# Population-level effects of diet, lifestyle, and health environment on obesity and non-communicable diseases in India

**Kuhu Joshi** ( kuhu.joshi@cgiar.org )
IFPRI

**Devesh Roy**
International Food Policy Research Institute

**Lora Iannotti**
Washington University in Saint Louis

**Aishwarya Nagar**
Washington University in Saint Louis

**Avinash Kishore**
International Food Policy Research Institute

---

**Research article**

**Keywords:** overweight, obesity, diabetes, hypertension

**Posted Date:** November 1st, 2019

**DOI:** https://doi.org/10.21203/rs.2.16683/v1



---

# Abstract

Background: Obesity is rising in developing countries like India and is associated with an increase in cardiometabolic problems. Rising incomes, rapid urbanization, and mechanization have induced lifestyle changes like consumption of more obesogenic foods and sedentary habits at work and leisure, contributing to a transition from under- to over-nutrition. This study maps the prevalence of adult (15-49 years) overweight and obesity across regions and socioeconomic groups in India, and estimates its association with lifestyle, health environment, dietary patterns, diabetes, and hypertension.

Methods: We employ a combination of 3 latest nationally representative datasets with over 700,000 adults. We use a linear probability regression model to identify the correlates of overweight/obesity and their relative magnitudes. We use intra-household regression to identify differences between men and women and coarsened exact matching to causally estimate the impact of obesity on diabetes and hypertension.

Results: Overweight/obesity rates have increased across all states, in rural and urban areas, and for all wealth levels. Women are more likely to be overweight/obese than men, even in the same household. Improved health environment (toilets, piped water, clean cooking fuel), urban jobs, television watching, and processed snacks increase the risk of overweight/obesity. Adults who are overweight/obese have a 5.6% higher risk of diabetes and a 9.7% higher risk of hypertension.

Conclusions: Our results underscore the need for policy intervention to reduce the burden of obesity and NCD's in India.


# Background

The World Health Organization (WHO) considered obesity as among the most neglected public health problems in 1997 (1). Adult obesity has continued to grow but remains a neglected issue in the developing world, where it is no longer a disease of the socioeconomic elite (2, 3, 4). India has transitioned from having 1.3% of the world's obese population in 1975 to 3.7% in 2014, featuring the third highest number of obese women in the world (3). In 2015, China and India also had the highest numbers of obese children, a precursor to obese adults (4). The National Family Health Survey shows that among those aged 15–49 years, 31% of women and 26% of men in urban areas - as well as 15% of women and 14% of men in rural areas - were overweight/obese in India in 2015–16.

While obesity is itself a health burden, it also increases the risk of several serious non-communicable diseases (NCDs), such as diabetes, hypertension, sleep apnoea, osteoarthritis, and cardiovascular diseases (2,5). India is second only to China in the incidence of diabetes (7). Indians and Asians are more vulnerable to obesity-related NCDs, facing a higher risk at BMI levels below the standard cut off of 25 $kg/m^2$ (8). BMI above 23 $kg/m^2$ is now recognized as overweight and BMI above 25 $kg/m^2$ as obese among the Asian population (9,10).

From a biological perspective, being overweight or obese is a result of an imbalance between energy intake and energy expenditure (11), but the phenomenon of rising obesity is far more complex. A nutrition transition is underway as a result of rising wealth and the associated changes in lifestyle (12). Factors such as the decline in the need for physical labor and calories, increase in the consumption of obesogenic food, easier availability of cheap calories, improvements in health conditions, increased mechanization, and sedentary habits at work and leisure, interact to create an obesogenic environment. Obesity is also associated with socio-cultural and geographical factors that are difficult to disentangle and are not clearly understood (12,13). A body of literature finds evidence of a social network effect as well, wherein obesity can spread among individuals sharing the same environmental factors (14,15). Adult obesity, if left unaddressed, can easily become the norm (16–18).

In 2015–16, 22.5% adults in India were thin (BMI<18), 57% were of normal weight, and 20.5% were overweight or obese (National Family Health Survey). Between 2005–6 and 2015–16, the percentage of thin adults fell by 12.5% and the percentage of adults who are of normal weight increased by 3.4%, while the percentage of adults who are overweight and obese increased by 9.0%. One-third of all adults had BMI $\geq$ 23 kg/m$^2$ in 2015–16 and a large number were on the margins, with BMI between 23 and 25 (*Table S1)*..

Our paper presents a comprehensive analysis of the current overweight/obesity prevalence among Indian adults and its evolution over the last 10 years. We hypothesize that a range of factors, such as diet, lifestyle, wealth, health environment, and ownership of assets creates a complex obesogenic environment. While there have been previous studies on obesity in India, they focus on specific sub-populations (12,17,18). Our analysis covers all adults in the 15–49 years age group across India. Second, we capture the large inter-district variations within India's states since the latest dataset, the National Family Health Survey 2015–16 (NFHS–4), is representative at the district level. Our third contribution to the literature is in systematically combining two nationally representative datasets—one used for health and nutrition-related information (National Family Health Survey) and the other used for consumption-related information (National Sample Survey)—to study the relationship between diet and overweight/obesity in the population.

Finally, we perform a causal analysis of the relationship between high BMI and the risk of two common non-communicable diseases: high blood sugar (diabetes) and high blood pressure (hypertension). Ours is the first paper to causally estimate this relationship for all-India using the latest nationally representative data and coarsened exact matching methodology.

In the rest of the paper, we discuss our data sources and regression methodologies, present our regression results, and conclude with a discussion of our main findings.

