Bio-Social Correlates of General and Abdominal Obesity in the Rural Population of Haryana, North India

THIYAM SEITYAJIT SINGH‡, ABIGAIL LALNUNENG†, & NAOREM KIRANMALA DEVI*

Department of Anthropology, University of Delhi, Delhi, 110007
E-mail: seityajit77@gmail.com

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ABSTRACT: Obesity is a major contributing factor to several non-communicable diseases (NCDs) constituting a persistent driver of morbidity and mortality. The present study was carried out to understand the prevalence and distribution of general and abdominal obesity, and to evaluate its association with socio-economic and behavioural factors in Palwal district, Haryana, India. A cross-sectional study of 180 participants aged 30 to 80 years, was selected from Palwal, Haryana, India. A comprehensive house-to-house survey collected socio-economic characteristics, behavioural habits, and anthropometric measurements (height, weight, waist circumference, and hip circumference). The prevalence of general obesity in the present study was 53.9%, and abdominal obesity was 71.1%, 92.2%, and 81.1% in WC, WHR, and WHtR, respectively. Sex was an important risk factor for high BMI and WC, where females showed significantly higher odds compared to males but confounded by smoking. Females showed a higher risk of high WHR even after controlling for confounding variables.

INTRODUCTION

Obesity continues to be a major global health problem, representing a significant risk factor for numerous non-communicable diseases (NCDs), such as diabetes mellitus, cardiovascular diseases, musculoskeletal disorders, and certain cancers (World Health Organisation (WHO, 2021). It imposes a substantial burden on well-being and quality of life. According to the WHO, obesity is defined as a chronic, complex disease characterized by excessive adiposity that can impair health (WHO 2018; WHO, 2023). In most cases, it is a multifactorial condition influenced by obesogenic environments, psycho-social factors, and genetic variants.

Various factors determine an individual's adiposity, including genetic and environmental factors within obesogenic environments. The increased consumption of relatively cheap and tasty food significantly contributes to the high prevalence of obesity (Temple, 2023). Socio- economic factors, such as age, sex, education, socioeconomic status, and annual household income (Venkatrao *et al.*, 2020; Choukem *et al.*, 2020; Ishida *et al.*, 2020), and behavioural factors, such as alcohol consumption, smoking, physical inactivity, and unhealthy diets, have been found to be associated with obesity (Keramat *et al.*, 2021; Al-Raddadi, *et al.*, 2019; Choukem *et al.*, 2020).

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‡Research Scholar, corresponding author

†Assistant Professor

*Associate Professor

rising since the beginning of the 21st century. As of 2016, the global population of obese individuals has surpassed 1.9 billion, comprising 650 million adults, 340 million adolescents, 39 million children, and 39% of adults aged 18 years and over were overweight and 13% were obese. (WHO, 2021; WHO,2022). Projections suggest that over half of the world's population (approximately 4 billion individuals) will grapple with overweight or obesity, and by 2035, 1 in 4 people (nearly 2 billion) will be affected by obesity if present trends persist (World Obesity Atlas, 2023). Globally, over 5 million deaths in 2019 were attributed to excessive body weight-related ill-health, with more than half occurring among individuals under 70 (Murray *et al.,* 2020). The WHO's target to reduce global obesity to 2010 levels by 2025 is likely to be unmet by most countries, posing a threat to the target with the increasing prevalence of overweight and obesity in India (Verma *et al.,* 2023).

The prevalence of obesity is on the rise in India, with the National Family Health Survey (NFHS) – 5 reporting a trend of 22.9% and 24.0% overweight and obesity in males and females, respectively, a notable increase from 18.9% and 20.6% in NFHS-4 (International Institute for Population Sciences [IIPS] & ICF, 2021a). Furthermore, the findings of NFHS-5 indicate that 56.7% of women and 47.7% of men exhibit abdominal obesity in the country (IIPS & ICF, 2021a). As of 2016, more than 70% of global overweight and obese individuals reside in low-income or middle-income countries (LMICS) (Schneider *et al.,* 2020), where the issue of under-nutrition is prevalent, posing the threat of a double burden of malnutrition (Popkin *et al.,* 2020). The prevalence of overweight and obesity in India is predicted to double among Indian adults aged 20–69 years between 2010 and 2040, with an expected threefold increase over the same period (Luhar *et al.,* 2020). The Global Obesity Atlas for 2023 projects a medium obesity index for India in 2035, with an annual increase of 5.2% in adult obesity and 9.1% in child obesity from 2020 to 2035. Overweight conditions are expected to impact the national GDP by 1.8% in 2035, with India ranking 99 out of 183 countries in global preparedness (World Obesity Atlas, 2023).

