels ($p < 0.01$ and $p < 0.05$, respectively). Alcohol consumption shows a statistically significant relationship with visceral fat % but not with body fat %, whereas tobacco consumption was weakly associated with body fat percentage ($p < 0.05$) but not with visceral fat. These findings suggest that physical activity and age significantly influence body composition.

Table 4 presents the correlation between age, anthropometric variables, and body composition parameters. Age showed a positive correlation with body fat percentage ($r = 0.120$, $p < 0.05$), subcutaneous fat ($r = 0.111$, $p < 0.05$), visceral fat ($r = 0.201$, $p < 0.01$), WHR ($r = 0.305$, $p < 0.001$), and WHtR ($r = 0.229$, $p < 0.001$), but a negative correlation with skeletal muscle percentage ($r = -0.466$, $p < 0.001$). Height had a positive correlation with skeletal muscle ($r = 0.296$, $p < 0.001$) and a negative correlation with BMI ($r = -0.212$, $p < 0.001$), body fat ($r = -0.176$, $p < 0.01$), and WHtR ($r = -0.315$, $p < 0.001$). Weight, BMI, and fat parameters showed strong positive correlations with each other, while skeletal muscle percentage was negatively correlated with all fat-related parameters. WHR and WHtR also demonstrated significant positive correlations with fat parameters and BMI.

Table 5 examines the association of BMI categories with the body fat percentage and visceral fat percentage cut-offs among different age groups. A significant relationship was observed across all groups ($p < 0.001$). In younger individuals (18-29 years), obesity was linked to higher body fat (57.2%) and visceral fat (35.8%), while those with normal BMI mostly had lower fat levels. As age increased, the proportion of obese individuals with high body and visceral fat increased notably. In the 30-39 years and 40-49 years age groups, over 60% of obese individuals had elevated body fat, and more than 70% had high visceral fat. Among those aged 50-59 years, 75.8% of obese individuals had high body fat, while 78.8% had high visceral fat. Across all groups, undernourished individuals had normal fat levels, highlighting a strong association between obesity and increased fat accumulation with age. Age combined result shows a significant association of BF% and VF% distribution with nutritional status among the studied population.

Discussion

Aging is a multifaceted process that disrupts homeostasis, diminishes physiological reserves, deteriorates organ functions, increases susceptibility to morbidity or multimorbidity, and heightens vulnerability to adverse social outcomes. Among the various physiological transformations that accompany aging, alterations in body composition may be the most prominent age-related phenotypic changes (Kim *et al.,* 2022). These shifts in body composition not only contribute to conditions such as obesity, osteoporosis, and sarcopenia but also serve as markers for predicting other health risks, including cardiovascular disease and dementia (Chen, 2023). Several studies have demonstrated that body composition parameters, such as fat mass, muscle mass, total body water, and bone mineral content, exhibit different developmental trajectories, with distinct peak ages (Gallagher *et al.,* 1997; Singhal *et al.,* 1983; Hughes *et al.,* 2004; Boneva-Asiova *et al.,* 2011). Height generally peaks in early adulthood, while body weight tends to reach its maximum later (Bose, 2002; Tian *et al.,* 2016).

A study by Meeuwsen *et al.* 2010 involving a large adult sample in the UK demonstrated that BMI and BF% have a curvilinear relationship influenced by age and sex. Numerous studies have explored age-related changes in body composition among non-tribal Indian populations (Bose *et al.,* 2003) and tribal communities (Bose et al., 2006), there remains a knowledge gap regarding the specific patterns and extent of these changes, particularly when comparing tribal and non-tribal populations in India. Longitudinal and cross-sectional research has indicated that factors such as gender (Strickland & Ulijaszek, 1993; Bisai *et al.,* 2008), physical activity levels (Emery et al., 1993), and ethnicity (Chumlea *et al.,* 2002; Kyusa *et al*., 2023; Feng *et al*., 2024) significantly influence age-related changes in body composition. Variations in visceral fat distribution according to sex and ethnicity have also been observed (Xu et al., 2022). Notably, Asian populations tend to exhibit a higher percentage of body fat compared to Western populations, even across different obesity statuses, including underweight individuals (Schaap et al., 2013). The present study highlights significant age-related trends and variations in body composition parameters, with several variables showing statistically significant results. Moreover, research suggests that muscle loss due to aging varies across populations. Additionally, sex and obesity-related differences must be factored in when evaluating body composition (Sulis *et al.,* 2024).