# Methods

*Data sources*

We use two rounds of a nationally representative household survey, the National Family Health Survey, conducted in 2005–06 (NFHS–3) and 2015–16 (NFHS–4). NFHS provides detailed information on health, nutrition, family planning, morbidity, and mortality and is readily comparable to DHS from other developing and middle-income countries around the world (19). NFHS–4 is the first time that measures of blood sugar and blood pressure of all adults aged 15–49 were recorded.

NFHS–3 covers a sample of 124,384 females aged 15–49 years and 74,369 males aged 15–54 years across 29 states of India. NFHS–4 covers a sample of 699,686 females aged 15–49 years and 103,525 males aged 15–54 years across 29 states and seven union territories of India. NFHS–3 data is representative at the state level and NFHS–4 at the district level. The regression analysis of overweight/obesity in this paper is based on data of 15–49-year-old individuals from the NFHS–4 dataset. We compare NFHS–3 and NFHS–4 data to show the changes in overweight/obesity rates in India in the last 10 years.

To analyze dietary patterns that impinge on overweight/obesity, we use nationally representative data from the household consumer expenditure survey (CES) of the National Sample Survey Organization (NSSO) round 68 conducted in 2011–12 (19). We denote this dataset as NSS-CES. The sample comprises 101,662 rural and urban households. We use the information on household expenditure on cereals, pulses, vegetables, fruits, processed foods/snacks, sugar, salt, and meat.

*A descriptive overview of obesity in India*

Obesity has increased across all sub-populations of India (*Table 1).* Urban obesity rates, already high in 2005–06, increased by 10 percentage points to 30.7% in 2015–16. Obesity in rural areas also increased by 8% during this time. Overweight/obesity rates are higher in older age groups and wealthier households. The increase in the incidence of obesity between 2005–06 and 2015–16 has been the fastest for urban men, adults older than 25 years of age, and adults in the upper ($3^{rd}$ and $4^{th}$) wealth quintiles. Obesity is more common among women in both rural and urban areas, but the gender gap is wider in urban areas.

*Figure 1* maps the average obesity rates across states in the two rounds of the NFHS. Punjab, Telangana, Kerala, and Tamil Nadu had the highest obesity rates in both NFHS rounds. 26% adults were overweight/obese in rich states while 17.5% were overweight/obese in poor states in 2015–16. The large sample of NFHS–4 allows for a more disaggregated picture of the average obesity rates across all 640 districts of India (*Figure* S1). More than 20% of adults are overweight/obese in nearly one-third (30%) of all districts of India and only a few districts (15%) have overweight/obesity rates below 10%. Overweight/obesity rates are higher than 20% in urban populations of almost all districts of India. Rural obesity is comparatively low. Still, there are only a few districts in the poorer eastern and central parts of India where rural overweight/obesity rates are below 10%, making obesity common in rural areas also (12). In fact, the rural obesity map of 2015–16 looks like the urban obesity map of 2005–06. These regional differences have been highlighted in other studies as well, but unlike here, previous studies have not used district-level data (20).

[TABLE 1 HERE]

[FIGURE 1 HERE]

*Regression analysis*

*Potential drivers of overweight/obesity:*

We first use a non-parametric local polynomial regression (LPR) to flexibly model the relationship between overweight/obesity and wealth, fitting a polynomial relationship between the *y* and *x* variables using locally weighted least squares.

Households are grouped into wealth quintiles based on the wealth index given in the NFHS data. NFHS creates a wealth index using information on household ownership of assets and amenities such as the type of house, toilet facility, source of lighting, main fuel for cooking, source of drinking water, separate room for cooking, and ownership of the house, agricultural land, irrigated land, livestock and certain consumer goods. The weights have been developed by the International Institute of Population Sciences and NFHS research team in India, based on their knowledge of the relative significance of ownership of these items. For example, a household which owns a color TV is considered three times as wealthy as one that owns its own house (21,22).

To further study the possible determinants of overweight/obesity, a linear probability model (LPM) and multivariate least squares regression model (MLSR) with a continuous measure of BMI are employed. In LPM, the outcome is equal to 1 if the individual's BMI is $\geq$ 25 kg/ $m^2$ and is equal to 0 if the individual's BMI is < 25 kg/ $m^2$, thereby indicating whether an individual is overweight/obese. We use both the data available in NFHS–4 and in NSS-CES to study the role of individual and household level variables: gender, age, education, wealth, the frequency of watching TV, caste, religion, household food consumption, assets, amenities, and health environment.

*The relationship between high BMI and non-communicable diseases:*

Overweight/obese adults are at a higher risk for non-communicable diseases like diabetes and hypertension (11). Over the past decade, diabetes prevalence has grown faster in low and middle-income countries than in high-income countries (23). In India, 7% of annual deaths are attributed to diabetes (23).

To empirically test the relationship between overweight/obesity and diabetes and hypertension, we use LPM and coarsened exact matching (CEM) (with the binary outcome whether the individual has a high blood sugar or high blood pressure).

Since overweight/obese individuals may differ from others in observable and unobservable characteristics that may also affect the probability of having high blood sugar or high blood pressure, we employ CEM to establish causal links between overweight/obesity and the two NCDs (24). The same set of control variables used in LPM are also used for matching. The average treatment effect of being

overweight/obese on the probability of having high blood sugar or high blood pressure is then calculated using the CEM probability weights for matched individuals.

We use district fixed effects in all LPM, MLSR, and CEM regressions to control for unobserved differences across districts in infrastructure, food availability, and other relevant factors. We also cluster the standard errors in all regressions at the primary sampling unit (PSU) level (the village in rural areas and the municipality in urban areas).

