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Abdominal obesity in India: sex stratified multilevel estimates across 707 districts from a nationally representative cross-sectional survey

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Pratheeba John, Rimjhim Bajpai, Sudheer Kumar Shukla, Prince Chugh, Ritesh Ranjan Pushkar, G Thavasi Murugan, Rajeev Sadanandan, Sita Rama Budaraju & Nishikant Singh

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Author names, Email IDs and Affiliations

Pratheeba John[1]
Email Id: pratheebaj@gmail.com

Rimjhim Bajpai[2]
Email Id: rimjhim.bajpai94@gmail.com

Sudheer Kumar Shukla[1]
Email Id: sudheer.iips@gmail.com

Prince Chugh[1]
Email Id: itsprince9@gmail.com

Ritesh Ranjan Pushkar[3]
Email Id: ritesh.r.pushkar@gmail.com

G Thavasi Murugan[4]
Email Id: geography_g.thavasaimurugan@vasantakfi.ac.in

Rajeev Sadanandan[1]
Email Id: rsadanandan@gmail.com

Sita Rama Budaraju[1]
Email Id: s.budaraju@hstp.org.in

Nishikant Singh[1] (Corresponding Author)
Email Id: nishiiips@gmail.com

[1]Health Systems Transformation Platform (HSTP), New Delhi, India.
[2]International Institute for Applied Systems Analysis (IIASA), Vienna, Austria.
[3]Office of the Registrar General of India, Census Operations, Bhubaneswar, Odisha, India.

[4]Vasanta College for Women, Banaras Hindu University (BHU), Uttar Pradesh, India.

Abdominal obesity in India: sex stratified multilevel estimates across 707 districts from a nationally representative cross-sectional survey

Abstract

Abdominal obesity, measured using the waist-to-hip ratio, is an emerging public health concern in India, yet national averages mask important subnational variation relevant for local policy and prevention planning. We sought to quantify district-level variation in abdominal obesity and to examine its individual- and contextual-level determinants across India. Using nationally representative data from the National Family Health Survey 2019–2021, we analysed 664,646 women aged 15–49 years and 96,010 men aged 15–54 years across 707 districts and 30,112 communities using multilevel logistic regression. Abdominal obesity was defined using WHO-anthropometric cut-offs for WHR (women: >0.85; men: >0.90). National prevalence was high, affecting 56.6% (95% confidence interval [CI]: 56.41–56.74) of women and 48.9% (95% CI: 48.31–49.46) of men, with higher levels among older adults, wealthier groups, and urban residents. Marked inter-district heterogeneity was observed, with clusters of high prevalence in northern and eastern India and distinct sex-specific spatial patterns. Variance partitioning indicated that individual-level factors accounted for about 67% of total variation among women and 70% among men, while community-, district-, and state-level factors together explained the remaining variation. These findings demonstrate the value of small-area estimates for identifying high-burden populations and informing geographically targeted public health planning.

Key words: Abdominal Obesity; Waist-to-Hip Ratio; Multilevel Regression; National Family Health Survey; India

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INTRODUCTION

Many low- and middle-income countries (LMICs) are experiencing a dual burden of malnutrition characterised by the coexistence of undernutrition and increasing prevalence of overweight and obesity[1,2]. Global evidence since the early 2000s indicates rising prevalence of both undernutrition and overweight-related malnutrition across most LMICs, with some exceptions in South and Southeast Asia[3]. While several countries have witnessed a decline in overall malnutrition, this progress is primarily due to reductions in underweight prevalence. Conversely, malnutrition in countries experiencing an increase is largely driven by rising obesity rates, indicating a shift from underweight-dominant to obesity-dominant malnutrition patterns[4].While infectious diseases and undernutrition remain persistent public health concerns, LMICs are experiencing a rapid epidemiological transition marked by the growing prevalence of non-communicable disease (NCD) risk factors[5], particularly obesity[4]. Notably, undernutrition and obesity can coexist not only at the population, community, and household levels, but also within individual, as excess body weight may occur alongside micronutrient deficiencies such as iron or folate[2,6,7]. In recognition of this complex burden, the Sustainable Development Goal (SDG) Target 2.2 aims to end “all forms of malnutrition”[8].

Obesity has emerged as a major global health concern, affecting one in every eight individuals around the world in 2022. Of the estimated 2.5 billion overweight adults, 890 million were obese. According to recent estimates of the World Health Organization (WHO)[9], adult obesity rates have more than doubled and adolescent obesity has quadrupled since 1990. It is a major risk factor for metabolic syndrome, including hypertension, cardiovascular disease, and diabetes. Evidence from multiple studies, including a meta-analysis of 2.3 million individuals, confirms a strong association between higher levels of abdominal obesity and increased cardiovascular risk, particularly among Asian populations including those in India[10–12].

Generating detailed estimates of abdominal obesity across India is critical for effective surveillance, guiding evidence-based policymaking, and equitable resource allocation particularly in identifying and supporting communities with the greatest need especially as healthy diet and physical activity are easier to promote at local level than national. Understanding the spatial distribution of abdominal obesity and key drivers of abdominal obesity requires granular and up-to-date data. However, most existing research is limited to national or broad sub-national estimates[10,13], which obscure local-level variations and limit the ability to the design of context-specific interventions. This gap limits the ability of policymakers and public health practitioners to prioritise areas with the greatest need for action. To address this, we generated estimates of abdominal obesity at the community and district level along with sub-national and national level estimates using the latest round of nationally representative data from National Family Health Survey (NFHS). Our objectives were threefold: (1) to map the geographic variation in sex-stratified abdominal obesity across India; (2) to identify sex-specific factors associated with abdominal obesity; and (3) to capture local-level contextual differences to inform the planning and evaluation of targeted community-based interventions.

DATA AND METHODOLOGY

Data

This study utilised nationally representative data from the fifth round of the National Family Health Survey (NFHS-5). Conducted in two phases due to the COVID-19 pandemic, the survey spanned from 17 June 2019 to 30 April 2021. It collected comprehensive information from 636,699 households, 724,115 women, and 101,839 men across all 36 states and union territories (UTs), covering 707 districts in India. A detailed account of the survey's methodology, sampling strategy, sample size determination, and key findings has been published elsewhere[14]. The sample selection of both male and female included in the study were illustrated in Figure 1.