Table 4. Correlation between Age, Anthropometric variables and Body Composition variables

Variables	Age	Height (cm)	Weight (kg)	BMI	Body Fat %	Subcutaneous Fat %	Visceral Fat %	Skeletal muscle (%)	WHR	WHtR
Age	1	-.073ns	-.030ns	-.003ns	.120*	.111*	.201**	-.466***	.305***	.229***
Height	-.073ns	1	.377***	-.212***	-.176**	-.133*	-.142*	.296***	-.06ns	.315***
Weight	.-.030ns	.377***	1	.818***	.580***	.610***	.708***	-.222***	.415***	.460***
BMI	-.003ns	-.212***	.818***	1	.719***	.711***	.835***	-.404***	.470***	.702***
Body Fat %	.120*	-.176**	.580***	.719***	1	.873***	.759***	-.568***	.379***	.556***
Subcutaneous Fat %	.111*	-.133*	.610***	.711***	.873***	1	.738***	-.592***	.348***	.548***
Visceral Fat %	.201**	-.142*	.708***	.835***	-.404***	.738***	1	-.517***	.490***	.654***
Skeletal Muscle %	-.466***	.296***	-.222***	-.404***	-.568***	-.592***	-.517***	1	-.318***	-.394***
WHR	.305***	-.06ns	.415***	.470***	.379***	.348***	.490***	-.318***	1	.626***
WHtR	.229***	.315***	.460***	.702***	.556***	.548***	.654***	-.394***	.626***	1

At the significance level of *p<0.05 ** p<0.01, *** p<0.001, ns p>0.05(statistically not significant).

Table 5. Age specific association of BMI categories with Visceral Fat % and Body Fat %

Age-group	BMI categories	Body fat (%)			χ^2	Visceral Fat (%)			χ^2
		Normal	High	Total		Normal	High	Total	
Gr I (18-29 yrs)	Undernourished	7 (100%)	0	7	23.058***	7 (100%)	0	7	33.712***
	Normal	25 (92.6%)	2 (7.4%)	27		27(100%)	0	27	
	Obese	6 (42.8%)	8 (57.2%)	14		9 (64.2%)	5 (35.8%)	14	
Gr II (30-39 yrs)	Undernourished	2 (100%)	0	2	27.536***	2 (100%)	0	2	43.207***
	Normal	24 (85.7%)	4 (14.3%)	28		26 (92.8%)	2 (7.2%)	28	
	Obese	8 (23.5%)	26 (76.5%)	34		9 (26.4%)	25 (73.6%)	34	
Gr III (40-49 yrs)	Undernourished	9 (90%)	1 (10%)	10	26.030***	10 (100%)	0	10	50.537***
	Normal	28 (87.5%)	4 (12.5%)	32		30 (93.7%)	2 (6.3%)	32	
	Obese	13 (36.1%)	23 (63.9%)	36		10 (27.7%)	26 (72.3%)	36	
Gr IV (50-59 yrs)	Undernourished	15 (88.2%)	2 (11.8%)	17	37.047***	17 (100%)	0	17	60.844***
	Normal	36 (81.8%)	8 (18.2%)	44		41 (93.1%)	3 (6.9%)	44	
	Obese	8 (24.2%)	25 (75.8%)	33		7 (21.2%)	26 (78.8%)	33	
Total (18-59 yrs)	Undernourished	33 (91.6%)	3 (8.4%)	36	113.54***	36 (100%)	0	36	182.99***
	Normal	113 (86.2%)	18 (13.8%)	131		124 (94.6%)	7 (5.4%)	131	
	Obese	35 (29.9%)	82 (79.1%)	117		35 (29.9%)	82 (79.1%)	117	

At the significance level of *p<0.05 ** p<0.01, *** p<0.001, ns p>0.05(statistically not significant).

The current study suggests that body composition changes progressively with age, characterized by an increase in fat accumulation and a decline in muscle mass, especially after the age of 30. These findings align with those of Chithira et al., 2016, who reported a similar pattern in adults from Ernakulam, Kerala, where body fat percentage increased significantly while skeletal muscle mass declined with age. Comparable findings were reported by Das *et al.,* 2020 in their study of age-related variations in anthropometry and body composition among Kheria Sabar males in Purulia, West Bengal. Similarly, Huayi *et al*., 2023 examined age- and sex-related trends in body composition among adults aged 20–60 years in Beijing, finding that body fat percentage increased while skeletal muscle mass decreased after the age of 30, which is consistent with the present study conducted among Nepali-speaking male tea estate workers. The use of bioelectrical impedance analysis (BIA) for estimating waist circumference (WC) and calculating the waist-to-hip ratio (WHR) in males and females underscores the biological differences in body composition, with females exhibiting higher fat mass percentages and males displaying higher fat-free mass percentages (Smolik *et al.,* 2025).

