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Age Trends in the Double Burden of Malnutrition (DBM) and Body Composition of the Jaunsari Adults of Uttarakhand, India

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Abstract

To investigate the age trends in body composition related to the double burden of malnutrition (DBM), the present cross-sectional study was conducted among the Jaunsari people living in Lakhamandal village of Dehradun district of Uttarakhand, India. A total of 304 Jaunsari adults (134 males, 170 females, 18-60 years) were randomly selected. Information on their socio-demographic profile was collected through a standardised schedule and anthropometric measurements of height (HT), weight (WT), waist circumference (WC) and hip circumference (HC) were taken following standard procedure. Derived variables including body mass index (BMI), waist-to-hip ratio (WHR), body fat percentage (BF %), fat mass (FM), fat-free mass (FFM), fat mass index (FMI), and fat-free mass index (FFMI) were calculated. To assess nutritional status including abdominal obesity, the World Health Organization's recommended cut-off values for BMI, WC and WHR were used. Results revealed the prevalence of overweight-obesity was higher among men than women (23.9 % vs. 22.4 %). Women were more undernourished (32.4 % vs. 26.9 %), but with higher abdominal obesity (WC: 21.2 % vs. 11.9 %, WHR: 30.0 % vs. 14.2 %). With increasing age, the mean values of most of the studied variables increased among women (except HT, FFM, FFMI, WHR). For men, the middle age group (26-39 years) exhibited the highest mean values for variables except BF %, FM, FMI, and WHR. The coexistence of undernutrition and overweight-obesity indicated the threat of DBM, demanding immediate nutritional intervention programmes among this community.

Keywords: Body composition, Double burden of malnutrition, Indian tribes, Jaunsari

1 Introduction

In 2022, the World Health Organization (WHO) estimated that globally 2.5 billion adults were overweight including 890 million obese, whereas 390 million were underweight (World Health Organization, 2024). Overweight/obesity is no longer a problem only in high-income countries. Today also low- and middle-income countries (LMICs) face the double burden of malnutrition (DBM), which is the coexistence of undernutrition and overweight/obesity in the population (Bhandari et al., 2021; Little et al., 2020; Mukherjee et al., 2022; Popkin et al., 2020; Singh, 2019). This DBM exists not only at the country or community level but within the same households as well (Little et al., 2020). It is even observed that individuals who were stunted in childhood have become overweight as adults (Ramachandran, 2019).

Like all other developing countries, India has long been suffering from the burden of malnutrition, especially undernutrition. However, recent trends show a rapid increase in overweight and obesity as well (Mukherjee et al., 2022). According to the latest National Family Health Survey-5 (NFHS-5) (2019-21) data, the prevalence of overweight among Indian adults (15-49 years) was higher for both men (22.9 %) and women (24.0 %) than underweight (men: 16.2 %; women: 18.7 %) (International Institute for Population Sciences, 2021). Further, NFHS-5 data also revealed that the prevalence of abdominal obesity among

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Indian men and women is 12 % and 40 %, respectively (Chaudhary & Sharma, 2023). It is, therefore, clear that India is undergoing a nutrition transition where undernutrition prevalence is declining while overweight/obesity is rising. The increasing prevalence of DBM has spurred significant research interest in understanding the associated changes in body composition with aging (Roy et al., 2020).

Anthropometric measurements of body composition help to track growth throughout life, understand how health and disease develop, formulate nutritional strategies, and see if treatments are working (Kuriyan, 2018). The most common and widely used model for assessing body composition is the two-compartment (2C) model, which divides body mass into fat mass (FM) and fat-free mass (FFM) (Jackson et al., 2013; James et al., 1988; Kuriyan, 2018; Saha & Sil, 2019). The amount of FM and FFM present in the human body has different health implications (Kulkarni et al., 2014; Saha & Sil, 2019). In particular, excess FM is associated with obesity-related chronic illnesses such as insulin resistance, hypertension, dyslipidemia, type 2 diabetes, heart disease, stroke, kidney disease, infertility, etc., whereas FFM helps to protect from chronic diseases like diabetes and osteoporosis (Das, Mukherjee, Ganguli, et al., 2020; James et al., 1988; Kulkarni et al., 2014; Milanović et al., 2011; Roy et al., 2020).