>>>Figure 1 about here<<<

Outcome Variable

Our primary outcome of the study was abdominal obesity which was measured through risky waist-to-hip ratio (WHR). Abdominal obesity was categorised as a binary variable where ‘1’ indicates the presence of abdominal obesity) and (ii) ‘0’ indicates its absence. Risky WHR was defined in accordance with WHO guidelines, with thresholds set at >0.90 for males and >0.85 for females[15]. Further, while calculating the abdominal obesity for women, we have excluded the currently pregnant women as well as those who had given birth in last two months before the survey. The similar criteria were followed in NFHS-5 reports and previous related study[10,13,16].

Causal framework and covariate selection

The selection of independent variables was guided by the previous relevant literature, availability of information in selected dataset[10,13]. We included individuals’ age in the form of five years interval (women:15-49 years; men:15-54 years), marital status, parity (for women only). Socioeconomic and demographic characteristics were captured through educational attainment (not literate, up to 8th grade, up to 10th grade, and intermediate or above) and household wealth. Household wealth was assessed using the NFHS-5 wealth index, a composite indicator of relative living standards derived using principal component analysis of household asset ownership, housing quality, and access to basic services. The wealth index was categorised into quintiles (poorest, poorer, middle, richer, and richest), and the specific components contributing to its construction are detailed in Supplementary Table 1. Place of residence (rural or urban) was included as an indicator of residential context. Lifestyle and behavioural factors included current smoker/tobacco use (yes or no), current alcohol consumption (yes or no) and consumption of junk food (never/occasionally/daily). A directed acyclic graph (DAG) was constructed to formalise the hypothesised relationships between individual-, community-, district-, and state-level determinants and abdominal obesity (Figure 2). The DAG conceptualises demographic and socioeconomic factors (age, marital status, parity, education, household wealth, and place of residence) as upstream determinants influencing behavioural risk factors, including tobacco use, alcohol consumption, and junk-food intake. Higher-level contextual influences operating at the community, district, and state levels are represented as unobserved structures shaping individual exposures. Physical activity, genetic predisposition, and psychosocial stress were considered as latent constructs to acknowledge potential unmeasured confounding.

>>>Figure 2 about here<<<

Statistical analysis

We estimated the prevalence of abdominal obesity for both women and men separately using individual-level NFHS-5 data across the 707 districts, 36 states and UTs in India. Further, the prevalence was reported across the selected demographic and socio-economic variables. We also performed Chi Square test with level of significance to understand the association between outcome and selected covariates. Given the complex survey design of NFHS, which involved cluster sampling, we applied sampling weights to adjust for differential selection probabilities and calculated weighted proportions with 95% confidence intervals (CIs) for each estimate.

Given the hierarchical structure of data- individuals nested within communities, which are nested within districts, and further nested within states- we adopted the four-level logistic regression model. This model accounts for the clustering at each level, allowing for more accurate estimation of both fixed effects (individual-level predictors) and random effects (contextual-level variations) with aim to disentangle the individual and contextual factors[17] associated with abdominal obesity, thereby informing targeted public health interventions. This approach is suitable for binary outcome variables and accounts for the nested data structure, thereby providing more reliable estimates by considering both individual and contextual factors[18,19]. We have shown null model and full model adjusting for selected demographic and socioeconomic characteristics along with levels of communities, district and state:

$$\text{logit}(P_{ijkl}) = \beta_0 + \sum_{p=1}^{P} \beta_p X_{pijkl} + u_l + v_{kl} + w_{jkl}$$

Where,

P_{ijkl} is the probability of abdominal obesity for individual (*i*) in community (*j*), district (*k*) and state (*l*).
β_0 is the fixed intercept.
β_p are the fixed-effect coefficients for the □th individual-level covariate X_{pijkl}

u_l represents the random effect at the state level.
vk_l represents the random effect at the district level.
w_{jkl} represents the random effect at the community level.

Further, to quantify the proportion of total variance attributable to each hierarchical level, we calculated the Variance Partition Coefficient (VPC) using the latent variable approach. In logistic regression models, the level-1 residual variance is fixed at $\pi^2/3 \approx 3.29$. Therefore, the VPC for each level was computed as:

$$VPC_{level} = \frac{\sigma^2_{level}}{\sigma^2_u + \sigma^2_v + \sigma^2_w + \frac{\pi^2}{3}}$$

Where, σ^2_{level} corresponds to the variance at the state (σ^2_u), districts (σ^2_v), or community (σ^2_w) level. To assess multicollinearity among explanatory variables in the fully adjusted multilevel models, we calculated the generalised variance inflation factor (gVIF) for all covariates. All statistical analysis was carried out using Stata version16[20].

Spatial analysis

We utilised ArcGIS Pro (version 3.6; Esri Inc., Redlands, CA, USA) to map district- and state-level spatial variation in abdominal obesity across India. Administrative boundary shapefiles were obtained from the publicly available Demographic and Health Surveys (DHS) spatial data repository and Survey of India administrative boundary datasets. To visualise the joint spatial distribution of abdominal obesity among women and men, a bivariate choropleth map[5,21] was constructed. The mapping process involved first standardising and classifying the prevalence estimates for women and men separately into three categories each, using the quantile classification method to ensure an even distribution of observations across classes. These classifications were then combined into a single attribute field, resulting in nine unique bivariate categories based on a 3 × 3 matrix. Symbology was applied using the unique values renderer corresponding to this combined attribute field. A custom bivariate colour scheme was employed, with one variable represented by a light-to-dark gradient along the vertical axis and the other along the horizontal axis, facilitating an intuitive visual interpretation of co-occurrence and intensity. The legend was manually constructed within the layout view as a matrix that mirrored the 3 × 3 classification scheme, enhancing the clarity and interpretability of spatial patterns in the final visual output.

ETHICAL APPROVAL AND CONSENT TO PARTICIPATE

The present analysis utilizes a secondary data set with no identifiable information on the survey participants. This dataset is available in the public domain for research use; hence no approval was required from any institutional review board as there is no question of human subject protection in this case.

RESULTS

Sample Characteristics

The overall analytical sample comprised 664,646 women and 96,010 men (Table 1). Age group distribution indicates that 17% of women and 16% of men were adolescents aged 15-19 years. Among women, 14% had four or more children. Across both genders, approximately 75% of the sample resided in rural areas. With respect to lifestyle behaviours, 6.3% of women reported tobacco use, 2.0% reported alcohol consumption, and 11.4% reported daily junk food intake. Among men, the corresponding proportions were higher at 30.0%, 26.3%, and 13.3%, respectively.