# Results

*Local polynomial regression (LPR) results:*

*Figure 2* shows the LPR between wealth and overweight/obesity for urban women, urban men, rural women, and rural men. Results show that the percentage of overweight/obese adults rises consistently with wealth for all four groups. Obesity is higher in urban areas and among women across all wealth quintiles. This is probably due to more sedentary lifestyles in urban areas (13). The gap in the incidence of obesity/overweight between rural and urban areas is higher for women than men. The gender gap in the prevalence of obesity is not significant for the bottom three wealth quintiles in rural areas.

Watching television for long hours is a sign of a sedentary lifestyle and people who spend more time watching TV are more likely to be overweight across all wealth quintiles (25,26) (*Figure S2). Figure S3* plots the same relationship for two occupation types: salaried work with comparatively low levels of physical activity (professional, technical, and managerial jobs) compared to manual labor (unskilled and skilled manual labor and agriculture). A higher percentage of the former are overweight/obese at every wealth level compared to farmers and casual laborers. The distance between the curves at each wealth quintile can be interpreted as the effect of the lifestyle gap on the incidence of obesity.

[FIGURE 2 HERE]

*Regression results of the effect of wealth and lifestyle on overweight/obesity:*

The probability of being overweight/obese is positively correlated with wealth (*Table 2)*.. Individuals in the second wealth quintile are 2.4% more likely to be overweight/obese compared to individuals in the bottom wealth quintile. Those in the third, fourth, and the top wealth quintiles are 6%, 12%, and 19% more likely to be overweight or obese compared to their poorest neighbors. Among all variables included in our model, the coefficients of the wealth variable are the largest in magnitude.

Individuals who watch TV daily are 2.7% more likely to be overweight/obese than individuals who never watch TV. Women are 3% more likely to be overweight/obese than men, and urban adults are 4% more likely to be overweight/obese than rural adults. Overweight/obesity rises more rapidly with wealth for women than for men.

Obesity also increases with age, although at a decreasing rate. A similar quadratic relationship is observed between obesity and education (12). A recent study finds a nonlinear relationship between education and overnutrition, possibly reflecting weight-control behaviors among the highly educated (13). An increase in the number of household members or children younger than 5 years is associated with a decline in the likelihood of being overweight/obese. Caste also plays a role. Individuals in the higher caste category (GEN) are 2% more likely to be overweight/obese than the lowest caste. Furthermore, Muslims are 4% more likely to be overweight/obese than Hindus. This could be because of a cleaner health environment due to a lower prevalence of open defecation in Muslim neighborhoods (27) and higher consumption of meat. Sikhs and Jains are 5% more likely to be overweight/obese than Hindus. This could be because of higher fat consumption in diets in these communities.

*Regression results showing comparisons within households:*

As the NFHS data is available at the individual level, we analyze the determinants of overweight/obesity within a household using household fixed effects in the overweight/obesity and BMI regressions (*Table S2)*.. The intra-household comparison shows similar results. The probability of being overweight/obese increases with both age and education but at a declining rate. In a household, adults who watch TV more are significantly more likely to be overweight/obese. The significantly higher incidence of overweight/obesity for women exists even when we compare them with men within their households.

[TABLE 2 HERE]

*Effect of health environment, assets, and amenities on overweight/obesity:*

Improvements in the health environment and increases in mechanization have improved the quality of life for most individuals in India (13). For example, increased access to piped water has reduced the drudgery involved in water collection (28,29). Improved sanitation and cleaner cooking fuel improve health, creating better appetite and absorption of food and nutrients (28,30,31). These changes also mean that individuals need to expend less physical energy (32).

We explore the association between ownership of (or access to) different amenities and BMI. Individuals in families that own mobile phones are more likely to be overweight/obese. Owning motorized vehicles is also positively associated with overweight/obesity. Indeed, ownership of a bicycle is negatively associated with overweight/obesity. Access to electricity has a small, but positive correlation with overweight/obesity. Individuals who do not have access to toilets are less likely to be overweight/obese. Open defecation in a village or municipality decreases the likelihood of overweight/obesity as it creates an unhealthy environment (33).

Overall, *Table 3* highlights that improvements in the health environment and increased ownership of assets are associated with the rise in overweight/obesity in India.

[TABLE 3 HERE]

*Regression results of the effect of diet on overweight/obesity:*

Diet is a big driver of BMI. Ideally, one would like to use the same dataset from where the BMI measures come, for information on diets as well. Though NFHS–4 collected data on the frequency of consumption of different food groups, the diet intake data are not reliable (19). For example, NFHS–4 shows that only 56% households consumed pulses on a regular basis, but the NSS-CES data shows that pulses are consumed regularly by almost all households in India. Griffiths and Bentley also reach a similar conclusion on diet data in an earlier round of NFHS (12). Therefore, we use household food consumption data from the NSS-CES, which is widely used and is known to be more reliable (34).