Body composition is influenced by several factors like age, sex, dietary habits, lifestyle, physical activity, hormones, genes, socio-economic condition, environment, disease, etc. (Das, Mukherjee, Ganguli, et al., 2020; Kulkarni et al., 2014; Kuriyan, 2018; Milanović et al., 2011; Saha & Sil, 2019). The natural progression of aging is accompanied by a number of physiological and nutritional changes such as a decrease in FFM and frequently an increase in FM, sometimes without visible changes in body mass (Milanović et al., 2011; Roy et al., 2020; St-Onge & Gallagher, 2010). Furthermore, studies also revealed that with aging, the accumulation of FM is more specifically concentrated in the abdominal region in both men and women (Roy et al., 2020; St-Onge & Gallagher, 2010). Therefore, the regular assessment of body composition changes with aging is crucial for health professionals to develop strategies for weight management and maintaining functional capacity (Roy et al., 2020).

A sizable portion of the Indian population is constituted by tribal people, who often live under unique social, cultural, and economic conditions. Indian tribes are among the most underprivileged sections of society, with high prevalence of undernutrition (Bhandari et al., 2021; Chaudhary & Sharma, 2023; Das, Mukherjee, Chanak, et al., 2020; Kshatriya & Acharya, 2016; Mukherjee et al., 2022; Singh, 2019). However, rapid urbanization has resulted in notable changes in the lifestyle of these people, particularly their dietary habits and occupational activities (Das, Mukherjee, Ganguli, et al., 2020; Mukherjee et al., 2022). The easy availability of less nutritious highly processed foods and beverages in local shops and supermarkets has affected body composition and aggravated the risk of excessive weight gain in tribal people (Kshatriya & Acharya, 2016; Mukherjee et al., 2022). A decade ago, the National Nutrition Monitoring Bureau (NNMB) conducted a study in tribal areas across nine states of India and reported that the prevalence of overweight among adult tribal people had increased from 5 % to 9 %, between 1997-98 and 2008-09 (National Nutrition Monitoring Bureau, 2009). Kshatriya & Acharya (2016) in their study reported that approximately 14.8 % of adult tribal men and 10.9 % of women were overweight and 1.7 % of men and 1.5 % of women were identified as obese. Such findings indicate that despite several initiatives taken by the state and central governments, the tribal people are suffering from DBM. This situation demands more exploratory studies among different indigenous communities living in varied ecological settings.

The present study focuses on the Jaunsari population residing in the Jaunsar region of Dehradun district, Uttarakhand, India. Traditionally, the Jaunsari community traces its ancestry to the Pandavas of the Mahabharata epic (Gill & Singh, 2023; Kumari et al., 2021; Majumdar, 1962; Mukherjee & Das, 2014; Tripathi, 2020). The Government of India designated the Jaunsar-Bawar region as a 'Scheduled Tribal Area' in 1967, granting ST status to its inhabitants (Gill & Singh, 2023; Kumari et al., 2021; Mukherjee & Das, 2014; Tripathi, 2020). The Jaunsar-Bawar region is characterized by geographic isolation and a distinct cultural identity. Notably, the Jaunsari practised fraternal polyandry, a form of marriage where multiple brothers share a wife (Gill & Singh, 2023; Kumari et al., 2021; Majumdar, 1962; Mukherjee & Das, 2014; Tripathi, 2020).

The Jaunsari population encompasses various castes within the Hindu caste system, including Brahmins, Rajputs, Luhar, Bajgi, Kolta, Dom, Chamar, etc. (Kumari et al., 2021; Mukherjee & Das, 2014). Social stratification and caste differentiation persist within the community (Kumari et al., 2021). Subsistence for the Jaunsari primarily revolves around agriculture and animal husbandry (Kumari et al., 2021; Mukherjee & Das, 2014; Tripathi, 2020). Landless individuals often rely on daily wage labour (Mukherjee & Das, 2014; Mukherjee et al., 2022; Pawar et al., 2017; Tripathi, 2020). According to the 2011 census, the total population of Jaunsari in Uttarakhand was 88,664 (Gill & Singh, 2023; Mitra, 2020). The Jaunsari constitute approximately 32.5 % of Uttarakhand's ST population (Mukherjee et al., 2022; Pawar et al., 2017).

Prior research on the Jaunsari has predominantly explored their marriage practices, ethno-medicinal practices, magical practices, food and beverages, life expectancy, identity politics, health care practices, etc. (Gill & Singh, 2023; Kshatriya et al., 1997; Kumari et al., 2021; Majumdar, 1962; Mukherjee & Das, 2014; Pawar et al., 2017; Rana et al., 2022; Rizvi, 2013; Tripathi, 2020). However, only a limited number of studies have specifically investigated the Jaunsari community's nutritional status, revealing the prevalence of DBM, where underweight ranges between 26 %-35 % and overweight between 11 %-18 % irrespective of gender (Mukherjee et al., 2022; Ravi et al., 2019).

