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Adiposity and Skeletal Muscle Distribution among Older Adults in Southern West Bengal: Emergence of a Sarcopenic Obesity-like Phenotype

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Abstract

Ageing is accompanied by marked changes in body composition, reflecting long-term biological, nutritional, and lifestyle processes. In populations undergoing nutritional and epidemiological transitions, older adults may exhibit a distinct phenotype characterized by the coexistence of adiposity and reduced skeletal muscle mass, commonly described as sarcopenic obesity. Most Indian studies are hospital-based, urban-focused, or rely on national datasets that do not capture regional variation. Furthermore, little information exists regarding the coexistence of adiposity and reduced muscle mass among older adults in West Bengal. The present study aimed to examine sex-specific body composition patterns and identify body composition profiles suggestive of sarcopenic obesity-like phenotypes among community-dwelling older adults in southern West Bengal. A community-based cross-sectional study was carried out on 331 individuals aged 60-80 years (186 females and 145 males) from southern West Bengal following simple random procedure. Anthropometric measurements were obtained using standard protocols, and nutritional status was classified using body mass index (BMI). Body composition parameters like the percentage of body fat, visceral fat, whole-body subcutaneous fat and whole-body skeletal muscle were measured using bioelectrical impedance analysis (BIA). Sex-wise comparisons and differences across nutritional categories were examined using descriptive statistics and one-way analysis of variance. Progressive increases in the percentage of total body fat, visceral fat, and subcutaneous fat were observed with increasing BMI categories in both sexes. In contrast, skeletal muscle percentage showed a tendency to plateau or decline among overweight and obese individuals. The concurrent presence of elevated adiposity and relatively reduced muscle mass in higher BMI categories indicates the emergence of a sarcopenic obesity-like body composition phenotype within this ageing population. Such patterns likely reflect long-term nutritional transition and lifestyle changes and have important implications for understanding biological ageing and population variation in contemporary Indian populations.

Keywords: Sarcopenic obesity, Body composition, Nutritional transition, Aging

1 Introduction

Human ageing is a multifaceted biological process shaped by the dynamic interaction of genetic inheritance, environmental exposures, nutritional history, and socio-cultural context (Guo et al., 2022; Rodriguez-Rodero et al., 2011). Rather than representing a uniform or linear decline, ageing manifests through diverse physiological trajectories that vary across populations and ecological settings (Arbeev et al., 2011). Among the most visible and biologically consequential changes associated with ageing is the redistribution of body tissues, particularly the progressive increase in adiposity alongside a decline in skeletal muscle mass (Palmer & Jensen, 2022). These changes are not merely cosmetic but are strongly associated with functional limitation, metabolic disorders, frailty, and mortality (Crews, 1993; Mondal, Chakraborty, Banerjee, et al., 2025). In recent years, the concurrent presence of excess adiposity and reduced muscle mass has

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been conceptualized as sarcopenic obesity, a phenotype of growing clinical and public health concern (Axelrod et al., 2023).

Sarcopenia is currently defined according to consensus guidelines such as those proposed by the European Working Group on Sarcopenia in Older People and the Asian Working Group for Sarcopenia. These frameworks emphasize low skeletal muscle mass in combination with reduced muscle strength and/or impaired physical performance as diagnostic criteria (Larsson et al., 2018). Sarcopenia reflects both intrinsic biological ageing and cumulative lifestyle influences such as physical activity, nutritional adequacy, and disease burden (Mondal, Banerjee, & Mukherjee, 2025; Tieland et al., 2018). Simultaneously, many ageing populations experience an increase in total and central adiposity, a pattern increasingly observed across both high-income and low- and middle-income countries (Popkin & Slining, 2013). Obesity, on the other hand, is conventionally defined using body mass index (BMI), although body fat percentage provides a more direct indicator of adiposity (Mainous et al., 2025).When these two processes occur concurrently, they give rise to a distinctive body composition phenotype known as sarcopenic obesity (Zamboni et al., 2008). This phenotype is associated with heightened vulnerability to function impairment, metabolic disorders, frailty, and reduced quality of life, making it a critical issue for ageing societies (How et al., 2025; Murawiak et al., 2022).