We combine the health and nutrition data from NFHS–4 with the household consumption data from NSS-CES. Both surveys are representative at the national and the state levels and collect data on ownership of a common set of household assets. We create new wealth quintiles using only the assets that are common between NFHS–4 and NSS-CES. For each wealth quintile, we match the average value of total expenditure per capita on different food items from the NSS-CES data to the overweight/obesity rates from the NFHS–4 data (*Table 4)*.. Per capita consumption expenditure on snacks or obesogenic foods—like ice cream, cold beverages, fruit juice, purchased cooked meals, purchased cooked snacks (including *chaat, golgappa, bhelpuri),*, cake, biscuits, chocolate, *namkeen,* chips, jam, jelly, pickles, and other packaged/processed food items—is significantly higher in urban areas across all wealth quintiles (*Figure S4)*.. In rural areas, the consumption of obesogenic foods increases monotonically with wealth. However, in urban areas, it is highest for households in the bottom two wealth quintiles. Then it declines for the 2$^{nd}$ to the 4$^{th}$ wealth quintile after which it rises again (*Table 4 and Figure S4)*.. The urban poor have the unhealthiest diets, with low consumption of pulses, fruits, and vegetables and very high consumption of obesogenic foods. The urban-rural difference in consumption of obesogenic food is reflected in the differences in the urban-rural overweight/obesity levels for the same wealth quintiles.

Regressions results shown in Table S3 explore correlations between average per capita consumption expenditure on different food items or food groups in an NSS cluster with the incidence of overweight/obesity among adults living in that cluster. Individuals living in clusters with a higher average consumption of snacks/obesogenic foods, oil, milk products, and cereals are more likely to be overweight/obese. These food items have also been associated with weight gain and obesity in previous studies (35,36).

[TABLE 4 HERE]

*Regression results of the relationship between overweight/obesity and NCDs:*

Blood sugar levels > 140 mg/dl are categorized as ‘high blood sugar’ and blood pressure readings with systolic > 140 and/or diastolic > 90 are categorized as ‘high blood pressure’. Both variables are based on the average value of three recorded measurements. On average, 6.3% of all adults in India have high blood sugar and 9.4% have high blood pressure. These rates are higher for men than women and higher in urban areas. 9% urban men and 7% rural men have high blood sugar. 14% urban men and 11% rural

men have high blood pressure. Similarly, 7% urban women and 5% rural women have high blood sugar. 9% urban women and 8% rural women have high blood sugar.

*Figures 3* presents district-level maps of the percentage of adults who are overweight/obese, adults who have high blood sugar, and adults who have high blood pressure. It appears that districts with high rates of overweight/obesity also have high rates of high blood sugar and high blood pressure.

[FIGURE 3 HERE]

We use LPM and CEM to estimate this relationship and present results in *Table 5.* From the LPM estimates, we find that an overweight/obese individual is 5.5% more likely to have high blood sugar and 8.7% more likely to have high blood pressure. We then use BMI instead of the binary overweight/obese variable and run the same regressions. The positive relationship still holds. Increase in an individual's BMI by 1 $kg/m^2$ is associated with a 0.5% increase in the probability of having high blood sugar and a 0.9% increase in the probability of having high blood pressure. CEM shows similar results as LPM. Overweight/obese adults are 5.6% more likely to have high blood sugar and 9.7% more likely to have high blood pressure.

[TABLE 5 HERE]

# Discussion

Our analysis shows a rapid rise in obesity over the last decade for both men and women across all wealth levels. This is true for rural and urban areas in all states of India. Wealth is positively associated with the increased burden of adult overweight/obesity. Adults who frequently watch television (indicating a sedentary lifestyle) are more overweight/obese at every wealth level than those who do not watch television. Frequent television watching is a strong predictor of overweight/obesity even within a household. Similarly, adults working in salaried jobs are more likely to be overweight/obese at every wealth level than those engaged in manual work.

Improvements in the health environment and access to amenities such as improved toilets, piped water, clean cooking fuel, reduced open defecation, increased mechanization, urban jobs, and eating processed snacks, both packaged and cooked, are all related to a higher likelihood of overweight/obesity.

Interestingly, we find that the poorest households in urban areas spend more on snacks and obesogenic foods, even higher than the wealthiest in rural areas. Urbanization and lack of awareness promote unhealthy dietary patterns. Cheaper purchased meals and snacks rich in sugar and saturated fat, have become easily available to the urban poor (37,38). Regression results also highlight the role of higher consumption of oil and cereals in increasing overweight/obesity.

Women in both urban and rural areas are more likely to be overweight/obese than men, even within the same household. The probability of being overweight/obese rises faster with wealth for women. As

households get wealthier and/or more women drop out of the labor force in India, they will face a higher risk of obesity (39).

Overweight has become more prevalent than underweight for women in several developing countries (40). At present, this is true in urban India, while in rural India a larger proportion of women are still underweight. While the incidence of overweight and obesity has been rising, nearly 53% women in India in the age group 15–49 continue to be anemic. Similar to many other developing countries, India now faces a dual burden of under and over nutrition (41–43). For lower socio-economic sections of rural society, obesity has increased in the past decade, but a larger proportion of adults are still undernourished (NFHS–4). Child undernutrition has declined in the past decade, but remains high, posing a challenge that now coexists with rising adult obesity (43,44).

Our analysis of the drivers of overweight/obesity has some limitations. NFHS does not collect data on childhood obesity (age group 5–14 years) which is a strong predictor of being obese as adults. It is not possible to distinguish between the effects of the health environment, lifestyle, and diets on overweight/obesity as these three factors are likely to be correlated with each other. We do not have data on time-use and dietary intake of households or individuals whose BMI data we analyze. Use of secondary data instead of primary data also limits our ability to ask our own questions. Future research should be directed towards addressing these limitations to fine-tune our analysis of overweight/obesity.

The rise in obesity and obesity-related diseases poses a complicated and unprecedented public health burden for India, which in the past only had to tackle undernutrition and infectious diseases (38,45). The two rounds of NFHS data establish noteworthy improvements in adult undernutrition over the past decade but also show the significantly rising incidence of NCDs. Increased incomes and improvements in the health environment are desirable from a human development perspective, posing a complex challenge for policy wherein economic development may exacerbate adult obesity.