Against this backdrop, this study aimed to assess the age trends in DBM and body composition characteristics among the Jaunsari people living in Lakhamandal village of Dehradun district of Uttarakhand, India.

2 Materials and Methods

The present cross-sectional study was conducted among a total of 304 Jaunsari adults (134 males, 170 females) aged 18-60 years residing in Lakhamandal village of Jaunsar region of Chakrata block of Dehradun district, Uttarakhand, India. Lakhamandal village has been selected purposively as a representative village of the Jaunsar region due to its notable similarities with neighbouring villages. The village is currently experiencing a transformation in its traditional lifestyle due to the interactions with tourists from various regions of the country as this location is well known for the renowned Lakhamandal Temple dedicated to Lord Shiva. According to local legend, this temple and the surrounding area are believed to be the site where Duryodhan, from the Mahabharata, plotted to burn the Pandavas alive in the Lakshagriha house (Mukherjee & Das, 2014).

As part of the Garhwal Himalayas, the Jaunsar-Bawar region is characterised by dense forests, rugged mountains, and gorges (Mitra, 2020; Mukherjee & Das, 2014). Its unique geography and history contribute to a distinct ecological and cultural identity (Gill & Singh, 2023). The region falls between 30°31' and 31°3' 30" N latitude and 77°45' and 78°7' 20" E longitude, encompassing an area of 343.5 square miles (Gill & Singh, 2023). Participants were randomly selected while adhering to specific inclusion criteria, ensuring they had no visible physical deformities or self-reported illnesses at the time of data collection. They were also screened for clinical signs of nutritional deficiencies, such as phrynoderma, glossitis, angular stomatitis, goiter, and anemia. Individuals exhibiting any of these deficiency signs were purposefully excluded from the final sample. The study obeyed the ethical guidelines for human participants outlined in the Declaration of Helsinki (Touitou et al., 2004). Necessary approval was obtained from the institutional ethical committee and local authorities. Data was collected after getting consent from the participants. Primary information on the socio-demographic profile including age, sex, family size, education, earning source, and per capita monthly income (Rs.) of the studied individuals was collected through a standardised schedule.

The anthropometric measurements, including height (HT) (cm), weight (WT) (kg), waist circumference (WC) (cm) and hip circumference (HC) (cm) were done following standard procedure (Lohman et al., 1988). HT was measured by Martin's anthropometer rod to the nearest 0.1 cm and WT was measured by a digital scale (OMRON HBF-212) to the nearest 0.1 kg. HC and WC were measured by a calibrated non-elastic measuring tape (Gulick Anthropometric Tape). The technical error of measurement (TEM) was found to be within acceptable limits (Ulijaszek & Kerr, 1999). Body mass index (BMI) was calculated with the formula: $WT(kg) / HT(m)^2$ (James et al., 1988). To measure abdominal obesity, the waist-to-hip ratio (WHR) was calculated using the standard formula: $WHR = WC(cm) / HC(cm)$ (Valdez et al., 1993). BMI cut-off values for the Asian population as proposed by WHO were considered here and the participants were categorised into three groups: underweight (BMI of <18.5 kg/m^2), normal (BMI of 18.5-22.9 kg/m^2) and overweight-obesity (BMI of $\geq$23.0 kg/m^2) (World Health Organization, 2000). To determine abdominal obesity, internationally accepted cut-off values for WC (men: $\geq$90 cm, women: $\geq$80 cm) (World Health Organization, 2000) and WHR (men: >0.95, women: >0.85) (World Health Organization, 1989) were used. Body composition variables, including body fat percentage (BF%), FM, FFM, fat mass index (FMI), and fat-free mass index (FFMI) were calculated following standard formulae (Deurenberg et al., 1991; VanItallie et al., 1990; Lohman, 1992; Heymsfield et al., 1996):

$$\text{BF\%} = (1.20 \times \text{BMI}) + (0.23 \times \text{Age}) - (10.8 \times \text{Sex}) - 5.4$$

where Sex: Male = 1, Female = 0.

$$\text{FM (kg)} = \text{Body Weight (kg)} \times \left(\frac{\text{BF\%}}{100}\right)$$

$$\text{FFM (kg)} = \text{Body Weight (kg)} - \text{FM (kg)}$$

$$\text{FMI (kg/m}^2\text{)} = \frac{\text{FM (kg)}}{\text{Height (m)}^2}$$

$$\text{FFMI (kg/m}^2\text{)} = \frac{\text{FFM (kg)}}{\text{Height (m)}^2}$$

All statistical analyses were conducted using SPSS software version 26.0 for Windows (IBM Corp., NY, USA). The participants were categorised into three age groups based on tertile values: Group I ($\leq$25 years), Group II (26-39 years), and Group III ($\geq$40 years). Descriptive statistics of mean and standard deviation (SD) were calculated for all anthropometric and derived variables. One-way ANOVA was performed to test significant mean differences between age groups for the studied variables. Pearson correlation and linear regression were used to find out the linear relationship between age and studied variables. In addition to this, the χ^2 test was conducted to examine the association between age groups, socio-demographic variables, and nutritional categories. A p-value of <.05 was considered to be statistically significant.