>>>Table 1 about here<<<

Prevalence of abdominal obesity

At the national level, the prevalence of abdominal obesity was markedly high, affecting 56.6% of women (95% CI: 56.41-56.74) and 48.9% of men (95% CI: 48.31-49.46) (Table 2). A clear age gradient was observed, with prevalence rising consistently with age among both sexes. Among women, abdominal obesity was high at 66.2% (95% CI: 65.74-66.64) in the age group of 45-49 year, while the highest prevalence among men was recorded in the 50-54 of age group at 62.5% (95% CI: 60.68-64.24). Reproductive history was also associated with abdominal obesity among women; those with four or more children had a prevalence of 61.4% (95% CI: 60.99-61.82). Socioeconomic gradients were evident across wealth quintiles for both women and men. Among women, prevalence increased from 55.4% (95% CI: 55.04-55.74) in the poorest quintile to 60.7% (95% CI: 60.24-61.08) in the richest. A similar pattern was observed among men, with abdominal obesity rising from 44.3% (95% CI: 43.08-45.55) in the poorest to 55.4% (95% CI: 53.87-56.96) in the richest quintile.

The bivariate map reveals substantial inter-district variation in the prevalence of abdominal obesity among women and men in India (Figure 3, Supplementary Figure 1 & 2, and Supplementary Table 2). High prevalence in both sexes was observed in districts of Punjab, Haryana, Delhi, Jammu & Kashmir, Himachal Pradesh, Uttarakhand, West Bengal, Odisha, and Arunachal Pradesh. Several districts in Maharashtra, Madhya Pradesh, Chhattisgarh, and Rajasthan exhibited low prevalence among both women and men. Notably, districts in Kerala, Tamil Nadu, and Andhra Pradesh showed high prevalence among women but low among men, while the reverse pattern-high in men and low in women-was evident in parts of Telangana, Andhra Pradesh, and Uttar Pradesh. Metropolitan districts surrounding Delhi NCR, Kolkata, and Chennai demonstrated elevated prevalence among both sexes.

>>>Figure 3 about here<<<

Factors associated with abdominal obesity

Factors associated with abdominal obesity are presented in Table 2. Multicollinearity among covariates in the fully adjusted models was assessed using the generalised variance inflation factor, with maximum values of 2.47 for women and 1.97 for men, indicating no evidence of problematic collinearity. The analysis revealed a strong and consistent association between increasing age and the likelihood of abdominal obesity among both women and men. Among women aged 45-49 years, the odds of having abdominal obesity were 2.4 times higher compared to those aged 15-19 years (OR: 2.43; 95% CI: 2.35-2.51; $p < 0.001$). A similar pattern was observed among men, with those aged 50-54 years exhibiting 3.8 times higher odds of abdominal obesity compared to aged 15-19 years (OR:3.76; 95%CI:3.46-4.09; $p < 0.001$). Parity was not found to have a consistent or linear association with abdominal obesity. Compared to those with zero parity, women with one child had a slightly higher likelihood of abdominal obesity (OR: 1.07; 95% CI: 1.04-1.10; $p < 0.001$). However, women with three children had a modestly lower odds of abdominal obesity (OR: 0.95; 95% CI: 0.93-0.98; $p = 0.003$). Regarding marital status, currently married women had 22% higher odds of abdominal obesity (OR: 1.22; 95% CI: 1.19-1.26; $p < 0.001$), while currently married men had 26% higher odds (OR: 1.26; 95% CI: 1.20-1.33; $p < 0.001$). A strong and graded association was observed between household wealth and the likelihood of abdominal obesity among both women and men. Compared to individuals in the poorest wealth quintile, the odds of abdominal obesity increased progressively with rising socioeconomic status. Among women, the odds ranged from 1.05 times higher in the poorer quintile (OR: 1.05; 95% CI: 1.03-1.08; $p < 0.001$) to 1.27 times higher in the richest quintile (OR: 1.27; 95% CI: 1.23-1.30; $p < 0.001$). The gradient was even steeper among men, with the odds increasing from 1.21 (95% CI: 1.15-1.27; $p < 0.001$) in the poorer quintile to 1.78 (95% CI: 1.66-1.91; $p < 0.001$) in the richest. Regarding to place of residence, among women, those living in rural areas had 14% lower odds of abdominal obesity relative to urban women (OR: 0.86; 95% CI: 0.83-0.89; $p < 0.001$). A similar, though less pronounced pattern was observed among men, with rural residence associated with a 7% reduction in odds (OR: 0.93; 95% CI: 0.88-0.99; $p = 0.024$).

>>>Table 2 about here<<<

Attributing variation in abdominal obesity to local community, district, and state levels

Figure 4 and Table 3 showed that the majority of variation in abdominal obesity among both women and men is attributable to the individual level in both the null and full models. For women aged 15-49 years, the individual-level variation accounted for approximately 67% in both models, followed by community-level variation at around 20%, district-level at less than 5%, and state-level at around 7%. A similar pattern is observed among men aged 15-54 years, where individual-level variation explained nearly 70% of the total, followed by community-level at around 18%, district-level below 5%, and state-level around 6%. These between-area variance components represent unobserved heterogeneity across communities, districts, and states rather than the effects of specific measured contextual characteristics.

>>>Figure 4 about here<<<

>>>Table 3 about here<<<

DISCUSSION

The rising global burden of abdominal obesity has drawn increasing attention over the past three decades[10,21,22]. In the Indian context, obesity has traditionally been assessed using body mass index (BMI), despite its limitations as a proxy for adiposity[13,23]. BMI does not reflect fat distribution, and individuals with a normal BMI may still exhibit excess body fat, particularly in the form of abdominal obesity or visceral adiposity, which is more strongly linked to cardiometabolic risk[24]. In a significant advancement, the fifth round of the NFHS included, for the first-time, direct measurements of waist and hip circumference to assess abdominal obesity[10,13,25–27]. To our knowledge, this is among the first studies to provide district-level estimates of abdominal obesity in India and to examine associated factors using a multilevel framework across individual, community, district, and state levels based on nationally representative data. This analytical approach provides critical insights for identifying high-risk populations and informing targeted, multilevel prevention strategies. Our findings highlight that abdominal obesity is now a predominant public health challenge in India, on par with or exceeding levels observed in several other LMICs[4,8]. In the context of global trends of rising obesity, India stands out given the sheer magnitude of its affected population and the potential downstream impact on metabolic diseases[4]. These results dispel existing misconceptions that overweight, and obesity are problems limited to affluent countries or small subgroups in India; instead, abdominal obesity is widespread and demands urgent nationwide attention.