## Conclusions

As India undergoes a nutrition transition, a health policy transition also needs to follow. Focussed policy action to tackle overweight and obesity is currently missing in public health policy and planning. Our analysis of the complex dynamics of overweight and obesity and its various causes across regions and social groups will help in informing such policy by designing varying intensity and types of interventions. A preventive approach, to check the impending future rise in both overweight/obesity and non-communicable diseases, is also needed.

## Declarations

- Ethics approval and consent to participate

# Not applicable

- Consent for publication

# Not applicable

- Availability of data and materials

# The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

- Competing interests

# The authors declare that they have no competing interests

- Funding

# This work was not supported by an external funding source.

- Authors' contributions

A. K., D. R., and K. J. designed research; A. K. and K. J. analysed data; A. K., K. J., D. R., L. I., and A. N. wrote paper. All authors read and approved the final manuscript.

- Acknowledgements

Not applicable

## References


1. WHO. Obesity : preventing and managing the global epidemic : report of a WHO Consultation on Obesity. 1997.
2. Monteiro CA, Moura EC, Conde WL, Popkin BM. Socioeconomic status and obesity in adult populations of developing countries: A review. Bull World Health Organ. 2004;82(12):940–6.
3. Stevens GA, Singh GM, Lu Y, Danaei G, Lin JK, Finucane MM, et al. National, regional, and global trends in adult overweight and obesity prevalences. Popul Health Metr. 2012 Nov 20;10.

4. The GBD 2015 Obesity Collaborators. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. N Engl J Med. 2017 Jul 6;377(1):13–27.
5. Martorell R, Khan LK, Hughes M, Grummer-Strawn L. Obesity in women from developing countries. Eur J Clin Nutr. 2000;54:247–52.
6. World Health Organization. Obesity : preventing and managing the global epidemic : report of a WHO consultation. World Health Organization; 2000.
7. International Diabetes Federation. IDF Diabetes Atlas, Eighth edition [Internet]. 2017. Available from: http://www.diabetesatlas.org/across-the-globe.html
8. Popkin BM, Adair LS, Ng SW. The Global Nutrition Transition: The Pandemic of Obesity in Developing Countries. Nutr Rev. 2012;70(1):3–21.
9. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet. 2004;363(9403):157–63.
10. Nguyen TT, Adair LS, Suchindran CM, He K, Popkin BM. The association between body mass index and hypertension is different between East and Southeast Asians. Am J Clin Nutr. 2009;89(6):1905–12.
11. Pednekar MS, Hakama M, Hebert JR, Gupta PC. Association of body mass index with all-cause and cause-specific mortality: Findings from a prospective cohort study in Mumbai (Bombay), India. Int J Epidemiol. 2008;37(3):524–35.
12. Griffiths PL, Bentley ME. The nutrition transition is underway in India. J Nutr. 2001;131(10):2692–700.
13. Siddiqui MZ, Donato R. Overweight and obesity in India: Policy issues from an exploratory multi-level analysis. Health Policy Plan. 2016;31(5):582–91.
14. Cohen-Cole E, Fletcher JM. Is obesity contagious? Social networks vs. environmental factors in the obesity epidemic. J Health Econ. 2008;27(5):1382–7.
15. Asirvatham J, Nayga RM, Thomsen MR. Peer-Effects in Obesity among Public Elementary School Children: A Grade-Level Analysis. Appl Econ Perspect Policy. 2014;36(3):438–59.
16. PAHO (Pan American Health Organization). Obesity and Poverty: a new public health challenge. Obes Poverty. 2000;
17. Pradeepa R, Anjana RM, Joshi SR, Bhansali A, Deepa M, Joshi PP, et al. Prevalence of generalized and abdominal obesity in urban and rural India—the ICMR-INDIAB Study (Phase-I) [ICMR- NDIAB–3]. Indian J Med Res. 2015;
18. Kalra S, Unnikrishnan A. Obesity in India: The weight of the nation. J Med Nutr Nutraceuticals. 2012;1(1):37.
19. Coffey D, Spears D. Child Height in India : Facts and Interpretations from the NFHS–4, 2015–16. Econ Polit Wkly. 2018;53(31).
20. Sengupta A, Angeli F, Syamala TS, Van Schayck CP, Dagnelie P. State-wise Dynamics of the Double Burden of Malnutrition among 15–49 Year-old Women in India: How Much Does the Scenario

Change Considering Asian Population-specific BMI Cut-off Values? Ecol Food Nutr. 2014 Nov 2;53(6):618–38.