3 Results

The associations between socio-demographic variables and nutritional categories of the studied participants are given in Table 1. The overall prevalence of underweight was found to be 29.9 % and overweight-obesity was 23 % when classified by BMI. Underweight prevalence (14.5 %) was found higher among young participants ($\leq$25 years). Medium-sized families of 4-6 members have the highest frequency (45.4 %) and higher prevalence of both underweight and overweight-obesity. Most of them were engaged in wage activities and agricultural work. 70 % of participants reported having a per capita monthly income below Rs.1001. Among different socio-demographic variables, education (χ^2 = 37.053, df = 22, p < .05) and earning source (χ^2 = 39.548, df = 20, p < 0.01) showed strong statistically significant association with nutritional categories.

Table 2 shows age trends in anthropometric and body composition variables of the studied participants. It was observed that with increasing age, the mean value of most of the studied variables increased among women (except for HT, FFM, FFMI, and WHR). For men, the middle age group (26-39 years) exhibited the highest mean values for variables except FM, FMI, and WHR. Statistically significant (p < .05) mean differences in anthropometric and body composition variables were observed for both men (except for HT) and women (except for HT, FFM, FFMI, and WHR) across different age groups.

Table 3 presents the age-wise distribution of the studied participants across different nutritional statuses. BMI assessment showed a higher prevalence of underweight in women than men (32.4 % vs. 26.9 %), while overweight-obesity was slightly more common in men (23.9 % vs. 22.4 %). Underweight was more frequent in younger age groups, whereas overweight-obesity increased with age. Abdominal obesity was more prevalent in women than men based on WC (21.2 % vs. 11.9 %) and WHR (30 % vs.

Table 1: Association between socio-demographic variables and nutritional status of the participants, with percentages in parentheses. * $p < .05$, ** $p < .01$, *** $p < .001$, NS, non-significant ($p > .05$).

Socio-demographic Characteristics	Nutritional Status (BMI)			Total	χ^2
	Underweight	Normal	Overweight-Obese		
Total	91 (29.9)	143 (47.0)	70 (23.0)	304 (100.0)	–
Age group (years)					26.0***
Group I (≤25 years)	44 (14.5)	63 (20.7)	9 (3.0)	116 (38.2)	
Group II (26-39 years)	22 (7.2)	44 (14.5)	30 (9.9)	96 (31.6)	
Group III (≥40 years)	25 (8.2)	36 (11.8)	31 (10.2)	92 (30.3)	
Family size (n)					21.3^{NS}
Less than 4	27 (8.9)	29 (9.5)	22 (7.2)	78 (25.7)	
4 – 6	43 (14.1)	69 (22.7)	26 (8.6)	138 (45.4)	
Above 6	21 (6.9)	45 (14.8)	22 (7.2)	88 (28.9)	
Education					37.1*
No education	13 (4.3)	23 (7.6)	18 (5.9)	54 (17.8)	
Primary	18 (5.9)	17 (5.6)	15 (4.9)	50 (16.4)	
Secondary	31 (10.2)	63 (20.7)	21 (6.9)	115 (37.8)	
Higher	29 (9.5)	40 (13.2)	16 (5.3)	85 (28.0)	
Earning source					39.5**
Daily Wage Labour	29 (9.5)	26 (8.6)	12 (3.9)	67 (22.0)	
Owner Cultivator	14 (4.6)	33 (10.9)	14 (4.6)	61 (20.1)	
Business	2 (0.7)	11 (3.6)	8 (2.6)	21 (6.9)	
Service	6 (2.0)	9 (3.0)	9 (3.0)	24 (7.9)	
Housewife	10 (3.3)	34 (11.2)	20 (6.6)	64 (21.1)	
Dependent	7 (2.3)	6 (2.0)	4 (1.3)	17 (5.6)	
Pensioner	3 (1.0)	3 (1.0)	2 (0.7)	8 (2.6)	
Student	20 (6.6)	21 (6.9)	1 (0.3)	42 (13.8)	
Per capita monthly income (Rs.)					26.0^{NS}
≤750.00	37 (12.2)	49 (16.1)	27 (8.9)	113 (37.2)	
751.00 – 1000.00	28 (9.2)	46 (15.1)	26 (8.6)	100 (32.9)	
≥1001.00	26 (8.6)	48 (15.8)	17 (5.6)	91 (29.9)	

14.2 %). Abdominal obesity increased with age in both sexes for both WC and WHR. The χ^2 test showed a significant association between age group and WC-based nutritional status in both sexes ($p < .01$). In contrast, BMI-based ($p < .001$) and WHR-based ($p < .01$) nutritional status were significantly associated with age only in men.