Haryana state has a prevalence of general obesity at 33.1% in females and 28.3% in males (IIPS & ICF, 2021b), a significant increase from 21% in males and 20% in females in the previous NFHS-4 survey. NFHS-5 also reports abdominal obesity (WHR) prevalence at 62.6% for females and 58.3% for males, significantly higher than general obesity. Among the rural population, the prevalence of general and abdominal obesity is 30.9% in females, 27.4% in males, 61.7%, and 57.7%, respectively (IIPS & ICF, 2021b). In India, there is a higher incidence of obesity in villages near townships, and the increase is correlated with rural development and economic transition (Aiyar *et al.,* 2021).

With India experiencing such a high incidence of obesity and the current growth trend is concerning, a rapid transition toward undesirable shifts in public health issues is underway. Obesity, being a major risk factor for various non-communicable diseases (NCDs), can have severe impacts and burdens on the economy. Consequently, obesity has become a critical public issue that requires study and reflection.

The present study, conducted in 2021 among adults aged 30 and above in three villages of Palwal district, Haryana, aims to determine the prevalence of general and abdominal obesity and its association with socioeconomic and behavioural factors in this rural population.

MATERIALS & METHODS

Study Design and Participants: The present study was a population-based, cross-sectional study conducted on a total of 180 participants of both sexes aged 30 to 80 years. The participants were residents of three villages—Jainpur, Janacholi, and Mandnaka—in the Hathin tehsil of Palwal district in Haryana, North India. The majority of the population in these villages follows Hinduism and is majorly dependent on agriculture and the rearing of livestock for their livelihoods. The agricultural fields are mainly cultivated with wheat, rice, sugarcane and mustard. The national bird of India, the Common Peafowl, and Nilgai are quite common and can be seen in these villages. The people are mostly dependent on a lacto-vegetarian diet, and dairy products from cattle reared at their homes are a main part of their dietary source. The culture and tradition of the region are reflected in these villages. Festivals which include Holi, Dussehra, Diwali, etc. and religious fairs held in the district also play an integral part in their social life.

Participants were randomly selected through a household survey conducted in March 2021, taking into consideration the population of the villages. Bedridden individuals and those suffering from major physical health conditions were excluded.

Ethical Approvals: The present study received approval from the Department Ethics Committee, Department of Anthropology, University of Delhi. Informed written consent, transcribed in Hindi, was obtained from each participant before data collection.

Data Collection: Socio-economic and behavioural data were collected at participants' homes using a pre-tested and modified interview schedule. Data on age, sex, marital status, educational status, occupation, and annual income. Behavioural variables covered dietary habits, smoking (beedi and/or hookah), alcohol consumption, and physical activity. Anthropometric variables were collected using a standard protocol, including height and weight measured with an anthropometer rod and weighing scale, waist circumference (WC) and hip circumference (HC) measured with a non-expendable steel tape.

General Obesity: General obesity was assessed using the body mass index (BMI), a globally accepted index representing overall obesity. While BMI serves as a widely recognized metric, it lacks the capacity to provide information regarding body fat distribution, specifically abdominal obesity, and has other inherent limitations (Tutunchi *et al.*, 2020). The standard BMI formula, involving the division of weight in kilograms by the square of height in meters, was employed for its calculation.

To categorize individuals, the Modified Asian Indian criteria for BMI cutoffs were followed, as proposed by Misra *et al.* (2009). This classification included underweight (BMI < 18.5 kg/m2), normal weight (BMI = 18.5–22.9 kg/m2), overweight (BMI = 23.0–24.9 kg/m2), and obese (BMI $\geq$ 25 kg/m2). The Asian criteria for BMI classification have been recognized for their efficacy in mitigating comorbid dysmetabolic conditions, such as hypertension (Verma *et al.*, 2019).

Abdominal Obesity: Abdominal obesity offers a more precise estimation of adiposity, addressing the limitation of BMI in its inability to capture regional fat distribution. Numerous epidemiological studies have documented a higher BMI associated with reduced mortality in older individuals, patients in acute clinical settings and people dealing with chronic disorders—a phenomenon recognized as the 'obesity paradox' (Carbone et al., 2019; Orsi et al., 2022). Research has consistently indicated that abdominal obesity exhibits a stronger association with cardiometabolic risk factors compared to BMI (Ashwell *et al.*, 2012; Jayedi *et al.*, 2020). BMI, in contrast, fails to adequately assess the cardiometabolic risk in adults with excess adiposity (Ross *et al.*, 2020).