21. IIPS. International Institute for Population Sciences (IIPS) and ORC Macro. National Family Health Survey (NFHS–2), 1998–99. [Internet]. 2000. Available from: https://www.dhsprogram.com/pubs/pdf/FRIND2/FRIND2.pdf
22. Bassani DG, Corsi DJ, Gaffey MF, Barros AJD. Local distributions of wealth to describe health inequalities in India:A new approach for analyzing nationally representative household survey data, 1992–2008. PLoS One. 2014;9(10):1992–2008.
23. World Health Organization. Global report on diabetes [Internet]. 2016. Available from: http://www.who.int/iris/handle/10665/204871
24. Iacus SM, King G, Porro G. Causal Inference without Balance Checking: Coarsened Exact Matching. Polit Anal. 2012 Jan 4;20(01):1–24.
25. Dietz W. Television, Obesity, and Eating Disorders. Adolesc Med. 1993 Oct;4(3):543–50.
26. Smith L, Fisher A, Hamer M. Television viewing time and risk of incident obesity and central obesity: the English longitudinal study of ageing. BMC Obes. 2015 Dec 1;2(1):12.
27. Vyas S, Spears D. Sanitation and Religion in South Asia: What Accounts for Differences across Countries? J Dev Stud. 2018;
28. Nandi A, Megiddo I, Ashok A, Verma A, Laxminarayan R. Reduced burden of childhood diarrheal diseases through increased access to water and sanitation in India: A modeling analysis. Soc Sci Med. 2017;180:181–92.
29. James AJ, Verhagen J, van Wijk C, Nanavaty R, Parikh M, Bhatt M. Transforming time into money using water: A participatory study of economics and gender in rural India. Nat Resour Forum. 2002 Aug;26(3):205–17.
30. Rah JH, Cronin AA, Badgaiyan B, Aguayo VM, Coates S, Ahmed S. Household sanitation and personal hygiene practices are associated with child stunting in rural India: a cross-sectional analysis of surveys. BMJ Open. 2015;5(2):e005180.
31. Smith KR, Sagar A. Making the clean available: Escaping India's Chulha Trap. Energy Policy. 2014;75:410–4.
32. Deaton A, Drèze J. Food and Nutrition in India: Facts and Interpretations. Econ Polit Wkly. 2009;44(7):42–65.
33. Coffey D, Gupta A, Hathi P, Khurana N, Spears D, Srivastav N, et al. Revealed Preference for Open Defecation Evidence from a New Survey in Rural North India. Econ Polit Wkly. 2014;XLIX(38):43–55.
34. Basole A, Basu D. Fuelling Calorie Intake Decline: Household-Level Evidence from Rural India. World Dev. 2015 Apr 1;68:82–95.
35. Jebb SA. Carbohydrates and obesity: from evidence to policy in the UK. Proc Nutr Soc. 2015;74(03):215–20.

36. Lai C-Q, Smith CE, Parnell LD, Lee Y-C, Corella D, Hopkins P, et al. Epigenomics and metabolomics reveal the mechanism of the APOA2-saturated fat intake interaction affecting obesity. Am J Clin Nutr. 2018;108(1):188–200.
37. Misra A, Singhal N, Sivakumar B, Bhagat N, Jaiswal A, Khurana L. Nutrition transition in India: Secular trends in dietary intake and their relationship to diet-related non-communicable diseases. J Diabetes. 2011 Dec;3(4):278–92.
38. Popkin BM, Horton S, Kim S, Mahal A, Shuigao J. Trends in Diet, Nutritional Status, and Diet-related Noncommunicable Diseases in China and India: The Economic Costs of the Nutrition Transition. Nutr Rev. 2009 Apr 27;59(12):379–90.
39. Soutik Biswas. Why are millions of Indian women dropping out of work? - BBC News. BBC News [Internet]. 2017 May 18; Available from: https://www.bbc.com/news/world-asia-india–39945473
40. Mendez MA, Monteiro CA, Popkin BM. Overweight exceeds underweight among women in most developing countries. Am J Clin Nutr. 2005;81(3):714–21.
41. Popkin BM, Keyou G, Zhai F, Guo X, Ma H, Zohoori N. The nutrition transition in China: a cross-sectional analysis. Eur J Clin Nutr. 1993;47(5):333–46.
42. Monteiro CA, D'A Benicio MH, Conde WL, Popkin BM. Shifting obesity trends in Brazil. Eur J Clin Nutr. 2000;54(4):342–6.
43. Subramanian S V, Perkins JM, Khan KT. Do burdens of underweight and overweight coexist among lower socioeconomic groups in India? Am J Clin Nutr. 2009;90(2):369–76.
44. Doak CM, Adair LS, Monteiro C, Popkin BM. Overweight and Underweight Coexist within Households in Brazil, China and Russia. J Nutr. 2000 Dec 1;130(12):2965–71.
45. Upadhyay RP. An overview of the burden of non-communicable diseases in India. Iran J Public Health. 2012;41(3):1–8.

# Tables

Table 1: Adult obesity trends by sub-populations: All India

| (BMI ≥ 25 kg/ $m^2$) | 1<br>Overweight/Obese<br>2005-06 (%) | 2<br>Overweight/Obese<br>2015-16 (%) | 3<br>The difference (pp) |
|---|---|---|---|
| Urban | 20.57 | 30.73 | 10.16 |
| Rural | 6.83 | 15.00 | 8.17 |
| Men | 9.30 | 18.90 | 9.60 |
| Women | 12.60 | 20.70 | 8.10 |
| Urban Men | 15.88 | 26.64 | 10.76 |
| Urban Women | 23.59 | 31.41 | 7.82 |
| Rural Men | 5.64 | 14.30 | 8.66 |
| Rural Women | 7.51 | 15.11 | 7.60 |
| *Age groups (years)* | | | |
| 15 – 19 | 2.20 | 4.30 | 2.10 |
| 20 – 25 | 5.90 | 11.27 | 5.37 |
| 26 – 35 | 12.96 | 23.51 | 10.55 |
| 36 – 49 | 20.34 | 32.34 | 12.00 |
| *Wealth quintiles* | | | |
| 1 Poorest | 1.73 | 5.72 | 3.99 |
| 2 Poorer | 3.30 | 11.19 | 7.89 |
| 3 Middle | 6.54 | 18.49 | 11.95 |
| 4 Richer | 13.45 | 27.70 | 14.25 |
| 5 Richest | 27.91 | 35.70 | 7.79 |