Table 4 displays a correlation analysis between age and anthropometric variables among the studied participants. The correlations indicate a significant linear relationship of anthropometric variables with age, except for HT and FFMI among men and HT, WT, and WHR among women. The strongest relationship was observed between age and BF% for both men ($r = .744$, $p < .001$) and women ($r = .643$, $p < .001$).

Table 5 represents the effect of age on the body composition variables of the studied participants. Age had a statistically significant positive impact on BF%, FM, and FMI. Its impact on FFM and FFMI was significantly negative for women but not men.

4 Discussion

This study examined the presence of DBM and age trends in body composition characteristics among the adult Jaunsaris in Uttarakhand, India. The community is experiencing a DBM. Socio-demographic variables

Table 2: Age trends in anthropometric and body composition variables (mean ± SD) of the participants. M = male; F = female; HT = height; WT = weight; WC = waist circumference; HC = hip circumference; BF% = body fat percentage; FM = fat mass; FFM = fat free mass; FMI = fat mass index; FFMI = fat free mass index; BMI = body mass index; WHR = waist-to-hip ratio. * $p < .05$, ** $p < .01$, *** $p < .001$, NS, non-significant (p > .05).

Variable	Sex	Group I (≤25 years)	Group II (26-39 years)	Group III (≥40 years)	F value
HT	M	163.56 ± 5.14	163.12 ± 5.25	161.4 ± 6.6	1.729^{NS}
	F	150.84 ± 5.76	151.58 ± 5.09	150.23 ± 5.06	0.891^{NS}
WT	M	50.74 ± 7.75	58.89 ± 8.03	56.12 ± 11.51	10.272***
	F	44.62 ± 7.65	47.99 ± 10.5	49.49 ± 11.75	3.527*
WC	M	68.01 ± 7.99	78.63 ± 9.21	77.17 ± 12.34	17.269***
	F	65.92 ± 7.53	71.21 ± 11.77	74.71 ± 12.09	9.958***
HC	M	82.26 ± 7.37	89.12 ± 6.36	86.21 ± 8.15	10.637***
	F	82.32 ± 7.46	85.88 ± 9.54	90.62 ± 9.88	12.156***
BF%	M	11.26 ± 2.71	18.01 ± 3.99	20.74 ± 4.19	89.088***
	F	23.06 ± 3.59	26.87 ± 4.96	32.7 ± 5.77	56.994***
FM	M	5.89 ± 2.42	10.84 ± 3.52	12.04 ± 4.76	41.149***
	F	10.53 ± 3.50	13.38 ± 5.80	16.77 ± 7.36	16.862***
FFM	M	44.84 ± 5.46	48.05 ± 5.01	44.09 ± 7.02	5.288**
	F	34.08 ± 4.34	34.6 ± 4.93	32.71 ± 4.96	2.337^{NS}
FMI	M	2.18 ± 0.81	4.07 ± 1.29	4.56 ± 1.58	52.069***
	F	4.61 ± 1.44	5.78 ± 2.33	7.42 ± 3.20	19.404***
FFMI	M	16.72 ± 1.38	18.05 ± 1.58	16.85 ± 1.89	9.013***
	F	14.95 ± 1.41	15.03 ± 1.73	14.46 ± 1.82	1.892^{NS}
BMI	M	18.90 ± 2.18	22.12 ± 2.74	21.42 ± 3.37	18.975***
	F	19.56 ± 2.83	20.81 ± 4.00	21.88 ± 4.87	4.892***
WHR	M	0.82 ± 0.05	0.88 ± 0.07	0.89 ± 0.08	12.570***
	F	0.80 ± 0.05	0.82 ± 0.07	0.82 ± 0.06	2.606^{NS}

Table 3: Age-wise distribution of the studied participants among different nutritional statuses. Numbers, with percentages in parentheses. M = male, F = female. * $p < .05$, ** $p < .01$, *** $p < .001$, NS, non-significant (p > .05).