Podstawski *et al.* 2023 also documented an increase in body fat percentage coupled with a decline in skeletal muscle mass with age. Roy *et al.,* 2020 similarly noted that the aging process among the Rajbanshi population of Darjeeling district was associated with metabolic, physiological, and functional impairments, including changes in body composition, mirroring the findings of the present study. These age-related transformations typically involve increased fat deposition and reduced muscle mass, especially after the age of 30. Comparable trends have been observed in French populations, as reported by Briand et al., 2025. Additionally, differences in bone and soft tissue composition may affect the accuracy of body fat estimation across sexes, with some methods potentially overestimating or underestimating body fat percentage depending on individual characteristics (Smolik *et al.,* 2025).

Interestingly, a comparative analysis by Rush *et al.* 2009 examining body composition among European, Māori, Pacific Island, and Asian Indian adults found that Asian Indian adults had higher body fat percentages and lower muscle mass, regardless of age. This finding highlights significant ethnic differences in body composition that contrast with the age-related trends observed in the present study. In contrast, Nawfal *et al.,* 2024 examined age-related changes in body composition among adults in the Delhi region and found an increase in body fat percentage with age but no significant decline in skeletal muscle mass, diverging from the consistent decline in muscle mass observed in the present study.

The current study also identified additional factors beyond age that influence variations in body fat and visceral fat percentages. Physical activity emerged as a significant determinant, with increased physical activity correlating strongly with reductions in both body fat and visceral fat percentages. These findings are consistent with those reported by Bowen *et al.,* 2015, who explored the independent effects of diet and physical activity on total body fat and its distribution in an Indian cohort. Similarly, Bradbury *et al.,* 2017 demonstrated that higher physical activity levels were associated with lower body fat percentages in a large population sample. Zou *et al*., 2020 also found a negative correlation between physical activity and body fat percentage in a middle-aged Chinese population, even after adjusting for BMI.

Alcohol consumption was another factor examined in this study. The findings align with Kazibwe et al., 2023, who identified a significant association between alcohol intake and visceral fat percentage in a multi-ethnic population. However, the current study did not establish a significant link between alcohol consumption and body fat percentage, contrasting with Traversy *et al.,* 2015, who reported a positive correlation between alcohol intake and body fat percentage. Additionally, the present study identified a weak but statistically significant relationship between body fat percentage and tobacco consumption. This finding contrasts with research conducted by AlKalbani *et al.,* 2023 on the Irish population, which found no significant association between tobacco use and body fat percentage, although a strong correlation with alcohol consumption was reported. The association found between regular physical activity and reductions in body fat percentage in the present study is also consistent with the findings of Marcos *et al.,* 2025.

A positive correlation between BMI and age with visceral fat percentage and total fat percentage was observed in the current study, while both variables exhibited a strong negative correlation with skeletal muscle percentage. These results are in line with the findings of Siddiqui *et al.,* 2016, who studied medical students and reported associations between age, BMI, and various body composition parameters. Previous research by Singal et al., 1988, Bagga 1998 has consistently demonstrated age-related changes in body composition, further supporting the current study's findings.

Visceral adipose tissue plays a critical role in metabolic syndrome, and studies have shown that visceral fat adiposity estimated using BIA is useful for detecting metabolic impairments (Mutsuzawa *et al.,* 2011; Wang *et al.,* 2011; Kitchlew *et al*., 2017). Studies conducted among Nigerian adults (Akindele *et al.,* 2016) and healthy adults in other regions (Gadekar *et al.,* 2020) have demonstrated a significant correlation between BMI and visceral fat percentage, similar to the present findings. A study conducted in Lahore among hospitalized patients also found a significant correlation between BMI, visceral fat, and body fat (Kitchlew *et al.,* 2017). The mean body fat percentage reported in the current study was slightly lower than that observed among Sri Lankan adults, with significant correlations between body fat percentage, BMI, and age (Ranasinghe *et al.,* 2013).

The present study shows a strong association between obesity and increased fat accumulation with age. One notable study by Rai *et al.,* 2023 conducted in India found a significant positive correlation between BMI and BF%, with this association strengthening with age. Similar to the current study, another study conducted among the population of Kerala found both BMI and BF% increased with age and also emphasising that BF% is a better predictor of adiposity than BMI alone (Vijayan *et al.,* 2024).