Our study highlights the sex-specific patterns in the prevalence of abdominal obesity. Women had a higher prevalence of abdominal obesity than men, despite men reporting a higher prevalence of lifestyle behaviours such as smoking and alcohol use. However, alcohol consumption was not independently associated with abdominal obesity after multivariable adjustment, suggesting that crude differences reflect confounding by age, wealth, or urban residence rather than a direct effect of alcohol use. This female excess in obesity is consistent with prior national surveys and epidemiological studies in India[28]. Several biological and social factors may contribute. Women generally have a higher percentage of body fat and may experience accelerated fat accumulation in the abdomen during menopausal transition or after multiple pregnancies[13,29]. Culturally, Indian women in some settings have less opportunity for recreational physical activity and may face constraints on healthy eating or weight control, which could exacerbate weight gain over the life course[30,31]. The observed sex difference could also reflect the postpartum weight retention and metabolic changes associated with childbearing[32,33]. Indeed, our analysis found that women's reproductive history was associated with abdominal obesity: women with higher parity or those who had children at a younger age tended to have greater waist circumference. This aligns with studies linking multiple pregnancies to increased visceral fat and long-term maternal weight gain[34]. Existing literature supports that higher parity is associated with increases in waist circumference and metabolic risk in later life[13,32–34].

Age was a powerful non-modifiable risk factor in our study, with abdominal obesity increasing sharply with advancing age in both men and women. Middle-aged and older adults showed the highest waist circumference levels. This age gradient is expected, as aging is associated with hormonal changes (such as menopause in women and andropause in men) and a natural redistribution of fat from peripheral to abdominal depots[29,35]. Our findings mirror patterns seen in other populations where visceral adiposity accumulates with age[29,36]. In India, the steep rise in abdominal obesity starting from the 30s and 40s is particularly concerning, given the country's relatively young demographic profile. As life expectancy improves and the population ages, an increasing proportion of Indians will enter the high-risk age brackets for abdominal obesity and related non-communicable diseases. This highlights a need for preventive strategies early in adulthood. Health promotion campaigns could focus on weight management for people in their 20s and 30s or even at school level to prevent the trajectory of weight gain. Additionally, regular screening for waist circumference in primary care may be warranted for middle-aged adults, so that those with expanding waistlines can be counselled before complications develop[13].

Our analysis also sheds light on social determinants of abdominal obesity, notably marital status and socioeconomic status. We found that in either sex being married was associated with higher odds of abdominal obesity compared to being never married. This association has been reported in various settings and is often attributed to lifestyle changes such as dietary shifts and reduced physical activities after marriage[10,13]. Socioeconomic factors emerged as a strong predictor where we observed that the odds of abdominal obesity rose progressively with wealth quintile. Individuals in the richest quintiles had significantly higher prevalence of abdominal obesity than those in the poorest quintile. This pro-rich obesity gradient is characteristic of countries undergoing the nutrition transition[10,26]. In traditional undernutrition-burdened societies, affluence brings greater access to calorie-dense foods, motorized transport, and sedentary occupations- leading to higher obesity rates among the wealthy[37]. India's pattern aligns with other LMICs where the highest obesity burden initially concentrates in urban, higher-income groups[4,26]. Nevertheless, our findings also point to the penetration of obesity into lower socioeconomic and rural groups[10,13,23]. The relatively high overall prevalence, even in less affluent segments, suggests that the gap may be closing as processed foods become cheaper and lifestyles more sedentary across the board, leading to a reversal of the social gradient, initially for risk factors and later for NCDs, as had happened in economically developed nations. From a policy perspective, the socioeconomic gradient in obesity calls for actions both universal and targeted. On one hand, broad policies such as front-of-pack food labelling, taxation of sugary drinks and ultra-processed foods, and strengthening of physical education in schools can help shift the environment for everyone[38,39]. On the other hand, targeted interventions might be needed for high-risk groups: for instance, customized community nutrition programs in urban slums or cash-transfer programs that incentivize healthy diets among low-income families could be considered[40]. The difference between rural and urban populations also point to the need for redesigning of urban landscapes to increase physical activity.

Geographic variation in abdominal obesity was another notable finding of our study. By leveraging the district-level representativeness of NFHS-5, we uncovered substantial spatial heterogeneity: some districts, particularly in parts of the north and east of India showed alarmingly high prevalence of abdominal obesity, whereas other districts (including many in abdominal, northeastern, and some southern areas) had considerably lower rates. This clustering of obesity 'hotspots' has important implications. It suggests that local environmental, cultural, or dietary factors modulate the risk of obesity beyond individual characteristics[26,41]. For instance, northern India particularly Punjab, Haryana, and Delhi have long reported higher obesity and cardio-metabolic rates, possibly related to richer diets such as high intake of fats and refined cereals, lower physical labour due to mechanized agriculture, and sociocultural norms that favour larger body size as a sign of prosperity[42,43]. Eastern India presents a more complex picture. While states like Bihar and Jharkhand have among the lowest obesity levels, which is possibly linked to persistent poverty and undernutrition, parts of West Bengal and Odisha have emerging pockets of abdominal obesity, potentially reflecting urbanizing populations and dietary shifts[42,44]. The identification of high-prevalence clusters at the district level is valuable for tailoring interventions. National and state health authorities could prioritize obesity control measures in the worst-affected districts. For example, districts in Punjab or urban hubs like Kolkata, which fall in high-obesity regions, could serve as focus areas for intensive pilot programs such as community fitness initiatives, weight management clinics in primary health centers, or local regulations on food vendors aimed to provide healthier options. Conversely, districts currently less affected should not be neglected; rather, they should receive preventive support to avoid following the trajectory of the high-prevalence areas. Our study demonstrates the utility of district-level data as state averages can mask intra-state variability, so a district-focused lens allows more efficient planning and allocation of resources and more culturally appropriate interventions.

The use of multilevel modelling in our analysis provides further insight by partitioning the variance in abdominal obesity risk across different levels of influence. We found that the bulk of variation (about 67% in women and 70% in men) was attributable to individual-level differences such as age, diet, and other health behavioural factors, with progressively smaller shares of variance attributable to community, district, and state levels. This predominance of individual-level variance aligns with findings from other low- and middle-income settings, where community or regional factors often explain only a modest fraction of abdominal obesity variation after accounting for individual factors[26]. It reinforces that interventions cannot ignore personal risk factors such as diet and tobacco/alcohol use which are ultimately decided at the individual or household level. However, the fact that around 30% of the variance observed at higher geographic levels reflects unobserved heterogeneity across communities, districts, and states and cannot be overlooked. For instance, community-level variance may capture aspects like the local food environment, walkability, or social norms around body weight; district-level variance might reflect broader factors such as economic development or food policies; state-level variance could relate to differences in governance or regional cuisine. Because our models did not include explicit contextual covariates at these levels, these variance components should be interpreted as geographic clustering rather than the effects of specific measured contextual characteristics. District level interventions could also influence personal risk factors by promoting greater awareness and creating an eco-system that facilitates personal factors such as diet and physical activity. The multilevel approach thus highlights that a comprehensive strategy is needed: one that addresses individual behaviour change while also creating supportive environments, which could have mutual nurturing effect. From a public health standpoint, this means pairing person-focused interventions (like lifestyle counselling, mobile health apps for weight loss, or high-risk group screening) with population-wide measures (like urban design for physical activity, regulations on food marketing, or fiscal policies to make healthy foods more affordable)[45–47]. The modest between-community and between-district differences observed also suggest that best practices can be shared: if certain districts have managed to keep obesity rates lower, perhaps through active public health campaigns or cultural practices, cross-learnings from those contexts could inform scalable interventions elsewhere. Moreover, our multilevel findings highlight the importance of decentralised health policy implementation. Since health in India is a state subject and even district health missions play a role, empowering states and districts to design context-specific interventions while learning from regional successes can promote more effective and locally responsive obesity prevention strategies.