Nutritional Categories		Age group (years)						Total		χ^2
		Group I (≤25 years)		Group II (26-39 years)		Group III (≥40 years)				
		M	F	M	F	M	F	M	F	
BMI	Underweight	21 (36.8)	23 (39.0)	5 (12.5)	17 (30.4)	10 (27.0)	15 (27.3)	36 (26.9)	55 (32.4)	M: 25.2*** F: 7.4^{NS}
	Normal	34 (59.6)	29 (49.2)	18 (45.0)	26 (46.4)	14 (37.8)	22 (40.0)	66 (49.3)	77 (45.3)	
	Overweight-obesity	2 (3.5)	7 (11.9)	17 (42.5)	13 (23.2)	13 (35.1)	18 (32.7)	32 (23.9)	38 (22.4)	
WC	Normal	56 (98.2)	55 (93.2)	33 (82.5)	42 (75.0)	29 (78.4)	37 (67.3)	118 (88.1)	134 (78.8)	M: 10.1** F: 12.2**
	Abdominal obesity	1 (1.7)	4 (6.8)	7 (17.5)	14 (25.0)	8 (21.6)	18 (32.7)	16 (11.9)	36 (21.2)	
WHR	Normal	55 (96.5)	48 (81.4)	34 (85.0)	37 (66.1)	26 (70.3)	34 (61.8)	115 (85.8)	119 (70.0)	M: 12.7** F: 5.8^{NS}
	Abdominal obesity	2 (3.5)	11 (18.6)	6 (15.0)	19 (33.9)	11 (29.7)	21 (38.2)	19 (14.2)	51 (30.0)	

like education and earning source exhibited a strong association with nutritional status. The findings also demonstrated significant variation in most anthropometric and body composition characteristics across different age groups. Specifically, as age increased, most variables tended to rise in women (with the exceptions of HT, FFM, FFMI and WHR), while in men, the middle-aged group (26-39 years) had the highest average values for most variables excluding BF%, FM, FMI and WHR. Correlation analysis showed a strong linear relationship between age and anthropometric variables, with the exceptions of HT and FFMI in men; and HT, WT and WHR in women. Moreover, younger individuals were more likely to be classified

Table 4: Correlations of age with anthropometric variables. M = male; F = female; HT = height; WT = weight; WC = waist circumference; HC = hip circumference; BF% = body fat percentage; FM = fat mass; FFM = fat free mass; FMI = fat mass index; FFMI = fat free mass index; BMI = body mass index; WHR = waist-to-hip ratio. * $p <$ .05, ** $p < .01$, *** $p < .001$, NS, non-significant (p > .05).

Sex	HT	WT	WT	WC	HC	BF%	FM	FFM	FMI	FFMI	BMI	WHR
M	-0.118^{NS}	0.229**	0.229**	0.327***	0.213*	0.744***	0.584***	-0.067^{NS}	0.619***	-0.020^{NS}	0.314***	0.317***
F	-0.103^{NS}	0.138^{NS}	0.138^{NS}	0.290***	0.327***	0.643***	0.381***	-0.202**	0.417***	-0.192*	0.194*	0.108^{NS}

Table 5: Linear regression analysis of age with body composition variables. M = male; F = female; BF% = body fat percentage; FM = fat mass; FFM = fat free mass; FMI = fat mass index; FFMI = fat free mass index. * $p < .05$, ** $p < .01$, *** $p < .001$, NS, non-significant (p > .05).

Body composition variables	Sex	B	95% CI	SE	Standardized β	t
BF%	M	1.704	1.440 – 1.967	0.133	.744	12.79***
BF%	F	1.375	1.126 – 1.625	0.126	.643	10.89***
FM (kg)	M	1.627	1.238 – 2.017	0.197	.584	8.27***
FM (kg)	F	0.813	0.512 – 1.114	0.152	.381	5.34***
FFM (kg)	M	-0.139	-0.496 – 0.218	0.180	-.067	-0.77
FFM (kg)	F	-0.564	-0.979 – -0.148	0.211	-.202	-2.68**
FMI (kg/m^2)	M	4.795	3.748 – 5.841	0.529	.619	9.06***
FMI (kg/m^2)	F	2.087	1.393 – 2.781	0.351	.416	5.94***
FFMI (kg/m^2)	M	-0.146	-1.140 – 1.119	0.639	-.020	-0.23
FFMI (kg/m^2)	F	-1.532	-2.725 – -0.339	0.604	-.192	-2.54*

as underweight, whereas older age groups had higher rates of overweight-obesity and abdominal obesity for both sexes.