As a result, there is a growing endorsement for the use of waist circumference (WC) in routine clinical and research settings (Carbone *et al.*, 2019; Ross *et al.*, 2020). WC measurements involve determining the smallest circumference between the lower ribs and the iliac crest, while hip circumference (HC) is measured at the buttock to establish the maximum circumference. Abdominal obesity is defined as WC $\geq$ 90 cm in males and WC $\geq$ 80 cm in females (Misra *et al.*, 2005; WHO, 2011). Waist-to-hip ratio (WHR), calculated as WC in cm / HC in cm, designates WHR $\geq$ 0.90 for males and WHR $\geq$ 0.80 for females as indicative of abdominal obesity (WHO, 2011). Similarly, the waist-to-height ratio (WHtR), calculated as WC in cm / Ht in cm, designates WHtR $\geq$ 0.50 as the threshold for defining abdominal obesity (Ashwell, Gunn, & Gibson, 2009; Ashwell, & Gibson, 2016).

Physical Activity: Following the Ainsworth *et al*. Compendium of Physical Activities (2011), the intensity of physical activity was classified into moderate and vigorous levels based on the MET value associated with each activity. Participants engaging in a minimum of 150 minutes of weekly physical activity were considered active. The duration of physical activity was determined by multiplying the number of days and minutes per day devoted to moderate and vigorous activities by each individual (WHO, 2010; Bicalho *et al.*, 2010).

Categorical Variables: Participants have been systematically categorized across various parameters. Age groups have been categorised into three groups, 30-34 years, 45-59 years and 60 years and above. Regarding education, individuals have been grouped based on whether they have received no formal education or have acquired some level of formal education. Annual income categories are defined by the below poverty line (BPL), representing an annual income less than 1,80,000, and above poverty line (APL), denoting an annual income equal to or exceeding 1,80,000, as per the criteria established by the Government of Haryana (Haryana Chief Minister's Office, 2023). Dietary habits have been classified into two groups: lacto-vegetarian and non-vegetarian. Smoking distinguishes between participants who smoked (yes) and those who did not smoke (no). Alcohol consumption is categorized into consuming alcohol (yes) and not consuming alcohol (no). Lastly, participants' physical activity levels are differentiated into those who are actively engaged and those who are inactive.

Statistical Analysis: Statistical analysis was performed using SPSS version 26.0. The prevalence of obesity and its distribution across socioeconomic and behavioural factors were summarized using frequency and percentage. The T-test and Chi-square test of the anthropometric measures were conducted to determine any significant differences in the distribution of continuous variables and the categorical variables respectively. A one-way ANOVA test was carried out to compare the means and standard deviation of socio-economic and behavioural factors on general obesity (BMI) and abdominal obesity (WC, WHR, WHtR). Binary logistic regression was used to calculate the odds ratio and estimate the association between the confounding factors and obesity. Statistical significance at $p < 0.05$ (two-sided) was considered for all tests.

Limitations: The present study is a cross-sectional study limited to three villages of Palwal, Haryana. Consequently, the findings may not be fully representative of the broader rural population in northern India. The uneven representation of variables such as age groups, sex, and alcohol consumption, combined with the relatively small sample size, poses limitations on the generalizability of the study outcomes. Despite these constraints, the study offers valuable insights into the patterns and associations of obesity with socioeconomic and behavioural factors among adults aged 30-80 years. Further research is warranted to comprehensively elucidate the variations in prevalence and associations with multiple factors influencing obesity.

RESULTS

Table 1 shows the general characteristics of the studied population and the distribution of the participants. Nearly the entire studied population adhered to a lacto-vegetarian diet, accounting for 99.4% (n=179), with only one participant following a different dietary pattern. The studied population exhibited a higher representation of female participants, comprising 70% (n=126), in contrast to the male counterpart, which constituted 30% (n=54). A higher proportion of participants had no formal education, amounting to 61.1% (n=110), and the majority fell under the below poverty line (BPL), totalling 66.7% (n=120). Notably, a substantial number of participants were identified as physically active, constituting 83.3% (n=150).

TABLE 1

Basic characteristics of the study population

Variables	Frequency (n = 180)	Percentage (%)
Villages		
Madnaka	86	47.8
Janacholi	38	21.1
Jainpur	56	31.1
Sex		
Females	126	70.0
Males	54	30.0
Age Groups		
30-44 years	21	11.7
45-59 years	81	45.0
60 and above	78	43.3
Education		
No formal education	110	61.1
Formally educated	70	38.9
Annual Income		
BPL	120	66.7
APL	60	33.3
Dietary Habits		
Lacto-Vegetarian	179	99.4
Non-Vegetarian	1	0.4
Smoking		
Smokers	90	50.0
Non-smokers	90	50.0
Alcohol Consumption		
Drinks	18	33.3
Doesn't drink	36	66.7
Physical Activity		
Active	150	83.3
Inactive	30	16.7

Table 2 shows the various anthropometric measurements taken for the present study according to sex distribution. Males were significantly taller (m=168.03, f=154.60, p<0.01), heavier (m=63.92, f=58.16, p<0.05) and had higher WHR (*m*=0.98, *f*=0.91, p<0.01) compared to their female counterparts. Whereas females showed significantly higher BMI (*m*=22.56, *f*=24.34, p<0.05), and HC (*m*=92.30, =96.06, p<0.05) compared to their male counterparts. However, WC and WHtR did not show significant differences.