From a policy and prevention standpoint, the implications of our study are clear. India needs a multipronged and inclusive strategy to combat abdominal obesity. At a high level, strengthening national NCD control programs is imperative. The government's flagship programs such as the National Programme for Prevention and Control of Non-Communicable Disease[48] may consider waist circumference and waist-to-hip ratio as standard risk assessment tools. Currently, much emphasis is placed on screening for hypertension and diabetes; our findings suggest that adding routine screening for abdominal obesity could improve early prevention. Public awareness campaigns are also crucial. Just as India successfully ran campaigns on sanitation (Swachh Bharat) and nutrition for children (Poshan Abhiyaan), a campaign highlighting the risks of abdominal obesity and promoting active lifestyles could shift community norms. Such a campaign should be culturally sensitive- for instance, countering the traditional perception of a 'prosperity belly' as a status symbol, and framing a healthier waistline as a sign of wellness and success[49]. The NCD benefit package at primary health care level also needs to include reduction of risk factors in addition to screening and managing the diseases.

STRENGTHS AND LIMITATIONS OF THE STUDY

This study has important implications for future research and public health practice. First, this research drew upon publicly available nationally representative data using multilevel analytical approach and provides a reproducible framework that can be extended to other important health outcomes. Second, future research may use our estimates for inferential work highlighting the relationship between diet culture and physical activities with abdominal obesity. From a practice standpoint, the generation of district-level estimates and spatial visualisations enables more precise identification of high-risk geographic and sociodemographic clusters. This granularity is essential for designing targeted interventions, prioritising resource allocation and informing evidence-based policymaking. The significant variation in abdominal obesity across districts reinforces the need for the strategic use of local-level data to guide programmatic action, inform funding proposals and develop context-specific implementation frameworks and models for obesity and NCD prevention. Future implementation research that evaluates contextual interventions across defined geographic areas within decentralised health systems could build on these findings to identify effective and scalable models of prevention.

This study was not exempted from limitations. The first limitation was related to the cross-sectional nature of data which restricted the causal inference. Second, the analysis could not fully explain the variance at the state, district, and community level due to unavailability of contextual variables at such granular level. Moreover, information on physical activities were not available in the data which are very important factor for determining the abdominal obesity status at an individual level. Despite these limitations, this study has many strengths that emphasize its contribution to the field. One of the major strengths of this study lies in the use of biomarker-based measurements of waist and hip circumference which was used to calculate the abdominal obesity. The application of multilevel modelling allowed for the generation of robust community and district level estimates that were previously unavailable. Moreover, the use of choropleth and bivariate maps enriched the spatial understanding of abdominal obesity across India, providing valuable visual insights for researchers, practitioners, and policymakers alike.

CONCLUSION

In conclusion, this study provides updated national evidence on the prevalence and distribution of abdominal obesity in India, revealing substantial sociodemographic and geographic variation. The observed patterns suggest that risk is shaped not only by individual characteristics but also by broader contextual factors. These findings contribute to understanding the contemporary epidemiology of abdominal obesity in India and underscore the importance of further research to examine how environmental and structural determinants influence these patterns over time.

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Not Applicable

Author contributions

N.K.S. and P.J. conceptualized the study. N.K.S., R.B. and S.K.S. performed the data analysis. R.B. and R.R.P. performed the geospatial analysis. N.K.S, R.R.P., S.K.S. and P.C. were involved in writing the draft. G.T.M., R.R.P., P.C., and S.R.B. revised the manuscript. P.J., N.K.S., R.S. and S.R.B. provided overall supervision for the study.

Data availability statement

The data utilized in this study are publicly available from the DHS upon request and filing the registration. DHS data are available on: https://dhsprogram.com/data/available-datasets.cfm . However, the datasets used can be made available from the corresponding author upon reasonable request.

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Competing interests

The authors declare no competing interests.

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Background characteristics	Abdominal obesity	95%CI	p-value	Total sample	Abdominal obesity	95%CI	p-val
	Women (15-49 years)				Men (15-54 years)		
Age			<0.001				<0.0
15-19	46.3	45.89-46.68		1,13,422	28.1	26.90-29.28	
20-24	51.1	50.62-51.49		1,00,458	37.0	35.56-38.53	
25-29	55.4	54.95-55.82		1,03,268	47.7	46.17-49.32	
30-34	58.3	57.86-58.76		93,661	55.2	53.59-56.78	
35-39	60.3	59.84-60.73		93,615	55.4	53.75-56.99	
40-44	63.4	62.95-63.90		78,674	58.6	56.97-60.31	
45-49	66.2	65.74-66.64		81,548	60.1	58.44-61.83	
50-54					62.5	60.68-64.24	
Parity of women			<0.001				
Zero	49.3	48.97-49.58		2,08,170			
One Child	60.7	60.22-61.18		84,501			
Two Children	59.0	58.67-59.32		1,72,567			
Three Children	58.8	58.37-59.19		1,06,094			
4+ Children	61.4	60.99-61.82		93,314			
Marital status			<0.001				<0.0
Never married	48.0	47.63-48.30		1,72,413	35.5	34.63-36.47	
Married	59.4	59.16-59.55		4,62,879	56.4	55.65-57.06	
Widowed/divorced/separated	59.6	58.76-60.39		29,354	48.6	43.97-53.29	
Education			<0.001				<0.0
No education	59.0	58.70-59.34		156318	50.8	49.19-52.33	
Primary	57.8	57.36-58.32		78835	51.8	50.16-53.43	
Secondary	55.0	54.77-55.25		338408	47.2	46.50-47.98	
Higher	57.1	56.62-57.56		91085	50.8	49.39-52.27	
Wealth quintile			<0.001				<0.0
Poorest	55.4	55.04-55.74		1,37,104	44.3	43.08-45.55	
Poorer	54.7	54.35-55.05		1,48,019	45.4	44.24-46.57	
Middle	55.2	54.81-55.54		1,40,274	47.3	46.14-48.46	
Richer	57.0	56.63-57.40		1,28,591	51.4	50.17-52.66	
Richest	60.7	60.24-61.08		1,10,658	55.4	53.87-56.96	
Consumption of Tobacco			<0.001				0.47
No	56.6	56.45-56.80		6,22,116	48.5	47.77-49.15	
Yes	55.5	54.72-56.20		42,530	50.0	49.01-51.04	
Consumption of alcohol			<0.001				<0.0
No	56.5	56.38-56.71		6,51,813	47.3	46.69-47.99	
Yes	60.7	59.28-62.06		12,833	54.1	52.85-55.27	
Consumption of junk food			<0.001				<0.0
Never	56.2	55.97-56.36		4,79,690	48.0	47.27-48.64	
Occasionally	55.9	55.48-56.29		1,09,182	52.3	50.91-53.72	
Daily	61.1	60.55-61.60		75,774	49.8	48.15-51.36	
Place of residence			<0.001				<0.0
Urban	59.8	59.49-60.18		1,63,402	51.7	50.47-52.90	
Rural	55.0	54.86-55.23		5,01,244	47.5	46.85-48.06	
Total	56.6	56.41-56.74		6,64,646	48.9	48.31-49.46	