Table 2: Regression estimates of the relationship between wealth, lifestyle, and adult overweight/ obesity.

| Model: | 1<br>LPM | | 2<br>MLSR | |
|---|---|---|---|---|
| **Dependent Variable:** | **P(Overweight/ Obese)** | **95% C.I.** | **BMI** | **95% C.I.** |
| *Wealth Quintile (Base =1, Poorest)* | | | | |
| 2, Poorer | 0.027*** | (0.019, 0.034) | 0.342*** | (0.249, 0.436) |
| 3, Middle | 0.065*** | (0.056, 0.074) | 0.906*** | (0.804, 1.009) |
| 4, Richer | 0.128*** | (0.116, 0.140) | 1.556*** | (1.430, 1.683) |
| 5, Richest | 0.212*** | (0.197, 0.227) | 2.519*** | (2.381, 2.658) |
| *The frequency of watching TV (Base = Never watches TV)* | | | | |
| Watches TV < once a week | 0.009*** | (0.004, 0.014) | 0.118*** | (0.064, 0.171) |
| Watches TV min. once a week | 0.014*** | (0.010, 0.019) | 0.160*** | (0.110, 0.210) |
| Watches TV daily | 0.027*** | (0.023, 0.032) | 0.365*** | (0.318, 0.413) |
| *Other control variables* | | | | |
| Female | 0.028*** | (0.023, 0.034) | 0.056 | (-0.013, 0.126) |
| Female x 2$^{nd}$ wealth quintile | -0.001 | (-0.009, 0.007) | 0.082 | (-0.016, 0.180) |
| Female x 3$^{rd}$ wealth quintile | 0.002 | (-0.008, 0.011) | 0.080 | (-0.025, 0.185) |
| Female x 4$^{th}$ wealth quintile | 0.011* | (-0.001, 0.023) | 0.302*** | (0.175, 0.430) |
| Female x 5$^{th}$ wealth quintile | 0.000 | (-0.015, 0.015) | 0.225*** | (0.084, 0.367) |
| Urban | 0.042*** | (0.037, 0.047) | 0.500*** | (0.452, 0.549) |
| Age in years | 0.026*** | (0.025, 0.027) | 0.467*** | (0.456, 0.478) |
| Age squared | -0.000*** | (-0.000, -0.000) | -0.005*** | (-0.005, -0.005) |
| Education in years | 0.015*** | (0.014, 0.016) | 0.162*** | (0.151, 0.172) |
| Education squared | -0.001*** | (-0.001, -0.001) | -0.008*** | (-0.008, -0.007) |
| No. of household members | -0.001* | (-0.002, 0.000) | -0.013*** | (-0.022, -0.005) |
| No. of children < 5 years | -0.004*** | (-0.006, -0.002) | -0.051*** | (-0.072, -0.031) |
| *Caste (Base = SC)* | | | | |
| ST | -0.010*** | (-0.016, -0.004) | -0.113*** | (-0.181, -0.044) |
| OBC | 0.003 | (-0.001, 0.008) | 0.043* | (-0.002, 0.088) |
| GEN | 0.020*** | (0.015, 0.026) | 0.281*** | (0.225, 0.337) |
| *Religion (Base = Hindu)* | | | | |
| Muslim | 0.040*** | (0.035, 0.046) | 0.512*** | (0.453, 0.571) |
| Christian | 0.011* | (-0.001, 0.024) | 0.142** | (0.013, 0.271) |
| Sikh | 0.049*** | (0.034, 0.064) | 0.480*** | (0.324, 0.635) |
| Jain | 0.049* | (-0.008, 0.107) | 0.334 | (-0.152, 0.820) |
| Constant | -0.553*** | (-0.590, -0.516) | 10.503*** | (10.077, 10.929) |
| District FE | Yes | | Yes | |
| Observations | 713,286 | | 713,286 | |
| R-squared | 0.160 | | 0.244 | |

Values in column 1 and 2 are estimated regression coefficients with 95% confidence intervals in parenthesis. Significance levels are denoted by * p <0.01, ** p<0.05, *** p<0.001. 'FE' stands for fixed effects. 'LPM' and 'MLSR' are short for linear probability model and multivariate least squares regression respectively. 'P(Overweight/Obese)' is th e probability of an adult being overweight or obese i.e., having body mass index (BMI) ≥ 25 kg/m$^2$.

Table 3: Regression estimates of the relationship between improved health environment, assets, amenities, and adult overweight/obesity.

| Model: | (1) LPM | | (2) MLSR | |
|---|---|---|---|---|
| **Dependent Variable:** | **P(Overweight/ Obese)** | **95% C.I.** | **BMI** | **95% C.I.** |
| Mobile phone | 0.020*** | (0.015, 0.024) | 0.394*** | (0.337, 0.451) |
| Car/truck | 0.034*** | (0.026, 0.042) | 0.456*** | (0.371, 0.540) |
| Motorcycle/scooter | 0.025*** | (0.021, 0.029) | 0.352*** | (0.312, 0.393) |
| Bicycle | -0.002 | (-0.006, 0.001) | -0.061*** | (-0.097, -0.024) |
| Electricity | 0.008*** | (0.004, 0.012) | 0.174*** | (0.128, 0.219) |
| Refrigerator | 0.060*** | (0.055, 0.065) | 0.687*** | (0.632, 0.742) |
| No toilet (open defecation) | -0.024*** | (-0.029, -0.019) | -0.320*** | (-0.375, -0.265) |
| Open defecation in PSU (%) | -0.000*** | (-0.000, -0.000) | -0.004*** | (-0.005, -0.003) |
| Improved toilet | 0.007*** | (0.002, 0.013) | 0.109*** | (0.052, 0.167) |
| Piped water | 0.004 | (-0.001, 0.008) | 0.052** | (0.003, 0.100) |
| Time taken to fetch water | -0.000* | (-0.000, 0.000) | -0.002*** | (-0.003, -0.001) |
| Clean cooking fuel | 0.046*** | (0.042, 0.050) | 0.555*** | (0.512, 0.598) |
| Other control variables | Yes | | Yes | |
| District FE | Yes | | Yes | |
| Observations | 712,500 | | 712,500 | |
| R-squared | 0.160 | | 0.246 | |