India provides a particularly important context for examining sarcopenic obesity-like phenotypes due to its rapid nutritional, epidemiological, and lifestyle transitions over recent decades (Pal et al., 2021). The country has witnessed a marked shift from traditional diets rich in coarse grains and plant-based foods toward more energy-dense, processed diets, accompanied by declining levels of habitual physical activity (N. Banerjee, Biswas, et al., 2021; Bardhan, Mondal, & Mukherjee, 2024; Mukhopadhyay et al., 2025). These changes have contributed to rising levels of overweight, obesity, and non-communicable diseases across much of the population (N. Banerjee, Chatterjee, et al., 2021; Bardhan, Saha, Mondal, Chatterjee, et al., 2024). While the health consequences of this transition have been documented extensively among children, adolescents, and working-age adults (N. Banerjee et al., 2022; Bardhan, Saha, Mondal, Das, et al., 2024; M. Dey et al., 2025; Saha et al., 2024), comparatively little attention has been given to older adults who have lived through multiple phases of nutritional and socioeconomic change (Mondal, Chakraborty, Chatterjee, et al., 2025).

For ageing individuals, contemporary body composition patterns cannot be understood solely in terms of current lifestyle (St-Onge & Gallagher, 2010). They rather reflect cumulative life-course exposures, including early-life undernutrition, episodes of infectious disease, reproductive history, occupational labor, and later-life shifts in diet and activity (Alam et al., 2019; Song et al., 2025). Many older Indians were born and raised during periods of food scarcity and high physical demands, followed by adulthood or later life in increasingly obesogenic environments (Kandapan et al., 2023). Sarcopenic obesity thus represents not merely a pathological condition, but a phenotypic outcome of long-term biological and cultural processes operating across the lifespan (Roh & Choi, 2020).

Globally, the prevalence of the sarcopenic obesity-like phenotype among older adults varies widely depending on definitions and measurement techniques, ranging from approximately 5% to over 20% in community-dwelling populations (Ji et al., 2022). Despite growing recognition of the sarcopenic obesity-like phenotype as an important geriatric health concern, empirical evidence from community-dwelling older adults in Eastern India remains limited. Existing Indian studies have largely focused on urban populations, hospital-based samples, or national datasets that may not adequately capture regional variation in body composition patterns (Pal et al., 2021; Verma et al., 2022). Furthermore, information on the coexistence of increased adiposity and reduced skeletal muscle mass among older adults in West Bengal is scarce (Majumder et al., 2023; Mondal, Banerjee, Parvin, et al., 2025). Understanding these patterns is important in the context of rapid nutritional and lifestyle transitions occurring in the region. Therefore, the present study aimed to examine sex-specific body composition characteristics among older adults in southern West Bengal and to identify body composition profiles suggestive of a high adiposity low muscle mass phenotype.

2 Materials and methods

2.1 Study population, design and sampling

The present study involved a community setting oriented cross-sectional method conducted in selected districts of southern West Bengal, India [Howrah (n:51), Nadia (n:56), Hooghly (n:46), Kolkata (n:50), North (n:74) and South (54) 24 Parganas)] between November 2024 and November 2025. A house-to-house survey was conducted in selected localities of the study districts. A sampling frame of households was prepared for each locality, and households were selected using a simple random sampling technique. Eligible older adults (60-80 years) residing in the selected households were invited to participate after providing informed consent. Initially, 414 individuals were screened. After applying the inclusion and exclusion criteria, 331 participants aged 60–80 years were included in the final analysis. The study protocol was ethically approved by the Institutional Human Ethics Committee of the university.

2.2 Inclusion and exclusion criteria

Individuals aged 60–80 years were included because 60 years is the commonly accepted threshold for defining older adults in India, while participants above 80 years were excluded due to the greater likelihood of severe comorbidities, mobility limitations, and measurement difficulties that could influence body composition assessment. Initially 414 people participated in the present study, but those aged below 60 years and above 80 years and those not able to complete the tests were excluded. Individuals with neurodegenerative diseases and/or taking medications that can alter body composition were also excluded.