Conclusion

The present study underscores the multifaceted nature of aging and its profound impact on body composition. It highlights that with advancing age, individuals experience significant changes characterized by increased fat accumulation, particularly visceral fat, and a decline in skeletal muscle mass. These age-related transformations contribute to a higher risk of developing metabolic disorders, cardiovascular diseases, and other health impairments. The findings emphasize that while BMI remains a widely used metric to assess adiposity, it may not accurately capture variations in fat distribution, especially across different populations and age groups. As such, the inclusion of body fat percentage and visceral fat estimation provides a more comprehensive understanding of age-related changes in body composition. The study further reveals that age-related changes in body composition are influenced by factors such as sex, ethnicity, physical activity, and lifestyle habits. In the present study only adult males are considered but males and females exhibit distinct patterns of fat and muscle distribution, with females generally having higher body fat percentages and males displaying greater fat-free mass. Ethnic variations also play a critical role, with Asian populations tending to have higher fat percentages at lower BMI levels compared to Western populations. Moreover, increased physical activity was found to mitigate the accumulation of body fat and visceral fat, highlighting its protective role in maintaining healthy body composition as individuals age. The results also draw attention to the strong correlation between BMI, body fat percentage, and visceral fat, reinforcing the importance of incorporating multiple body composition parameters in health assessments. Despite the vast body of literature on age-related changes in body composition, there remains a knowledge gap concerning the unique patterns observed among different ethnic and tribal populations. Addressing this gap through further research is essential for developing targeted interventions and policies to mitigate the adverse effects of aging on body composition and overall health. The study's findings underscore the need for a more nuanced and population-specific approach to body composition assessment, particularly in the context of aging.

References

Akindele, M.O., Phillips, J.S., Igumbor, E.U. (2016). The Relationship between Body Fat Percentage and Body Mass Index in Overweight and Obese Individuals in an Urban African Setting. *Journal of public health in Africa*, *7*(1): 515. https://doi.org/10.4081/jphia.2016.515

AlKalbani, S.R., Murrin, C. (2023). The Association between Alcohol Intake and Obesity in a Sample of the Irish Adult Population, a Cross-Sectional Study. *BMC Public Health, 23*(1): 2075. https://doi.org/10.1186/s12889-023-16946-4

Andreoli, A., Garaci, F., Cafarelli, F. P., & Guglielmi, G. (2016). Body composition in clinical practice. *European Journal of Radiology*, *85*(8), 1461–1468. https://doi.org/10.1016/j.ejrad.2016.02.005

Ayvaz, G., Cimen, A.R. (2011). Methods for Body Composition Analysis in Adults. *The Open Obesity Journal*, *3*(1): 62-69. http://dx.doi.org/10.2174/1876823701103010062

Bagga, A. (1998). Normality of Ageing-a cross-cultural Perspective. *Journal of Human Ecology, 9*(1): 35-46.

Bergman, R.N., Stefanovski, D., Buchanan, T.A., Sumner, A.E., Reynolds, J.C., Sebring, N.G., Xiang, A.H. Watanabe, R.M., (2011). A Better Index of Body Adiposity. *Obesity*, *19*(5): 1083-1089. https://doi.org/10.1038/oby.2011.38

Bisai, S., Bose, K., Ganguli, S., Mumtaz, H., Mukhopadhyay, A. Bhadra, M., (2008). Sexual Dimorphism and Age Variations in Anthropometry, Body Composition and Nutritional Status among Kora Mudi Tribals of Bankura District, West Bengal, India. *India. Stud. Tribes and Tribals*, *2:* 103-109

Boneva-Asiova, Z., Boyanov, M. (2011). Age-Related Changes of Body Composition and Abdominal Adipose Tissue Assessed by Bioelectrical Impedance Analysis and Computed Tomography. *Endocrinologia Y Nutricion*, *58*(9): 472-477. https://doi.org/10.1016/j.endonu.2011.07.004

Borga, M., West, J., Bell, J.D., Harvey, N.C., Romu, T., Heymsfield, S.B. Dahlqvist Leinhard, O. (2018). Advanced Body Composition Assessment: From Body Mass Index To Body Composition Profiling. *Journal of Investigative Medicine*, *66*(5): 1-9. https://doi.org/10.1136/jim-2018-000722

Bose, K. (2002). Age Trends in Adiposity and Central Body Fat Distribution among Adult White Men Resident in Peterborough, East Anglia, England. *Collegium Antropologicum*, *26*(1): 179-186.

Bose, K., Bisai, S., Chakraborty, F. (2006). Age Variations In Anthropometric and Body Composition Characteristics and Underweight among Male Bathudis–A Tribal Population of Keonjhar District, Orissa, India. *Collegium Antropologicum*, *30*(4): 771-775.