Note: Abdominal obesity was defined using waist-to-hip ratio (WHR) cut-offs of >0.85 for women and >0.90 for men, as recommended by the World Health Organization.

Table 2: Factors associated with abdominal obesity among women and men in India, 2019-21

Explanatory variables	Women (15-49 years)			Men (15-54 years)		
	aOR	95%CI	p-value	aOR	95%CI	p-value
Age						
15-19 (ref.)						
20-24	1.13	1.10-1.15	0.000	1.41	1.33-1.49	0.000
25-29	1.39	1.35-1.43	0.000	2.00	1.87-2.14	0.000
30-34	1.63	1.58-1.68	0.000	2.64	2.45-2.84	0.000
35-39	1.84	1.78-1.90	0.000	2.99	2.77-3.22	0.000
40-44	2.13	2.06-2.20	0.000	3.46	3.19-3.74	0.000
45-49	2.43	2.35-2.51	0.000	3.64	3.36-3.95	0.000
50-54				3.76	3.46-4.09	0.000
Parity of women						
Zero (ref.)						
One Child	1.07	1.04-1.10	0.000			
Two Children	0.99	0.96-1.02	0.492			
Three Children	0.95	0.93-0.98	0.003			
4+ Children	1.00	0.97-1.03	0.891			
Marital status						
Single (ref.)						
Married	1.22	1.19-1.26	0.000	1.26	1.2-1.33	0.000
Widowed/divorced/separated	1.17	1.13-1.22	0.000	0.92	0.81-1.05	0.212
Education						
No education (ref.)						
Primary	1.03	1.01-1.06	0.002	1.14	1.07-1.21	0.000
Secondary	1.05	1.03-1.07	0.000	1.23	1.17-1.3	0.000
Higher	1.04	1.01-1.07	0.002	1.23	1.16-1.32	0.000
Wealth quintile						
Poorest (ref.)						
Poorer	1.05	1.03-1.08	0.000	1.21	1.15-1.27	0.000
Middle	1.13	1.10-1.15	0.000	1.37	1.29-1.45	0.000
Richer	1.19	1.16-1.22	0.000	1.57	1.48-1.67	0.000
Richest	1.27	1.23-1.30	0.000	1.78	1.66-1.91	0.000
Consumption of Tobacco						
No (ref.)						
Yes	0.91	0.88-0.93	0.000	0.99	0.95-1.03	0.492
Consumption of alcohol						
No (ref.)						
Yes	1.02	0.98-1.07	0.351	1.01	0.97-1.05	0.775
Consumption of junk food						
Never (ref.)						
Occasionally	1.02	1.00-1.03	0.087	1.07	1.03-1.12	0.002
Daily	0.99	0.97-1.01	0.297	1.05	1-1.11	0.066
Place of residence						
Urban (ref.)						
Rural	0.86	0.83-0.89	0.000	0.93	0.88-0.99	0.024

Note: Table 2 presents adjusted odds ratios (aOR) from the full four-level multilevel logistic regression model (individuals nested within communities/PSUs, districts, and states).

Table 3: Estimated variance and model parameters for abdominal obesity among men and women in India

Women	**Null Model**			**Full Model**		
	Estimates	**95% CI**	**SE**	**Estimates**	**95% CI**	**SE**
Random-effects parameters						
State level variance	0.383	0.23-0.63	0.0975	0.424	0.26-0.70	0.1078
District level variance	0.182	0.16-0.21	0.0116	0.188	0.17-0.21	0.0120
Community level variance	0.959	0.94-0.98	0.0113	0.998	0.98-1.02	0.0118
Model parameters						
AIC	793863.4			778729.8		
BIC	793909			779049.2		
Df	4			28		
Number of Individuals	6,64,646			6,64,646		
Number of states	36			36		
Number of districts	707			707		
Number of communities (PSU)	30,112			30,112		
Men						
Random-effects parameters						
State level variance	0.244	0.15-0.41	0.06	0.237	0.14-0.40	0.0627
District level variance	0.092	0.07-0.11	0.01	0.104	0.08-0.13	0.0113
Community level variance	0.696	0.66-0.74	0.02	0.768	0.73-0.81	0.0222
Model parameters						
AIC	123895.2			118274.6		
BIC	123933.0			118511.4		
Df	4			25		
Number of Individuals	96,010			96,010		
Number of states	36			36		
Number of districts	707			707		
Number of communities (PSU)	9,073			9,073		

Note: Table 3 reports random-effects variance estimates at the state, district, and community levels, along with model fit statistics, for the same four-level multilevel logistic regression models whose fixed-effect estimates are presented in Table 2. Full models are adjusted with age, parity (in case of women), marital status, education, wealth quintile, consumption of tobacco and alcohol, consumption of junk food, and place of residence.

Multicollinearity was assessed using the generalised variance inflation factor (gVIF). The maximum gVIF values were 2.47 for women and 1.97 for men, both below commonly used thresholds for problematic multicollinearity (e.g., gVIF > 5 or > 10).

FIGURES

Figure 1: Final analytical samples for women and men selected in the study.