2.3 Anthropometry and body composition assessment

Body height (cm) was measured while the individuals stood erect, without shoes and without holding any support, using the anthropometric measurement set (D. Dey et al., 1999). Body weight (nearest to 0.1 kg) was taken using a weighing scale while participants were wearing minimum socially acceptable clothing (Atiea et al., 1994). Body Mass Index or BMI was calculated as body weight in kg divided by body height in meters squared and categorized as per WHO recommendation for the South Asian population (<18.5: Underweight, 18.5-22.9: Normal, 23-24.9: overweight or at risk of obesity, 25-29.9: Obese I and $\geq$30: Obese II). Body composition parameters such as percentage of body fat (PBF), visceral fat (VF%), whole-body subcutaneous fat (WBSC%) and whole-body skeletal muscle (WBMS%) were measured using a bioelectrical impedance analysis (BIA) device under standardized conditions and procedure (Roubenoff et al., 1997).

2.4 Operational definition of high-adiposity – low-muscle phenotype

Sarcopenia is conventionally defined according to the Asian Working Group for Sarcopenia (AWGS) and the European Working Group on Sarcopenia in Older People (EWGSOP), requiring assessment of muscle mass together with muscle strength and/or physical performance. As these parameters were not included, the study focused on identifying a body composition pattern suggestive of a sarcopenic obesity-like phenotype among the older adults, rather than estimating and/or measuring the prevalence of sarcopenic obesity. High adiposity was defined as body fat percentage (PBF) above the sex-specific 75th percentile (Weber et al., 2013), while low muscle mass was defined as whole-body skeletal muscle percentage (WBMS%) below the sex-specific 25th percentile (Yu et al., 2014). Participants exhibiting both characteristics were classified as having a high adiposity-low muscle phenotype. This operational approach was adopted to identify individuals demonstrating body composition characteristics suggestive of sarcopenic obesity while avoiding formal clinical diagnosis.

2.5 Statistical analysis

IBM SPSS 31 was used to carry out all statistical analyses for the present study. Descriptive statistics were used to summarize anthropometric and body composition variables. Sex-wise differences were assessed using independent samples t-tests. To examine the relationship between adiposity and skeletal muscle distribution, participants were stratified into sex-specific quartiles based on whole-body skeletal muscle percentage (WBMS%). Differences in body fat percentage (PBF), visceral fat percentage (VF%), and whole-body subcutaneous fat percentage (WBSC%) across WBMS quartiles were assessed using one-way analysis of variance (ANOVA). Pearson correlation analysis was performed separately for males and females to examine relationships between age, BMI, PBF, VF%, WBSC%, and WBMS%. Multiple linear regression analysis was conducted separately for males and females to evaluate whether body fat percentage (dependent variable) was independently predicted by skeletal muscle percentage and age (independent variables). Regression assumptions were checked prior to analysis. The prevalence of the high adiposity–low muscle phenotype was calculated separately for males and females and expressed as percentages with 95% confidence intervals. A p value of <.05 was considered statistically significant.

3 Results

The study included 331 older adults among whom 186 (56.2%) were females and 145 (43.8%) were males. The average age of participants was comparable between females (67.5 ± 6.08 years) and males (67.5 ± 5.85 years; t = 0.01, p =.991). The characteristics of the study variables are presented in Table 1.

Table 1: Characteristics of the study variables

Characteristics	Females (n=186)			Males (n=145)			*t*	*p* value
	AM ± SD	Min	Max	AM ± SD	Min	Max		
Body height (cm)	147.9 ± 6.18	130	164	162.2 ± 7.36	136	181.5	19.20	.001
Body weight (kg)	52.0 ± 11.18	27.9	77.6	59.9 ± 10.89	34	87	6.47	.001
BMI (kg/m^2)	23.7 ± 4.50	14	34.7	22.7 ± 3.53	14.3	32.3	2.09	.038
PBF	39.0 ± 5.00	22.3	49.2	28.5 ± 5.07	14.3	46	18.78	.001
VF%	8.3 ± 4.90	0.5	22	9.8 ± 5.19	0.5	23.5	2.76	.006
WBSC%	30.8 ± 5.08	17	42.5	19.5 ± 3.99	9.6	37.2	21.93	.001
WB MS%	20.0 ± 2.15	14.4	27	26.5 ± 2.57	18	32	24.80	.001