Bose, K., Chaudhuri, A.B. (2003). Age Variations in Adiposity and Body Fat Composition among Older Bengalee Hindu Women of Calcutta, India. *Anthropologischer Anzeiger*, 311-321. https://www.jstor.org/stable/29542473

Bowen, L., Taylor, A.E., Sullivan, R., Ebrahim, S., Kinra, S., Krishna, K.R., Kulkarni, B., Ben-Shlomo, Y., Ekelund, U., Wells, J.C. Kuper, H. (2015). Associations between Diet, Physical Activity and Body Fat Distribution: A Cross Sectional Study in an Indian Population. *BMC Public Health*, *15*(1): 281. https://doi.org/10.1186/s12889-015-1550-7

Bradbury, K.E., Guo, W., Cairns, B.J., Armstrong, M.E. Key, T.J. (2017). Association between Physical Activity and Body Fat Percentage, With Adjustment for BMI: A Large Cross-Sectional Analysis of UK Biobank. *BMJ Open*, *7*(3): e011843. https://doi.org/10.1136/bmjopen-2016-011843

Briand, M., Raffin, J., Gonzalez-Bautista, E., Ritz, P., Abellan Van Kan, G., Pillard, F., Faruch-Bilfeld, M., Guyonnet, S., Dray, C., Vellas, B. de Souto Barreto, P. (2025). Body Composition and Aging: Cross-Sectional Results From the INSPIRE Study in People 20 To 93 Years Old. *Geroscience*, *47*(1): 863-875. https://doi.org/10.1007/s11357-024-01245-6

Campa, F., Toselli, S., Mazzilli, M., Gobbo, L. A., & Coratella, G. (2021). Assessment of body composition in athletes: A narrative review of available methods with special reference to quantitative and qualitative bioimpedance analysis. *Nutrients*, *13*(5), 1620. https://doi.org/10.3390/nu13051620

Chen, L.K. (2023). Aging, Body Composition, And Cognitive Decline: Shared And Unique Characteristics. *The Journal of Nutrition, Health & Aging*, *27*(11): 929-931. https://doi.org/10.1007/s12603-023-2022-x

Chithira, K.R., Joseph, A. (2016). Age and Gender Related Changes In Body Composition Parameters Among Adults. *International Journal of Home Science*, *2*(3): 349-352.

Chumlea, W.C., Guo, S.S., Kuczmarski, R.J., Flegal, K.M., Johnson, C.L., Heymsfield, S.B., Lukaski, H.C., Friedl, K. Hubbard, V.S. (2002). Body Composition Estimates from NHANES III Bioelectrical Impedance Data. *International Journal of Obesity*, *26*(12): 1596-1609. https://doi.org/10.1038/sj.ijo.0802167

Das, B.M. Roy, S.K. (2010). Age Changes in the Anthropometric and Body Composition Characteristics of the Bishnupriya Manipuris of Cachar District, Assam. *Advances in Bioscience and Biotechnology*, *1*(02): 122-130. http://dx.doi.org/10.4236/abb.2010.12017

Das, K., Mukherjee, K., Ganguli, S., Pal, S., Bagchi, S.S. (2020). Age-Related Variations In Anthropometry, Body Composition And Nutritional Status Among The Adult Kheria Sabar Males of Purulia, West Bengal, India. *Collegium Antropologicum*, *44*(2): 73-80. https://doi.org/10.5671/ca.44.2.2

Dempster, P.H.I.L.I.P., Aitkens, S.U.S.A.N. (1995). A New Air Displacement Method for the Determination of Human Body Composition. *Medicine and Science in Sports and Exercise*, *27*(12): 1692-1697. https://doi.org/10.1249/00005768-199512000-00017

Emery, E.M., Schmid, T.L., Kahn, H.S., Filozof, P.P. (1993). A Review of the Association between Abdominal Fat Distribution, Health Outcome Measures, and Modifiable Risk Factors. *American Journal of Health Promotion*, *7*(5): 342-353. https://doi.org/10.4278/0890-1171-7.5.342

Feng, Q., Bešević, J., Conroy, M., Omiyale, W., Lacey, B. Allen, N. (2024). Comparison of Body Composition Measures Assessed By Bioelectrical Impedance Analysis versus Dual-Energy X-Ray Absorptiometry in the United Kingdom Biobank. *Clinical Nutrition ESPEN*, *63*: 214-225. https://doi.org/10.1016/j.clnesp.2024.06.040

Gadekar, T., Dudeja, P., Basu, I., Vashisht, S. Mukherji, S. (2020). Correlation of Visceral Body Fat with Waist–Hip Ratio, Waist Circumference and Body Mass Index in Healthy Adults: A Cross Sectional Study. *Medical Journal Armed Forces India*, *76*(1): 41-46. https://doi.org/10.1016/j.mjafi.2017.12.001

Gallagher, D., Heymsfield, S.B., Heo, M., Jebb, S.A., Murgatroyd, P.R. Sakamoto, Y. (2000). Healthy Percentage Body Fat Ranges: An Approach For Developing Guidelines Based On Body Mass Index. *The American Journal of Clinical Nutrition*, *72*(3): 694-701. https://doi.org/10.1093/ajcn/72.3.694