TABLE 2

T-test of anthropometric measures

Measures	Male		Female		P value
	N	Mean ± SD	N	Mean ± SD	
Height	54	168.03 ± 7.00	126	154.60 ± 5.74	0.00**
Weight	54	63.92 ± 12.03	126	58.16 ± 12.43	0.01*
BMI	54	22.56 ± 3.50	126	24.34 ± 5.14	0.02*
WC	54	90.75 ± 10.55	126	96.06 ± 10.95	0.06
HC	54	92.30 ± 6.30	126	96.06 ± 9.29	0.01*
WHR	54	0.98 ± 0.07	126	0.91 ± 0.07	0.00**
WHtR	54	0.54 ± 0.06	126	0.56 ± 0.01	0.11

Note: * p<0.05; ** p<0.0

Table 3 presents the prevalence of general obesity (BMI), and abdominal obesity (WC, WHR, WHtR). Among the measures, WHR showed the highest (92.2%) prevalence of obesity in the study population, with females having a higher prevalence (95.2%) than males (85.2). This was followed by a high prevalence of high WHtR (*total* 81.1%, *f* 83.3%, *m* 75.9%), and high WC (*total* 71.1%, *f* 77.0%, *m* 57.4%). The prevalence of general obesity (BMI) (*total* 53.9%, *f* 58.7%, *m* 42.6%) is lowest when compared to the other measures of abdominal obesity.

TABLE 3

Prevalence of general obesity and abdominal obesity

Measures	Overall n = 180 (%)	Male n = 54 (30%)	Female n = 126 (70%)
BMI			
≤ 22.9 kg/m²	83 (46.1)	31 (57.4)	52 (41.3)
> 23.0 kg/m²	97 (53.9)	23 (42.6)	74 (58.7)
WC			
<80 cm (f)/ <90 cm (m)	52 (28.9)	23 (42.6)	29 (23.0)
>80 cm (f)/ >90cm (m)	128 (71.1)	31 (57.4)	97 (77.0)
WHR			
<0.8 (f)/ <0.9 (m)	14 (7.8)	8 (14.8)	6 (4.8)
>0.8 (f)/ >0.9 (m)	166 (92.2)	46 (85.2)	120 (95.2)
WHtR			
<0.5	34 (18.9)	13 (24.1)	21 (16.7)
>0.5	146 (81.1)	41 (75.9)	105 (83.3)

Table 4 presents the results of a one-way ANOVA conducted to compare the mean BMI WC, WHR, and WHtR. Among the variables taken, age demonstrated a significant association with WHR (F = 10.72, p < 0.01), where WHR increases with increases in the age group. Sex exhibited a significant association with BMI (F = 5.41, p < 0.05) and WHR (F = 37.96, p < 0.01), where females showed a higher mean in BMI compared to males and vice versa for WHR where males showed a higher mean of WHR compared to females. Furthermore, alcohol consumption was found to be significantly association with WHR (F = 13.45, p < 0.01) where participants who did not consume alcohol showed a higher mean compared to participants who consumed alcohol. Smoking showed a significant association with BMI (F = 10.28, p < 0.01), WHR (F = 10.34, p < 0.01), and WHtR (F = 7.87, p < 0.05), smokers had higher means in BMI and WHtR compared to non-smokers, participants who did not smoke showed higher means in WHR than those who smoked. Lastly, physical activity showed a significant association with WHR (F = 5.01, p < 0.05), where active participants had a higher mean WHR compared to inactive participants. However, no significant associations were observed between education, annual income, and any of the obesity measures.