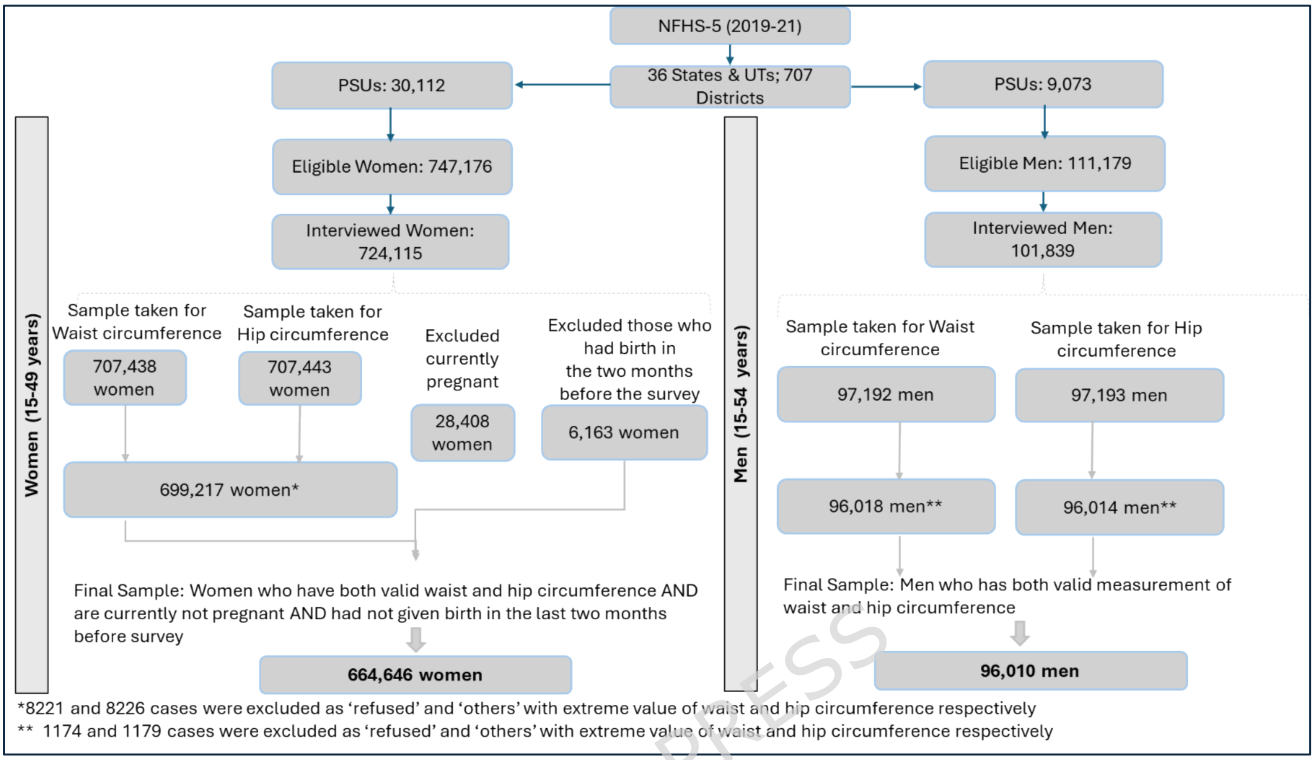
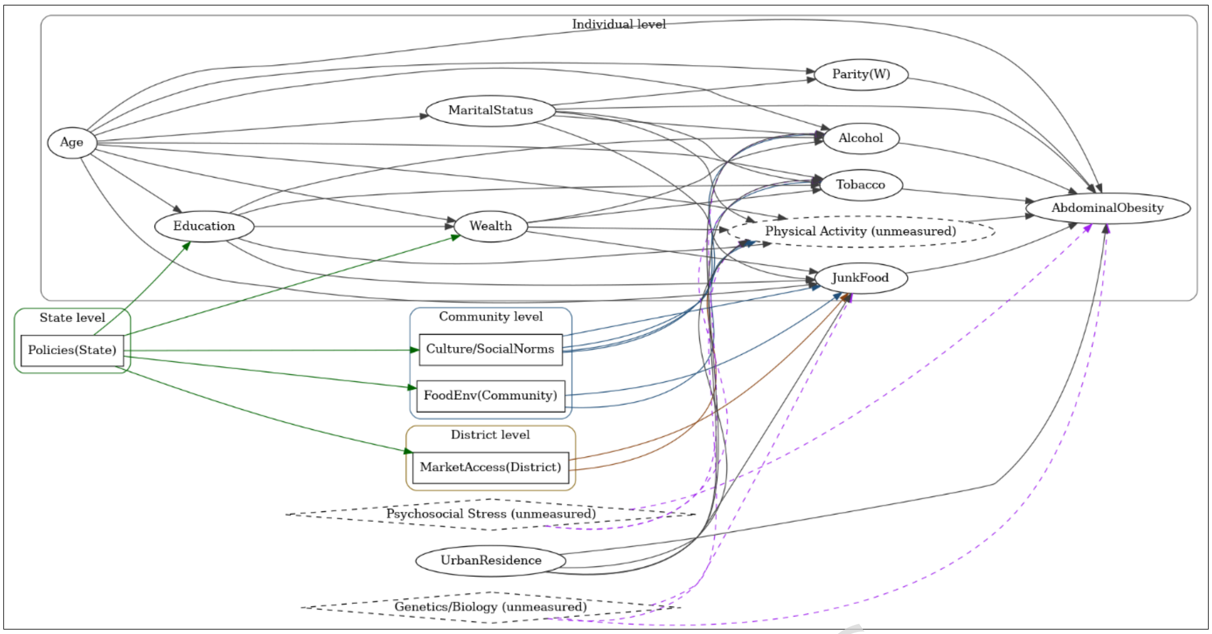
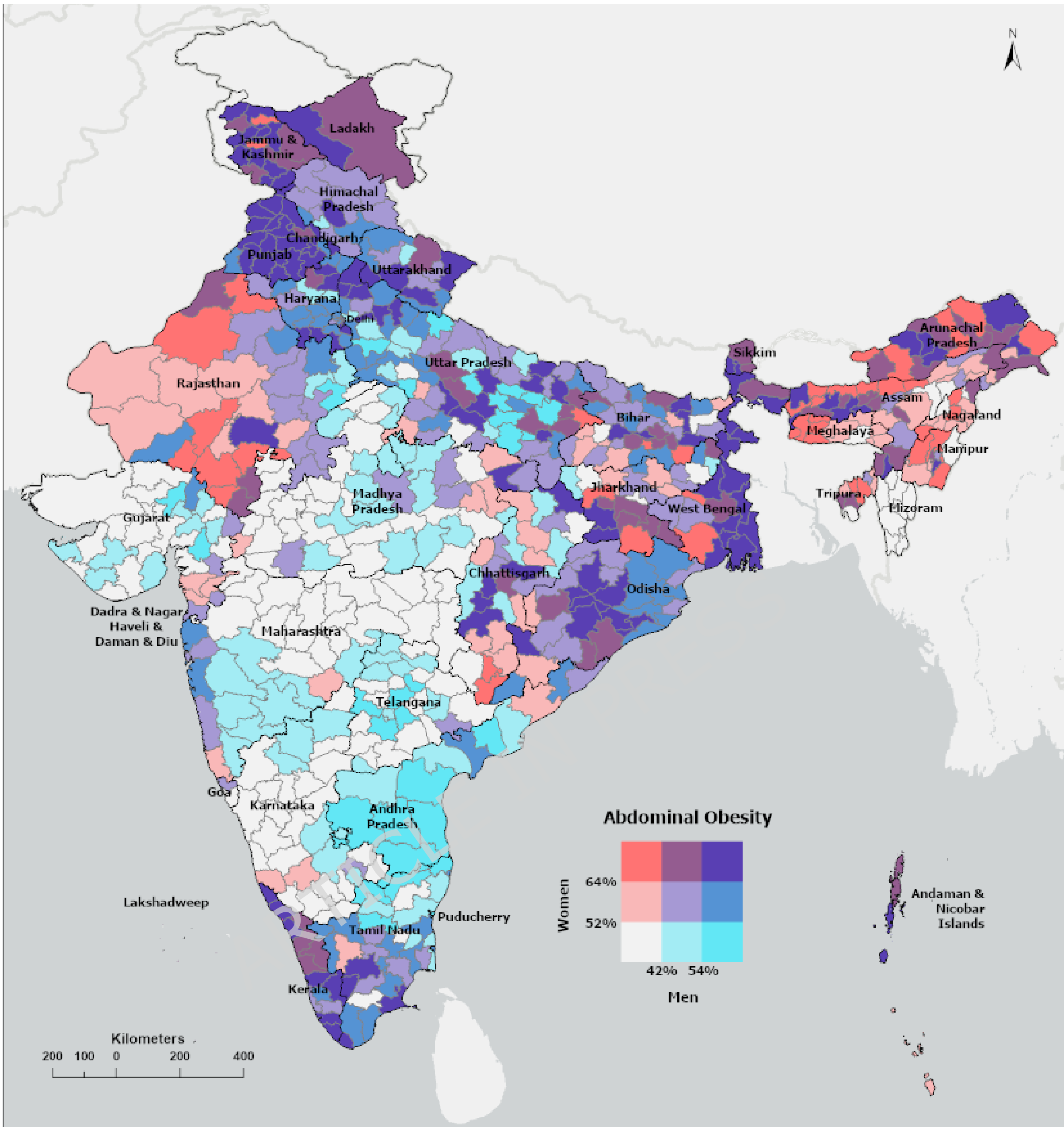