Gallagher, D., Visser, M., De Meersman, R.E., Sepúlveda, D., Baumgartner, R.N., Pierson, R.N., Harris, T. Heymsfield, S.B. (1997). Appendicular Skeletal Muscle Mass: Effects Of Age, Gender, And Ethnicity. *Journal of Applied Physiology*, *83*(1): 229-239. https://doi.org/10.1152/jappl.1997.83.1.229

Haroun, D., Taylor, S.J., Viner, R.M., Hayward, R.S., Darch, T.S., Eaton, S., Cole, T.J. Wells, J.C. (2010). Validation of Bioelectrical Impedance Analysis in Adolescents across Different Ethnic Groups. *Obesity*, *18*(6): 1252-1259. https://doi.org/10.1038/oby.2009.344

Heymsfield, S. B., Lohman, T. G., Wang, Z., & Going, S. B. (Eds.). (2005). *Human body composition* (2nd ed.). Human Kinetics.

Holmes, C.J., Racette, S.B. (2021). The Utility of Body Composition Assessment in Nutrition and Clinical Practice: An Overview of Current Methodology. *Nutrients*, *13*(8): 2493. https://doi.org/10.3390/nu13082493

Hsieh, S.D., Muto, T. (2004). A Simple And Practical Index For Assessing The Risk Of Metabolic Syndrome During Routine Health Checkups. *Nihon Rinsho. Japanese Journal of Clinical Medicine*, *62*(6): 1143-1149.

Huayi, Z., Gang, X., Laiyuan, L., Hui, H. (2023). Age-And Sex-Related Trends In Body Composition Among Beijing Adults Aged 20–60 Years: A Cross-Sectional Study. *Bmc Public Health*, *23*(1): 1519. https://doi.org/10.1186/s12889-023-16459-0

Hughes, V.A., Roubenoff, R., Wood, M., Frontera, W.R., Evans, W.J., Singh, M.A.F. (2004). Anthropometric Assessment of 10-Y Changes in Body Composition in the Elderly. *The American Journal of Clinical Nutrition*, *80*(2): 475-482. https://doi.org/10.1093/ajcn/80.2.475

Kazibwe, R., Chevli, P.A., Evans, J.K., Allison, M., Michos, E.D., Wood, A.C., Ding, J., Shapiro, M.D. Mongraw-Chaffin, M. (2023). Association between Alcohol Consumption and Ectopic Fat in the Multi-Ethnic Study of Atherosclerosis. *Journal of the American Heart Association*, *12*(18): e030470. https://doi.org/10.1161/JAHA.123.030470

Kim, S., Won, C.W. (2022). Sex-Different Changes of Body Composition in Aging: A Systemic Review. *Archives of Gerontology and Geriatrics*, *102*: 104711. https://doi.org/10.1016/j.archger.2022.104711

Kitchlew, R., Chachar, A.Z.K. Latif, S. (2017). Body Mass Index; Visceral Fat And Total Body Fat Distribution And Its Relation To Body Mass Index In Clinical Setting Using Bio-Impedance Body Composition Monitor. *The Professional Medical Journal*, *24*(02): 326-334. https://doi.org/10.17957/TPMJ/17.3815

Kyusa, M.M., Kruger, H.S. de Lange-Loots, Z. (2023). Differences In Calculated Body Fat Percentage Estimated From Published Equations Based On Bioelectric Impedance Analysis In Healthy Young South African Adults. *Journal of Public Health Research*, *12*(3): 22799036231196732. https://doi.org/10.1177/22799036231196732

Liao, Y.S., Li, H.C., Lu, H.K., Lai, C.L., Wang, Y.S. Hsieh, K.C. (2020). Comparison of Bioelectrical Impedance Analysis and Dual Energy X-Ray Absorptiometry for Total and Segmental Bone Mineral Content with a Three-Compartment Model. *International Journal of Environmental Research and Public Health*, *17*(7): 2595. https://doi.org/10.3390/ijerph17072595

Lohman, T.G., Roche, A.F., Martorell, R. (1988). Anthropometric Standardization Reference Manual. *Human Kinetics Books, Chicago*, 6(1).