Several studies have already reported that age plays a crucial role in influencing body composition, as various changes take place in the body over time, including alterations in muscle mass, fat distribution, and bone density (Das, Mukherjee, Ganguli, et al., 2020; Roy et al., 2020; St-Onge & Gallagher, 2010). In the present study, as age progresses, the mean ± SD of BF%, FM and FMI consistently increased in both sexes. In men, FFM and FFMI gradually decline with age, while in women, these measures do not show a consistent decrease over time. Previous studies have reported an increase in BF% and FM, alongside a decline in FFM and FFMI with age (Das, Mukherjee, Ganguli, et al., 2020; Roy et al., 2020; St-Onge & Gallagher, 2010). However, some researchers have also argued that FFM does not necessarily decrease with age (Kalantari et al., 2017; Verreijen et al., 2017). In Jaunsari females, the increase of WT may be driven mainly by the accumulation of fat accompanied by a rather minor loss of muscle or other lean body mass. An interesting finding in our study was that a significant number of the women were involved in agricultural work and daily wage labour, about as frequently as the men. This suggests that physical activity might have played a crucial role in maintaining FFM, potentially counteracting the age-related decline in FFM reported by others (Das, Mukherjee, Ganguli, et al., 2020; Kulkarni et al., 2014; Roy et al., 2020). However, the slight reduction in FFM observed still requires further investigation.

Abdominal obesity is a major health issue for women in India, as many women with a normal BMI still carry excess fat around their abdomen, which raises the risk of metabolic disorders and non-communicable diseases such as type 2 diabetes (Chaudhary & Sharma, 2023). Numerous global studies have shown gender differences in obesity, with women being more prone than men to abdominal obesity (Ahmad et al., 2016; Kanter & Caballero, 2012). The prevalence of abdominal obesity among women in the present study is almost double that of men (WC: 21.2 % vs. 11.9 % ; WHR: 30.0 % vs. 14.2 %). A similar trend was observed among the Barwar community of Uttar Pradesh (WC: 23.6 % vs. 7.1 % ; WHR: 65.5 % vs. 34.8 %) (Mahapatra, 2023), rural people of Tamil Nadu (WC: 42.0 % vs. 25.2 %) (Little et al., 2020), and scheduled tribes from the latest NFHS-5 data (WC: 24.0 % vs. 6.1 %) (Chaudhary & Sharma, 2023). High prevalence of abdominal obesity is also reported from previous global studies among women from Malaysia (WC: 66.4 % ; WHR: 54.2 %) (Ahmad et al., 2016), Iran (WC: 54.4 %) (Veghari et al., 2016), Syria (WC: 55.0 % ; WHR: 33.0 %) (Bakir et al., 2017) and Bangladesh (WC: 48.7 % ; WHR: 79.1 %) (Siddiquee et al., 2015). The factors associated with abdominal obesity in these studies are biological aspects, economic status, educational level, physical activity level, dietary habits, sedentary life, degree of urbanization, etc. (Ahmad et al., 2016; Bakir et al., 2017; Chaudhary & Sharma, 2023; Kanter & Caballero, 2012; Siddiquee et al., 2015). In India, tribal communities are currently experiencing an economic transition driven by rapid urbanization, which has led to rising prosperity and more comfortable lifestyles. This shift has introduced easier access to transportation, changes in occupation, urban processed foods, and more opportunities for sedentary living (Das, Mukherjee, Ganguli, et al., 2020; Mukherjee et al., 2022). The Jaunsar-Bawar region, which attracts tourists year-round due to the presence of the Lakhamandal Temple, has introduced urban influences such as modern amenities and changing food habits to the locals. This exposure may have played a role in the high rates of abdominal obesity observed in the Jaunsari population.

The current study observes a gradual increase from underweight to overweight-obesity with advancing age. The age group I of $\leq$25 years shows the highest prevalence of underweight, while those of group III aged $\geq$40 years have the highest prevalence of overweight-obesity. These findings align with an earlier study based on NFHS-4 data reporting the highest underweight prevalence among individuals aged 15-19 years (men: 44.9 %, women: 42.0 %) and the highest overweight/obesity prevalence among those aged 35-49 years (men: 27.6 %, women: 32.2 %) (Dutta et al., 2019).