TABLE 4

ANOVA test for obesity measures by socioeconomic and behavioural factors

Variables	BMI Mean ± SD	WC Mean ± SD	WHR Mean ± SD	WHtR Mean ± SD
Age				
30-44 years	24.94 ± 4.81	88.05 ± 12.63	0.88 ± 0.07	0.56 ± 0.08
45-59 years	23.91 ± 4.03	87.22 ± 10.58	0.92 ± 0.07	0.55 ± 0.06
60 and above	23.38 ± 5.42	89.83 ± 10.74	0.96 ± 0.08	0.56 ± 0.09
F – value	0.917	1.16	10.72**	0.06
Sex				
Male	22.56 ± 3.50	90.75 ± 10.55	0.98 ± 0.07	0.54 ± 0.01
Female	24.34 ± 5.14	87.46 ± 10.95	0.91 ± 0.07	0.56 ± 0.09
F - value	5.41*	3.49	37.96**	2.57
Education				
No formal education	24.12 ± 5.52	88.36 ± 11.47	0.92 ± 0.08	0.56 ± 0.09
Formally educated	23.30 ± 3.24	88.58 ± 10.05	0.94 ± 0.08	0.54 ± 0.05
F - value	1.27	0.02	1.78	1.02
Annual Income				
BPL	23.93 ± 5.06	88.56 ± 11.16	0.93 ± 0.08	0.55 ± 0.09
APL	23.54 ± 4.14	88.21 ± 10.47	0.94 ± 0.07	0.56 ± 0.06
F - value	0.27	0.04	0.54	0.46
Alcohol Consumption				
Yes	23.92 ± 4.91	88.18 ± 10.91	0.92 ± 0.08	0.56 ± 0.08
No	22.75 ± 3.08	90.86 ± 10.88	0.99 ± 0.07	0.54 ± 0.05
F- value	0.98	0.98	13.45**	0.44
Smoking				
Yes	24.91 ± 4.80	89.10 ± 10.74	0.91 ± 0.07	0.57 ± 0.07
No	22.69 ± 5.50	87.80 ± 11.98	0.95 ± 0.08	0.54 ± 0.08
F - value	10.28**	0.62	10.34**	7.87*
Physical activity				
Active	23.76 ± 4.90	88.94 ± 11.23	0.94 ± 0.08	0.55 ± 0.08
Inactive	24.04 ± 4.12	85.96 ± 8.85	0.90 ± 0.08	0.55 ± 0.08
F – value	0.09	1.88	5.01*	0.00

Note: * p<0.05; ** p<0.0

Table 5 outlines the prevalence and distribution of general obesity (BMI), and abdominal obesity (WC, WHR, WHtR) and its association with socioeconomic and behavioural variables. The prevalence of general obesity (BMI) decreases with an increase in age group (30-44 -year-old=66.7%, 45-59 -year-old=53.1%, 60 and above-year-old=51.3%), but the 45-59-year-old age group demonstrated a higher incidence of abdominal obesity (WC=71.6%, WHR=95.1%, WHtR=82.7%). However, there is no significant association between age and general obesity and abdominal obesity (BMI, c^2=1.61, p>0.05; WC, c^2=0.02, p>0.05; WHR, ^{2}=1.67, p>0.05; WHtR, c^2=0.27, p>0.05).

Females showed a significantly higher BMI (*m*=42.6%, f =58.7%, c^2 = 3.96, p<0.05), high WC (*m*=57.4%, f =77.0%, c^2 = 7.05, p<0.05), and high WHR (*m*=85.2%, f =95.2%, c^2 = 5.33, p<0.05) compared to their male counterparts. Females also showed a higher incidence of WHtR (*m*=75.9%, f =83.3%) compared to males but the association was not statistically significant (p>0.05).

Participants with formal education showed a higher prevalence of WHR (*y*=90.0%, *n*=62.0%,) and WHtR (*y*=82.9%, *n* =80.0%,), while participants who had no formal education showed a higher prevalence of BMI (*y*=55.0%, *n*=53.3%), and (WC *y*=67.1%, *n* =73.6%). However, the relationship between education and obesity (general obesity and abdominal obesity) is not statistically significant (p>0.05).

With respect to income, participants who belong to APL showed a higher incidence of both general obesity (BMI, *APL*=51.4%, *BPL*=55.5%) and abdominal obesity (WC, *APL*=75.0%, *BPL*=69.2%; WHR, *APL*=95.0%, *BPL*=90.8%; WHtR, *APL*=85.0%, *BPL*=79.2%) compared to participants belonging to BPL. The relationship between obesity (general obesity and abdominal obesity) and income was not statistically significant (p>0.05).

As for alcohol consumption, participants who did not consume alcohol showed a higher BMI, WC and WHR (BMI, *y*=50.0%, *n*=54.3%; WC, *y*=55.6%, *n*=72.8%; WHR, *y*=83.3%, *n*=93.2%) compared to those who drank alcohol. However, alcohol consumers showed higher WHtR (*y*=50.0%, *n*=80.9%) compared to those who did not consume alcohol. The relationship between alcohol consumption and obesity (general obesity and abdominal obesity) was not statistically significant (p>0.05).