Figure 2. Directed acyclic graph (DAG) illustrating assumed causal structure underlying our adjusted multilevel regression analysis.



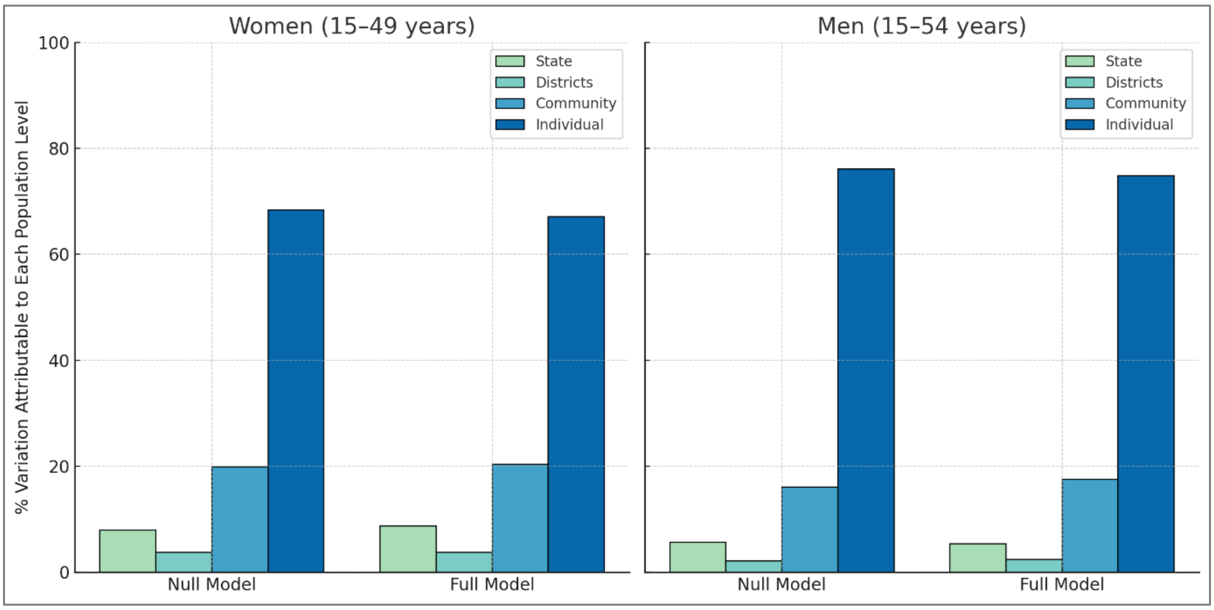
Note: Arrows are colour-coded by analytical level (state, district, community, and individual), and purple dashed arrows denote unmeasured (latent) factors. The DAG guided covariate selection to reduce over-adjustment and collider bias in the multilevel regression models.

Figure 3: Bivariate map showing the district level prevalence of abdominal obesity among women (15-49 years) and men (15-54 years) in India, 2019-21



Note: 1. The prevalence of sex-specific abdominal obesity across 707 districts was estimated using predicted probabilities (refer Supplementary Table-1) derived from models adjusted for demographic and socioeconomic covariates. 2. Maps were generated using ArcGIS Pro (version 3.6; Esri Inc., Redlands, CA, USA; https://www.esri.com).

Figure 4: Percent of variation in abdominal obesity attributable to population levels in India



Note: Full models are adjusted with age, parity (in case of women), marital status, education, wealth quintile, consumption of tobacco and alcohol, consumption of junk food, and place of residence.