Overall, women were found more undernourished than men (32.4 % vs. 26.8 %) in the present study. This result corroborates previous studies on the same community by Ravi et al. (2019), which reported 35.0 % of women and 32.0 % of men were undernourished, as well as with findings from rural adults of Uttarakhand (women: 43.5 %) (Pant, 2016). However, contrasting trends were noted among neighbouring communities in Uttarakhand, such as the Tharus (men: 26.4 %; women: 18.0 %) (Mukherjee et al., 2015) and the Rajis (men: 55.8 %; women: 37.3 %) (Alam & Jha, 2018). A large-scale cross-sectional study on nine tribes from three states in India also revealed a higher prevalence of undernutrition among tribal women than men (46.6 % vs. 32.1 %) (Kshatriya & Acharya, 2016). Various developmental and economic initiatives by state and central government agencies have enabled many tribes to achieve a relatively affluent lifestyle to varying degrees (Dutta et al., 2019; Kshatriya & Acharya, 2016; Rai et al., 2021). These communities now receive rice, wheat, and sugar at highly subsidized rates through government schemes, increasing their reliance on public food assistance programs (Dutta et al., 2019; Kshatriya & Acharya, 2016). This shift from traditional food autarky to a more limited diet, heavily reliant on public distribution systems, may be a key factor affecting the prevalence of undernutrition and obesity among India's tribal populations (Dutta et al., 2019; Rai et al., 2021). Research suggests that early-life undernutrition, followed by exposure to diets high in refined carbohydrates, increases the likelihood of obesity (Wells & Siervo, 2011; Grijalva-Eternod et al., 2012). The high prevalence of overweight-obesity (23.01 %) in the present study population may align with these observations.

According to the study by Meshram et al. (2016), the total prevalence of overweight and obesity in India is 29.0 %. In a recent study, Luhar et al. (2020) predicted the future prevalence of overweight and obesity among Indian adults aged 20-69 years and estimated that overweight will increase from 12.6 % to 30.5 % among men and 14.7 % to 27.4 % among women between 2010 and 2040. Over the same period, the prevalence of obesity is forecasted to increase from 2.4 % to 9.5 % among men and 4.4 % to 13.9 % among women (Luhar et al., 2020). Several recent studies expressed their concern about the increasing prevalence of overweight/obesity, despite persistent undernutrition, among indigenous populations of India (Ghosh, 2022; Kshatriya & Acharya, 2016; Mahapatra, 2023; Mukherjee et al., 2022; National Nutrition Monitoring Bureau, 2009; Singh, 2019). The prevalence of overweight-obesity in the present population (men: 23.9 %; women: 22.4 %) is higher than that among the Tharus (men: 14.9 %; women: 13.5 %) (Mukherjee et al., 2015), Jaunsaris (men: 15.0 %; women: 18.0 %) (Ravi et al., 2019), and Rajis (men: 0.0 %; women: 2.0 %) (Alam & Jha, 2018), as well as the state-level prevalence reported in the NFHS-4 data (men: 17.7 %; women: 20.4 %) (Ahirwar & Mondal, 2019), but lower than that in the

Bhotias of Uttarakhand (men: 54.8 %; women: 57.6 %) (Kandpal et al., 2016).

A notable finding of the present study is that, although 32.4 % of Jaunsari women were categorized as underweight based on BMI, 21.2 % and 30.0 % were found to be abdominally obese when assessed by WC and WHR, respectively. The coexistence of underweight and abdominal obesity among females in the present study aligns with the findings from various other studies conducted in India (Little et al., 2020; Meshram et al., 2016; Pengpid & Peltzer, 2019). Therefore, the high prevalence of overweight/obesity (23.01 %) alongside undernutrition (29.9 %) represents a significant health challenge for the studied population. The present study assumes several possible factors including the emergence of urban market centres near the region, exposure to urban diets and shifts in traditional lifestyles toward a more sedentary life, significantly impacting health and increasing the risk of several chronic diseases like cardiovascular disease, diabetes, multimorbidity, reducing overall health and well-being.

The present study, while providing valuable insights, is constrained by several methodological limitations. One of the primary concerns is the small sample size, which may compromise the study's ability to accurately represent the broader population resulting in a reduced statistical power, making it challenging to detect significant differences or associations between variables. Since the sample was collected from a single rural village, the trends of malnutrition may differ significantly among the semi-urban or urban Jaunsari population. Further, the study lacks quantification of individual physical activity. This may hinder the establishment of a causal relationship between physical activity and the dependent variables. Moreover, the cross-sectional design of the study also presents a methodological challenge and limits the ability to establish a clear temporal relationship between variables, making it difficult to delineate cause-and-effect relationships.

5 Conclusion

This study established the presence of DBM among the adult Jaunsari population, including a trend of age-related increase in abdominal obesity. Additionally, a significant age effect on body composition was seen. Interestingly, unlike other body composition variables, FFM did not show a predictable pattern with age, indicating a possible resistance in the population to chronic diseases. However, this finding underscores the complexity of body composition, suggesting that multiple factors must be considered when examining these changes. Understanding these shifts is essential for creating effective strategies to promote health and mitigate the risks of excess abdominal fat.

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Conflict of Interest

The authors declare no conflict of interest.

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