Regarding smoking, participants who did not smoke showed a significantly higher BMI and WC (BMI, *y*=41.1%, *n*=66.7%, c^2 = 11.83, p<0.01; WC, *y*=60.0%, *n*=82.2%, c^2 = 10.82, p<0.01) compared to those who smoked. Smoking did not show a significant association with WHR and WHtR, and smokers showed higher incidences of WHtR (*y*=75.6%, *n*=86.7%) compared to non-smokers, meanwhile, the prevalence was the same in WHR (92.2).

Physically inactive participants exhibited a higher BMI (*active*=52.7%, *inactive*=60.0%) than those physically active. While physically active participants showed a higher WC, WHR, and WHtR (WC, *active*=71.4%, *inactive*=69.2%; WHR, *active*=93.5%, *inactive*=84.6%; WHtR, *active*=81.2%, *inactive*= 80.8%) compared to physically inactive participants. Physical activity was found to be only significantly associated with WHR (c^2 = 3.97, p<0.05).

TABLE 5

Prevalence and association of general and abdominal obesity with socio-economic and behavioural variables

Variables	General obesity		Abdominal obesity	
	BMI ³ *23.0 kg/m^2* 65 (36.1%)	WC $\geq$ *90 cm (m)/$\geq$80 cm (f)* 128 (71.1%)	WHR $\geq$ *0.90 (m)/$\geq$ 0.80 (f)* 166 (92.2%)	WHtR ³ *0.5* 146 (81.1%)
Age				
30-44 years	14(66.7)	15 (71.4)	19 (90.5)	17 (81.0)
45-59 years	43 (53.1)	58 (71.6)	77 (95.1)	67 (82.7)
60 and above	40 (51.3)	55 (70.5)	70 (89.7)	62 (79.5)
χ^2- value	1.61	0.02	1.67	0.27
Sex				
Male	23 (42.6)	31 (57.4)	46 (85.2)	41 (75.9)
Female	74 (58.7)	97 (77.0)	120 (95.2)	105 (83.3)
χ^2 - value	3.96*	7.05*	5.33*	1.35
Education				
No education	61 (55.5)	81 (73.6)	103 (62.0)	88 (80.0)
Formally educated	36 (51.4)	47 (67.1)	63 (90.0)	58 (82.9)
χ^2 - value	0.28	0.88	0.79	0.23
Annual Income				
BPL	64 (53.3)	83 (69.2)	57 (90.8)	51 (79.2)
APL	33 (55.0)	45 (75.0)	109 (95.0)	95 (85.0)
χ^2 - value	0.04	0.66	0.97	0.89
Alcohol Consumption				
Yes	9 (50.0)	10 (55.6)	15 (83.3)	15 (83.3)
No	88 (54.3)	118 (72.8)	151 (93.2)	131 (80.9)
χ^2 - value	0.12	2.36	2.20	0.064
Smoking				
Yes	37 (41.1)	54 (60.0)	83 (92.2)	68 (75.6)
No	60 (66.7)	74 (82.2)	83 (92.2)	78 (86.7)
χ^2 - value	11.83**	10.82**	0.00	3.63
Physical activity				
Active	79 (52.7)	107 (71.4)	141 (93.5)	121 (81.2)
Inactive	18 (60.0)	21 (69.2)	25 (84.6)	25 (80.8)
χ^2 - value	0.54	0.02	3.97*	0.12

Note: * p<0.05; ** p<0.0

Risk Factors of General Obesity (BMI) and Abdominal Obesity (WC, WHR, WHtR)

Table 6 presents the odds ratio resulting from logistic regression analysis, where sex and behaviour are the significant risk factors of high general and abdominal obesity. To have a better understanding of whether general obesity (BMI) and abdominal obesity (WC, WHR, WHtR) were independently associated with sex and behavioural factors, we used the odds ratio (OR) derived from logistic regression analysis to test the nature of the relationship by adjusting correlated variables.

As for BMI, females showed significantly higher odds of having a high BMI than their male counterparts (OR = 1.92, 95% CI = 1.01-3.66, $p<0.05$). However, the effect of sex on high BMI became non-significant after adjusting for smoking (OR = 1.23, 95% CI = 0.59-2.53, $p>0.05$). This indicates that the effect of sex on high BMI was also influenced by confounding factors like smoking.

Smokers showed significantly lower odds of high BMI compared to those who did not smoke even after adjusting for sex (OR = 0.38, 95% CI = 0.19-0.74, $p<0.01$).

In the case of WC, females showed significantly higher odds of having high WC than males (OR = 2.48, 95% CI = 1.26-4.90, $p<0.05$). The effect of sex on high WC was not significant when adjusting for smoking (OR = 1.66, 95% CI = 0.78-3.52, $p>0.05$). This demonstrates that the effect of sex on high WC was also influenced by confounding factors, in this case, smoking.