Note. AM: Arithmetic mean; SD: Standard deviation; Min: Minimum; Max: Maximum; BMI: Body mass index; PBF: Percent body fat; VF%: Visceral fat percentage; WBSC%: Whole body subcutaneous fat percentage; WBMS%: Whole body skeletal muscle percentage.

Table 1 shows that females exhibited significantly (p <.05) higher mean body fat percentage and subcutaneous fat percentage than males, whereas males showed significantly higher skeletal muscle percentage. Descriptive statistics for the body composition variables of the study participants measured with BIA as per their nutritional status category are presented in Table 2.

Table 2 presents sex-specific differences in adiposity and skeletal muscle indicators across BMI categories. Although body fat percentage, visceral fat percentage, and subcutaneous fat percentage increased progressively with higher BMI categories, skeletal muscle percentage remained unchanged or declined. This divergence between adiposity and muscle mass was more evident among obese participants and suggests the coexistence of elevated adiposity with relatively low skeletal muscle mass. The BIA measured adiposity indicators classified according to the WBMS% quartiles are presented in Table 3.

Table 2 shows that in both females and males, participants belonging to the lowest muscle mass quartile (Q1) exhibited the highest body fat percentage (PBF), visceral fat percentage (VF%), and whole-body subcutaneous fat percentage (WBSC%), whereas those in the highest muscle mass quartile (Q4) demonstrated the lowest adiposity levels. These findings demonstrate a significant (p<.05) inverse relation-

Table 2: Descriptive statistics for the body composition variables of the study participants measured with BIA

Nutritional status category (n)	PBF Female	PBF Male	VF% Female	VF% Male	WBSC% Female	WBSC% Male	WBMS% Female	WBMS% Male
Underweight (F:25, M:15)	34.4±5.27	26.2±9.02	2.1±0.91	2.0±1.32	23.9±2.88	17.0±5.52	19.9±2.44	26.8±3.76
Normal (F:64, M:60)	37.6±5.22	27.0±4.57	5.1±1.45	6.8±2.03	28.1±2.96	18.1±3.11	20.4±2.48	27.0±2.50
At risk of obesity (F:22, M:30)	39.4±3.63	28.6±3.31	8.3±1.47	11.3±1.74	31.3±1.81	19.9±2.91	20.3±1.69	26.9±1.78
Obese-I (F:62, M:36)	41.2±3.24	31.1±2.85	11.8±2.09	15.8±2.28	34.5±2.50	21.8±2.68	19.8±1.85	25.3±2.35
Obese-II (F:13, M:4)	43.3±3.01	36.4±2.11	19.2±2.48	20.9±3.04	39.6±2.08	28.0±6.21	19.5±1.79	24.2±0.90

Note. AM ± SD: Arithmetic mean ± Standard deviation. Abbreviations as in Table 1.

Table 3: Adiposity indicators according to WBMS% quartiles of the study participants

WBMS%	**Female**				**Male**			
Quartiles	**n (WBMS% range)**	**PBF**	**VF%**	**WBSC%**	**n (quartile range)**	**PBF**	**VF%**	**WBSC%**
Q1 (lowest)	45 (<18.7)	43.7 ± 3.01	9.3 ± 5.28	33.3 ± 4.36	34 (<25.1)	33.0 ± 4.38	11.9 ± 5.92	23.3 ± 4.37
Q2	44 (18.7–19.99)	40.1 ± 3.40	9.0 ± 5.64	31.8 ± 5.28	34 (25.1–26.79)	30.3 ± 3.08	10.8 ± 5.69	20.4 ± 2.30
Q3	49 (20–21.19)	39.0 ± 2.49	9.0 ± 4.03	31.5 ± 3.48	41 (26.8–28.04)	28.1 ± 3.19	9.6 ± 3.96	19.2 ± 2.17
Q4 (highest)	48 (≥21.2)	33.5 ± 4.36	6.0 ± 3.93	26.8 ± 4.74	36 (≥28.05)	23.1 ± 3.69	7.3 ± 4.20	15.6 ± 2.66
		F=73.57, p<.001	F=5.15, p=.002	F=18.40, p<.001		F=48.09, p<.001	F=5.62, p=.001	F=39.98, p<.001