Lokpo, S.Y., Ametefe, C.Y., Osei-Yeboah, J., Owiredu, W.K., Ahenkorah-Fondjo, L., Agordoh, P.D., Acheampong, E., Duedu, K.O., Adejumo, E.N., Appiah, M. Asiamah, E.A. (2023). Performance olf Body Adiposity Index and Relative Fat Mass in Predicting Bioelectric Impedance Analysis-Derived Body Fat Percentage: A Cross-Sectional Study among Patients with Type 2 Diabetes in the Ho Municipality, Ghana. *Biomed Research International*, *2023*(1): 1500905. https://doi.org/10.1155/2023/1500905

MacDonald, A.J., Greig, C.A. Baracos, V. (2011). The Advantages and Limitations of Cross-Sectional Body Composition Analysis. *Current Opinion in Supportive and Palliative Care*, *5*(4): 342-349. https://doi.org/10.1097/spc.0b013e32834c49eb

Matsuzawa, Y., Funahashi, T., & Nakamura, T. (2011). The concept of metabolic syndrome: Contribution of visceral fat accumulation and its molecular mechanism. *Journal of Atherosclerosis and Thrombosis*, *18*(8), 629–639. https://doi.org/10.5551/jat.7922

Meeuwsen, S., Horgan, G.W., Elia, M. (2010). The Relationship between BMI and Percent Body Fat, Measured by Bioelectrical Impedance, In a Large Adult Sample is Curvilinear and Influenced by Age and Sex. *Clinical Nutrition*, *29*(5): 560-566. https://doi.org/10.1016/j.clnu.2009.12.011

Nawfal, K.I., Tiwari, S., Tiwari, S. Haq, M.A.U. (2024). Using A Cross-Sectional Analysis Of Age-Related Variations In Anthropometric Indices And Their Association With Cardiometabolic Health In Adult Men. *Physical Education Theory and Methodology*, *24*(6): 881-890. https://doi.org/10.17309/tmfv.2024.6.04

Neeland, I.J., Ayers, C.R., Rohatgi, A.K., Turer, A.T., Berry, J.D., Das, S.R., Vega, G.L., Khera, A., McGuire, D.K., Grundy, S.M. de Lemos, J.A. (2013). Associations of Visceral and Abdominal Subcutaneous Adipose Tissue with Markers of Cardiac and Metabolic Risk in Obese Adults. *Obesity*, *21*(9): E439-E447. https://doi.org/10.1002/oby.20135

Omron Healthcare. (2008). *HBF-514C full body sensor body composition monitor and scale: Instruction manual*. Omron Healthcare, Inc.

Orr, C.M., Dufour, D.L. Patton, J.Q., 2001. A Comparison of Anthropometric Indices of Nutritional Status In Tukanoan And Achuar Amerindians. *American Journal of Human Biology: The Official Journal Of The Human Biology Association*, *13*(3): 301-309. https://doi.org/10.1002/ajhb.1053

Pietrobelli, A., Formica, C., Wang, Z., & Heymsfield, S. B. (1996). Dual-energy X-ray absorptiometry body composition model: Review of physical concepts. *American Journal of Physiology-Endocrinology and Metabolism*, *271*(6), E941–E951. https://doi.org/10.1152/ajpendo.1996.271.6.E941

Podstawski, R., Omelan, A., Borysławski, K. Wąsik, J. (2023). Relationships Between Anthropometric And Body Composition Characteristics And Age In Polish Women Over 60 As Affected By Their Socioeconomic And Health Status And Physical Activity Levels. *Frontiers In Physiology*, *14*: 1198485. https://doi.org/10.3389/fphys.2023.1198485

Rai, R., Ghosh, T., Jangra, S., Sharma, S., Panda, S., Kochhar, K.P. Panda. (2023). Relationship between Body Mass Index and Body Fat Percentage in a Group Of Indian Participants: A Cross-Sectional Study From A Tertiary Care Hospital. *Cureus*, *15*(10): e47817. https://doi.org/10.7759/cureus.47817

Ranasinghe, C., Gamage, P., Katulanda, P., Andraweera, N., Thilakarathne, S. Tharanga, P. (2013). Relationship between Body Mass Index (BMI) and Body Fat Percentage, Estimated By Bioelectrical Impedance, In a Group of Sri Lankan Adults: A Cross Sectional Study. *BMC Public Health*, *13*(1): 797. https://doi.org/10.1186/1471-2458-13-797

Reber, E., Gomes, F., Vasiloglou, M.F., Schuetz, P. Stanga, Z. (2019). Nutritional Risk Screening and Assessment. *Journal Of Clinical Medicine*, *8*(7): 1065. https://doi.org/10.3390/jcm8071065

Roy S., Pal A., Sen J. (2020). Age-Specific And Sex-Specific Variations In Body Composition of Adults Belonging To The Rajbanshi Population Of Darjeeling District, West Bengal, India. *Online Journal of Health and Allied Sciences*, *19*(4): 2.