Regarding smoking, smokers showed significantly lower odds of high WC compared to non-smokers even after adjusting for sex (OR = 0.40, 95% CI = 0.19-0.84, $p<0.05$).

As for WHR, sex showed a significant association, with females showing higher odds of high WHR compared to their male counterparts (OR = 3.47, 95% CI = 1.14-10.57, $p<0.05$). The association of females having high odds of WHR remained significant even after adjusting for physical activity (OR = 5.16, 95% CI = 1.45-17.78, $p<0.05$). This finding emphasized the importance of sex as an important risk factor for WHR.

TABLE 6

Odds ratio (OR) derived from logistic regression analysis for the risk factor of obesity

Obesity Measure	Odds Ratio (OR)	P-Value	95% CI
BMI $\geq$ *23.0 kg/m²*			
Sex *(f)*	1.92	0.05*	1.01-3.66
Smoking *(y)*	0.35	0.00**	0.19-0.64
Sex *(f)*/ Adjusted for Smoking	1.23	0.58	0.59-2.53
Smoking *(y)*/ Adjusted for Sex	0.38	0.00**	0.19-0.74
WC $\geq$ *90 cm (m)/* $\geq$*80 cm (f)*			
Sex *(f)*	2.48	0.01*	1.26-4.90
Smoking *(y)*	0.32	0.00**	0.16-0.64
Sex *(f)*/ Adjusted for Smoking	1.66	0.19	0.78-3.52
Smoking *(y)*/ Adjusted for Sex	0.40	0.02*	0.19-0.84
WHR $\geq$ *0.90 (m)/* $\geq$ *0.80 (f)*			
Age (↑)	0.99	0.59	0.933-1.04
Sex (*f*)	3.47	0.03*	1.14-10.57
Alcohol consumption (*y*)	0.36	0.15	0.09-1.45
Smoking (*y*)	1	1	0.34-2.98
Physical Activity (*a*)	3.13	0.06	0.97-10.13
Sex *(f)*/ Adjusted for physical activity	5.16	0.01*	1.45-17.78
WHtR $\geq$ *0.5*			
Smoking (*y*)	0.48	0.06	0.22-1.03

Note: * p<0.05; ** p<0.01
↑ = increase, *f* = females,
y = yes, *a* = active

DISCUSSIONS

India, classified as a low- to middle-income country (LMIC), exhibits a noteworthy rise in the prevalence and proportion of individuals grappling with obesity. This surge can be attributed to the swift trajectory of development and urbanisation, fostering deleterious dietary practices and sedentary lifestyles. Consequently, there is a pronounced upswing in obesity, exacerbating the burden of non-communicable diseases (NCDs), prominently cardiovascular diseases (CVDs). The present study explores the prevalence and distribution of both general and abdominal obesity, discerning their associations with socioeconomic and behavioural factors.

An intriguing finding of the present study is the substantially higher incidence of abdominal obesity compared to general obesity (BMI). The prevalence of abdominal obesity, as indicated by waist circumference (WC=71.1%, WHR=92.2%, WHtR= 81.1%), was markedly higher than that of general obesity (BMI=53.9%), aligning with the findings of the NFHS 5 report, however, the prevalence in the present study was much higher. In Haryana, the reported prevalence of general obesity (BMI) stood at 30.9% in females and 27.4% in males, with corresponding rates for abdominal obesity (WC) recorded as 61.7% and 57.7%, respectively, among the rural population (IIPS & ICF, 2021b). It is noteworthy that the evaluation of obesity in the context was based on WHO estimates, and had Indian-specific cutoffs been applied, our results would have closely mirrored the reported proportions. In a study conducted in the Uttarakhand region, Kandpal *et al.*, (2016) documented elevated levels of BMI at 56.6% and abdominal obesity at 33.7%. Meanwhile, in Bangladesh, Islam *et al.*, (2020) reported prevalence rates of 28% for general obesity (BMI) and 49% for abdominal obesity. Notable, among the measures for abdominal obesity, WC gave a closer estimate when compared to BMI, while WHR produced an estimate of abdominal obesity at an extreme proportion.

In the present study, a notable sex difference was seen in BMI, with females exhibiting a significantly higher prevalence of obesity (58.7%) compared to males (42.6%). This difference was further corroborated through an odds ratio analysis, which indicated significantly higher odds of high BMI among females compared to their male counterparts (OR = 1.92, 95% CI = 1.01-3.66, $p<0.05$). This finding aligns with a previous study conducted by Venkatrao *et al.*, (2020), who observed a higher prevalence of general obesity among women (41.88%) compared to men (38.67%). Rocha *et al.* (2023) also reported that females have approximately three times higher odds of obesity than males in LMICs.