Note. Abbreviations as in Table 1.

ship between skeletal muscle percentage and multiple indicators of adiposity, suggesting that individuals with lower muscle mass tend to exhibit substantially greater fat accumulation. To further identify individuals exhibiting concurrent low muscle mass and high adiposity, participants were classified according to sex-specific quartile cut-offs. Low muscle mass was defined as WBMS% within the lowest quartile (Q1), whereas high adiposity was defined as PBF within the highest quartile (Q4; ≥42.8% in females and ≥32.0% in males). Participants exhibiting both characteristics were classified as having a high adiposity–low muscle (HALM) phenotype.

A total of 55 participants (16.6%) were identified as having the HALM phenotype. The prevalence was 17.2% (32/186) among females and 15.9% (23/145) among males. These findings indicate that approximately one in six older adults in the study population exhibited the coexistence of elevated adiposity and relatively low skeletal muscle percentage.

Pearson correlations were performed separately for females and males and the correlation coefficient (r) values are presented in Tables 4 and 5 in matrix form. The tables show that in both sexes, body fat percentage showed a strong negative correlation with skeletal muscle percentage. BMI showed strong positive correlations with PBF, VF% and WBSC%. Age demonstrated a modest positive relation with body fat percentage and a negative association with skeletal muscle percentage. These findings indicate that increasing adiposity is accompanied by relative muscle depletion.

Multiple linear regression analysis was conducted separately for females and males to evaluate whether skeletal muscle percentage and age independently predicted body fat percentage. The results are presented in Table 6.

Among females, the overall model was statistically significant (F=158.6, p<.001) and explained 63.4% of the variance in body fat percentage (adjusted R^2 = .63). Skeletal muscle percentage emerged as a strong negative predictor (β = -.838, p<.001), indicating that higher muscle percentage was associated with lower adiposity. Age also showed a modest but significant negative association (β = -.125, p =.011).

Among males, the model was also significant (F = 80.4, p<.001) and explained 53.1% of the variance (adj. R^2 = .52). Skeletal muscle percentage was a significant independent predictor (β = -.750, p<.001), whereas age did not show a significant independent effect (p = .322).

Table 4: Correlation coefficient (*r*) values of the study variables in female study participants

	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	PBF	VF%	WBSC%	WBMS%
Age	1	-.11	-.09	-.06	.21**	.02	.09	-.40**
Height		1	.51**	.15*	-.18*	.07	.02	.59**
Weight			1	.93**	.40**	.86**	.78**	.12
BMI				1	.52**	.96**	.89**	-.10
PBF					1	.61**	.82**	-.79**
VF%						1	.90**	-.24**
WBSC%							1	-.48**

* $p < .05$, ** $p < .01$
Note. Abbreviations as in Table 1.

Table 5: Correlation coefficient (*r*) values of the study variables in male study participants

	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	PBF	VF%	WBSC%	WBMS%
Age	1	-.16*	-.07	.01	.27**	.09	.18*	-.38**
Height		1	.54**	.05	-.29**	.01	-.22**	.58**
Weight			1	.87**	.26**	.82**	.37**	.07
BMI				1	.45**	.97**	.55**	-.23**
PBF					1	.44**	.89**	-.73**
VF%						1	.46**	-.26**
WBSC%							1	-.68**

* $p < .05$, ** $p < .01$
Note. Abbreviations as in Table 1.