Rush, E.C., Freitas, I. Plank, L.D. (2009). Body Size, Body Composition and Fat Distribution: Comparative Analysis of European, Maori, Pacific Island And Asian Indian Adults. *British Journal of Nutrition*, *102*(4): 632-641. https://doi.org/10.1017/S0007114508207221

Schaap, L.A., Koster, A. Visser, M. (2013). Adiposity, Muscle Mass, and Muscle Strength In Relation To Functional Decline in Older Persons. *Epidemiologic Reviews*, *35*(1): 51-65. https://doi.org/10.1093/epirev/mxs006

Siddiqui, N.I., Khan, S.A., Shoeb, M. ose, S. (2016). Anthropometric Predictors of Bio-Impedance Analysis (BIA) Phase Angle In Healthy Adults. *Journal of Clinical and Diagnostic Research: JCDR*, *10*(6): CC01. https://doi.org/10.7860/JCDR/2016/17229.7976

Singal, P., Sidhu, L.S., Bhatnagar, D.P. (1988). Estimated Fat, Bone Mineral, Total Body Water and Cell Solids in Females of Two Communities of Punjab, India. *Anthropologischer Anzeiger*, 51-57. https://www.jstor.org/stable/29539853

Sinha, I., Pal, A., Sen, J. (2018). Age and Sex Variations in Anthropometric Characteristics and Body Composition of Adults Belonging to the Rajbanshi Population of Darjeeling District, West Bengal. *South Asian Anthropologist,* 18(2), 203–213.

Smolik, R., Gaweł, M., Kliszczyk, D., Sasin, N., Szewczyk, K. Górnicka, M. (2025). Comparative Analysis of Body Composition Results Obtained By Air Displacement Plethysmography (Adp) And Bioelectrical Impedance Analysis (Bia) In Adults. *Applied Sciences*, *15*(7): 3480. https://doi.org/10.3390/app15073480

Strickland, S.S., Ulijaszek, S.J. (1993). Body Mass Index, Ageing And Differential Reported Morbidity In Rural Sarawak. *European Journal of Clinical Nutrition*, *47*(1): 9-19.

Sulis, S., Falbova, D., Benus, R., svabova, P., Hozakova, A. Vorobelova, L. (2024). Sex and Obesity-Specific Associations of Ultrasound-Assessed Radial Velocity of Sound with Body Composition. *Applied Sciences*, *14*(16): 7319. https://doi.org/10.3390/app14167319

Tian, S., Morio, B., Denis, J.B. Mioche, L. (2016). Age-Related Changes in Segmental Body Composition by Ethnicity and History of Weight Change across the Adult Lifespan. *International Journal of Environmental Research and Public Health*, *13*(8): 821. https://doi.org/10.3390/ijerph13080821

Traversy, G. Chaput, J.P. (2015). Alcohol Consumption And Obesity: An Update. *Current Obesity Reports*, *4*(1): 122-130. https://doi.org/10.1007/s13679-014-0129-4

Vijayan, D.V., Panchu, D.P., Bahuleyan, D.B., Rajaratnam, D.S.A. Dayalan, D.D. (2024). Exploring the Relationship between Body Mass Index and Body Fat Percentage across Age and Gender: A Cross – Sectional Study. *South Eastern European Journal of Public Health*, 1000–1007. https://doi.org/10.70135/seejph.vi.1924

Wang, D., Li, Y., Lee, S.G., Wang, L., Fan, J., Zhang, G., Wu, J., Ji, Y., Li, S. (2011). Ethnic Differences in Body Composition and Obesity Related Risk Factors: Study In Chinese and White Males Living in China. *PloS one*, *6*(5): e19835. https://doi.org/10.1371/journal.pone.0019835

Webb, G.P. (2002). Nutrition: A Health Promotion Approach (2nd Ed.). *Nutrition & Food Science*, 32(4): 165–166.https://doi.org/10.1108/nfs.2002.32.4.165.4.

World Health Organization. (2003). *Diet, nutrition, and the prevention of chronic diseases: Report of a joint WHO/FAO expert consultation* (WHO Technical Report Series No. 916). World Health Organization.

World Health Organization. Regional Office for the Western Pacific. (2000). *The Asia-Pacific perspective: Redefining obesity and its treatment*. Health Communications Australia.

Xu, F., Earp, J.E., Adami, A., Lofgren, I.E., Delmonico, M.J., Greene, G.W. Riebe, D. (2022). The Sex and Race/Ethnicity-Specific Relationships of Abdominal Fat Distribution and Anthropometric Indices in US Adults. *International Journal of Environmental Research and Public Health*, *19*(23): 15521. https://doi.org/10.3390/ijerph192315521

Zou, Q., Su, C., Du, W., Ouyang, Y., Wang, H., Wang, Z., Ding, G. Zhang, B. (2020). The Association between Physical Activity and Body Fat Percentage with Adjustment for Body Mass Index among Middle-Aged Adults: China Health and Nutrition Survey in 2015. *Bmc Public Health*, *20*(1): 732. https://doi.org/10.1186/s12889-020-08832-0

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Informed Consent Statement

All the athletes included in the study provided written informed consent.

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