Additionally, smoking also had a noticeable influence on BMI. Smokers displayed a significantly lower prevalence of high BMI (41.1%) compared to non-smokers (66.7%). Further odds ratio analysis also showed that smokers had lower odds of having a high BMI compared to non-smokers (OR = 0.35, 95% CI = 0.19-0.64, $p<0.01$). This association aligns with earlier studies (Gümüº *et al.*, 2013; Ginawi *et al.*, 2016), and recent research by Sun *et al.* (2019), Marconcin *et al.* (2021) and Jacobs (2019) that showed a negative association between smoking with BMI. However, some recent research has also introduced conflicting results, suggesting a positive association between smoking and obesity (Baalbaki *et al.*, 2019, Al Sabbah *et al.*, 2022). Furthermore, our analysis shows that smoking acts as a significant confounding factor for the relationship between females and high BMI. When participants smoked, the impact of sex on having a high BMI became non-significant ($p>0.05$).

While examining waist circumference (WC), females exhibited a significantly higher prevalence of high WC (77.2%) compared to males (57.4%). Odds ratio analysis reaffirmed these differences, revealing significantly higher odds of high WC among females than males (OR = 2.48, 95% CI = 1.26-4.90, $p<0.05$). This aligns with findings from Prasad *et al.*, (2020), who reported a higher prevalence of high WC among females when compared to male participants. Wong *et al.* (2020) also reported that the global prevalence of high WC was higher among females (47.6%) when compared with males (30.4%).

Similar to BMI, smoking emerged as an important factor, with smokers demonstrating a significantly lower prevalence of high WC (60%) compared to non-smokers (82.2%), and smokers having lower odds of having high WC compared to non-smokers (OR = 0.32, 95% CI = 0.16-0.64, $p<0.01$). A recent study by Askari *et al.* (2022) showed smokers had lower odds of having high WC than non-smokers. However, in contrast to our findings, Oguoma *et al.* (2021) found that smokers had higher odds of having high WC than non-smokers, indicating a positive association between smoking and WHR.

Intriguingly, the association of females having a high WC was mitigated when the influence of smoking was controlled, rendering it statistically non-significant ($p>0.05$). This highlights smoking as a confounding factor, reflecting the complex relationship between smoking, sex, and WC as was seen in BMI.

The prevalence of high waist-to-hip ratio (WHR) also showed a pronounced sex difference similar to BMI and WC, with females exhibiting significantly higher rates of high WHR (95.2%) compared to males (85.2%). Odds ratio analysis further emphasized these sex differences, revealing significantly higher odds of high WHR among females than their male counterparts (OR = 3.47, 95% CI = 1.14-10.57, $p<0.05$). The association of females with higher odds of high WHR continues to be statistically significant, even when adjusting for physical activity. This demonstrated the importance of sex as an important risk factor for high WHR. Our finding matches Chen et al. (2021)'s study that showed females (76.90%) had a higher prevalence of high WHR than males (69.44%). Similarly, a recent study by Muhammad *et al.* (2022) revealed that older females had a higher proportion of high WHR than their older male counterparts. Females have higher levels of body fatness and menopause is positively associated with the incidence and consequences of obesity which could account for women being more likely to be obese than their male counterparts (Heras-Molina *et al.*,2020).

Although waist-to-height ratio (WHtR) is an important measure of abdominal obesity, no significant association was found with any of the socioeconomic and lifestyle variables. Sex and smoking are important risk factors for obesity but confounded by smoking.

CONCLUSION

Obesity stands out as a significant risk factor contributing to the onset of major non-communicable diseases, a matter of serious concern for India's public health sector. India also witnessed a rapid increase in the prevalence of abdominal obesity compared to general obesity which is reflected in the present study. The present study underscores the important risk factors associated with obesity, where sex is a significant risk factor confounded by smoking.

Given the global disparities based on sex, it might be imperative to consider sex-specific and tailored interventions for effectively addressing the ongoing obesity pandemic. While solutions aimed at obesity prevention, spanning from community-level initiatives to national policies may be similar for men and women, conveying them in a sex-specific manner could enhance the effectiveness. Smoking, a modifiable risk factor is an important confounder in the present study, and understanding the role of confounding variables can strengthen the effectiveness of intervention strategies.

Future research should explore the complex dynamics of obesity with larger sample size in the context of socioeconomic, behavioural, and environmental factors, as well as the role of genetics in developing effective strategies that can contribute to the overall well-being of the population.

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