Table 6: Multiple linear regression predicting total body fat percentage (PBF) with whole-body skeletal muscle percent (WBMS%) and age

Sex	Predictor	B	SE	β	t	p	Adj. R^2
Female	WBMS%	-1.944	0.113	-0.838	-17.188	<0.001	0.63
	Age	-0.103	0.040	-0.125	-2.569	0.011	
Male	WBMS%	-1.480	0.123	-0.750	-12.055	<0.001	0.52
	Age	-0.054	0.054	-0.062	-0.993	0.322	

* $p < .05$, ** $p < .01$
Note. Abbreviations as in Table 1.

It was observed that 7.5% of females and 10.3% of males have the combination of low muscle mass and high subcutaneous fat, indicating the phenotype of sarcopenic obesity among them.

4 Discussion

The principal finding of the present study is the strong inverse relationship between skeletal muscle percentage and adiposity indicators among older adults. Participants belonging to the lowest WBMS quartile consistently exhibited the highest levels of body fat percentage, visceral fat percentage, and subcutaneous fat percentage, whereas those in the highest muscle quartile showed the lowest adiposity levels. This pattern was evident in both females and males and demonstrates that reduced muscle mass is accompanied by increased fat accumulation in later life. These findings are consistent with recent evidence indicating that ageing is characterized by a progressive redistribution of body composition involving skeletal muscle loss and fat accumulation. Recent studies have highlighted that excess adiposity promotes chronic low-grade inflammation, insulin resistance and anabolic resistance, thereby accelerating muscle loss and contributing to the development of sarcopenic obesity-related phenotypes (Axelrod et al., 2023; How et al., 2025; Li et al., 2022).

The correlation and regression analyses further reinforced this relationship. Skeletal muscle percentage demonstrated strong inverse correlations with body fat percentage in both females ($r = -.79$) and males ($r = -.73$). Moreover, skeletal muscle percentage emerged as the strongest independent predictor of body fat percentage, explaining 63.4% of the variance among females and 53.1% among males. These findings suggest that muscle depletion is more closely associated with adiposity than chronological ageing itself. Similar observations have been reported in recent investigations demonstrating that muscle mass is a key determinant of metabolic health in older adults and may be a stronger predictor of adverse outcomes than BMI alone (How et al., 2025; Mainous et al., 2025). The findings therefore support growing recommendations that body composition assessment should include both adiposity and muscle-related measures rather than relying exclusively on BMI.

A notable finding of the present study is that 16.6% of participants exhibited a high adiposity–low muscle (HALM) phenotype, with similar prevalence among females (17.2%) and males (15.9%). Although the present study did not assess muscle strength or physical performance and therefore cannot establish a clinical diagnosis of sarcopenic obesity, the identified HALM phenotype reflects the coexistence of elevated adiposity and reduced skeletal muscle percentage. The observed prevalence falls within the range reported internationally for body composition profiles suggestive of sarcopenic obesity among community-dwelling older adults. Recent studies have reported prevalence estimates varying from approximately 5% to over 20%, depending on diagnostic criteria, ethnicity, and measurement techniques (Axelrod et al., 2023; Ji et al., 2022). Similarly, analyses from Indian populations have documented measurable burdens of sarcopenic obesity-related conditions among older adults, although prevalence estimates vary according to operational definitions (Pal et al., 2021; Verma et al., 2022).

Collectively, these findings suggest that a substantial proportion of older adults in southern West Bengal experience concurrent fat accumulation and muscle depletion. Given the established associations of such body composition patterns with frailty, impaired physical function, metabolic disorders and reduced quality of life, early identification through routine body composition assessment may facilitate targeted interventions focused on physical activity, resistance exercise, and nutritional optimization.

In the Indian context, such patterns underscore the importance of considering ageing within frameworks of nutritional transition and socio-cultural change. Such population-level evidence is essential not only for informing public health strategies, but also for advanced perspectives on human variability in ageing processes across diverse ecological and cultural contexts.

4.1 Limitation and future scopes

The study is cross-sectional in nature and the sample size was determined pragmatically, based on the feasibility of community-based data collection, and is comparable to that used in previous anthropological

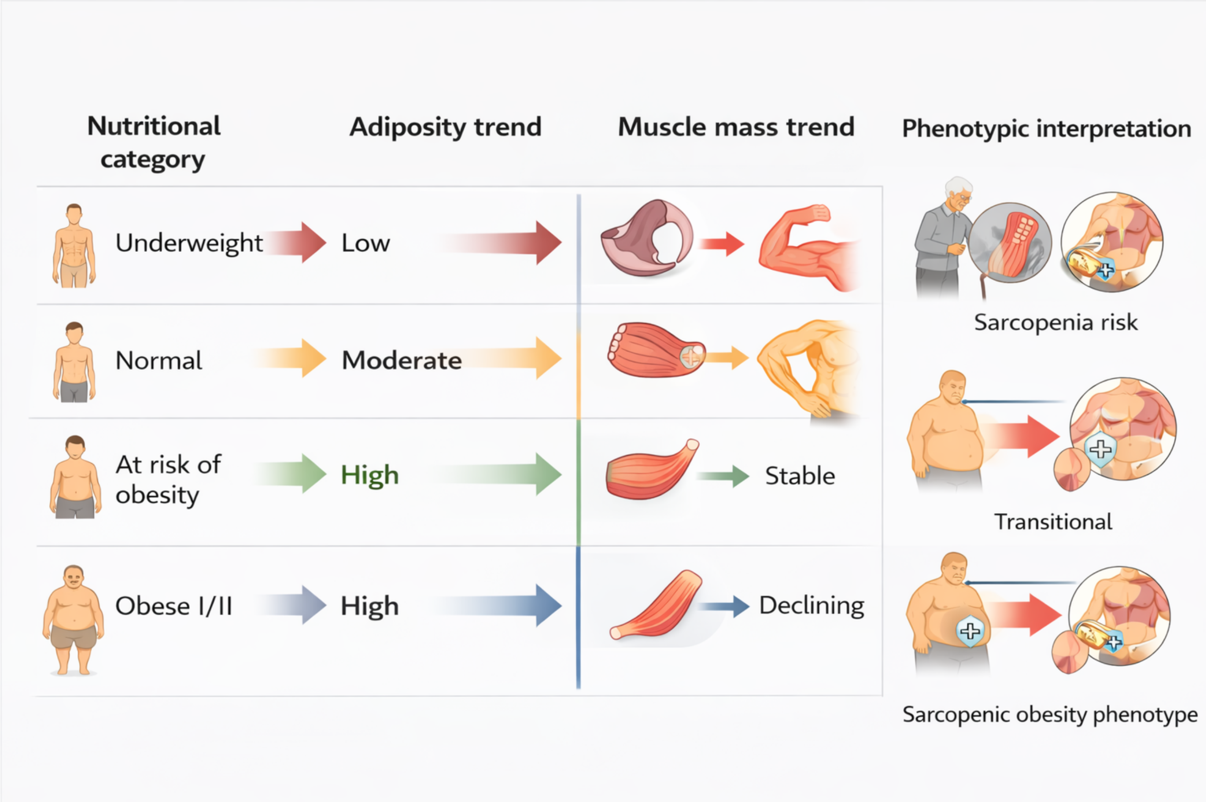

Figure 1: Conceptual representation of the High Adiposity–Low Muscle (HALM) phenotype suggestive of sarcopenic obesity among older adults

and population-based studies of body composition among older adults in India. Although the study was not designed to estimate prevalence, the sample is adequate for describing population-level patterns of body composition and phenotypic variation. Importantly, this work serves as a preliminary report on the presence of the sarcopenic obesity-like phenotype in the study population. Future longitudinal and analytical studies examining causal pathways, exposure-outcome relationships, and susceptibility factors may provide deeper insights into this condition.

4.2 Conclusion

The present study demonstrated a significant ($p<.05$) inverse relationship between skeletal muscle percentage and adiposity among older adults in southern West Bengal. Approximately 16.6% of participants exhibited a high adiposity–low muscle (HALM) phenotype, highlighting the importance of assessing body composition beyond BMI.

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Conflict of interest

None declared.

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