Values in column 1 and 2 are estimated regression coefficients with 95% confidence intervals in parenthesis. Significance levels are denoted by * p <0.01, ** p<0.05, *** p<0.001. ‘FE’ stands for fixed effects. ‘LPM’ and ‘MLSR’ are short for linear probability model and multivariate least squares regression respectively. ‘P(Overweight/Obese)’ is the probability of an adult being overweight or obese i.e., having body mass index (BMI) ≥ 25 kg/m2. ‘Other control variables’ includes urban residence, gender, age, education, caste, religion, and frequency of watching Tv. All covariates are binary variables indicating whether the individual owns the asset, or has access to the amenity, except for ‘Time taken to fetch water’ which is measured in minutes and ‘Open defecation in PSU’ which is the percentage of households practicing open defecation in a PSU (village or municipality).

Table 4: Food consumption patterns and overweight/obesity across wealth quintiles

| Wealth quintile | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **URBAN** | | | | | |
| **Percentage of adults overweight/obese from NFHS 4 (BMI≥25):** | | | | | |
| Overweight/obese | 13.46 | 20.14 | 26.45 | 32.02 | 37.22 |
| **Average total value of per capita consumption in last 30 days (Rs.) from NSS-CES:** | | | | | |
| Cereals | 90.81 | 130.02 | 166.70 | 178.91 | 202.47 |
| Pulses | 28.94 | 41.34 | 54.15 | 55.46 | 66.51 |
| Milk and milk products | 54.74 | 88.88 | 130.00 | 150.54 | 295.74 |
| Vegetables | 46.15 | 68.31 | 84.06 | 84.81 | 100.27 |
| Fruits | 24.30 | 32.24 | 33.83 | 39.67 | 69.32 |
| Egg, Fish, Meat | 38.46 | 66.94 | 91.56 | 96.89 | 102.56 |
| Sugar | 11.90 | 16.22 | 22.03 | 25.42 | 33.47 |
| Oil | 27.35 | 41.07 | 53.40 | 57.62 | 71.97 |
| Snacks/ Obesogenic food | 465.02 | 507.65 | 205.97 | 129.96 | 160.15 |
| **RURAL** | | | | | |
| **Percentage of adults overweight/obese from NFHS 4 (BMI≥25):** | | | | | |
| Overweight/obese | 6.63 | 12.07 | 17.52 | 22.82 | 28.51 |
| **Average total value of per capita consumption in last 30 days (Rs.) from NSS-CES:** | | | | | |
| Cereals | 138.22 | 150.61 | 161.19 | 166.81 | 174.57 |
| Pulses | 38.41 | 41.36 | 47.86 | 50.52 | 56.30 |
| Milk and milk products | 62.74 | 94.58 | 120.12 | 146.72 | 285.48 |
| Vegetables | 64.09 | 64.56 | 69.07 | 70.60 | 79.79 |
| Fruits | 11.37 | 15.64 | 24.23 | 29.93 | 47.52 |
| Egg, Fish, Meat | 45.01 | 56.87 | 78.57 | 80.10 | 81.01 |
| Sugar | 17.08 | 19.62 | 22.29 | 25.55 | 38.77 |
| Oil | 41.30 | 44.61 | 47.18 | 50.74 | 59.52 |
| Snacks/Obesogenic food | 49.70 | 47.02 | 45.02 | 47.79 | 72.13 |

Table 5: Regression estimates of the relationship between adult overweight/obesity and non-communicable diseases (NCD's) using a linear probability model (LPM) and coarsened exact matching (CEM).

| Model: | (1) LPM | (2) LPM | (3) CEM | (4) LPM | (5) LPM | (6) CEM |
|---|---|---|---|---|---|---|
| Dependent variable: | High blood sugar | High blood sugar | High blood sugar | High blood pressure | High blood pressure | High blood pressure |
| | | | | | | |
| Overweight/Obese | 0.055*** | | 0.056*** | 0.087*** | | 0.097*** |
| | (0.052, 0.058) | | (0.051, 0.059) | (0.083, 0.090) | | (0.093, 0.099) |
| Body mass index | | 0.005*** | | | 0.009*** | |
| | | (0.005, 0.006) | | | (0.009, 0.009) | |
| | | | | | | |
| Other control variables | Yes | Yes | Yes | Yes | Yes | Yes |
| District FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 710,767 | 710,767 | 689,585 | 686,843 | 686,843 | 667,924 |
| R-squared | 0.042 | 0.043 | 0.016 | 0.074 | 0.076 | 0.031 |

Values are estimated regression coefficients with 95% confidence intervals in parenthesis. Significance levels are denoted by * p <0.01, ** p<0.05, *** p<0.001. 'FE' stands for fixed effects. 'LPM' and 'CEM' stand for linear probability model and coarsened exact matching respectively.

# Figures

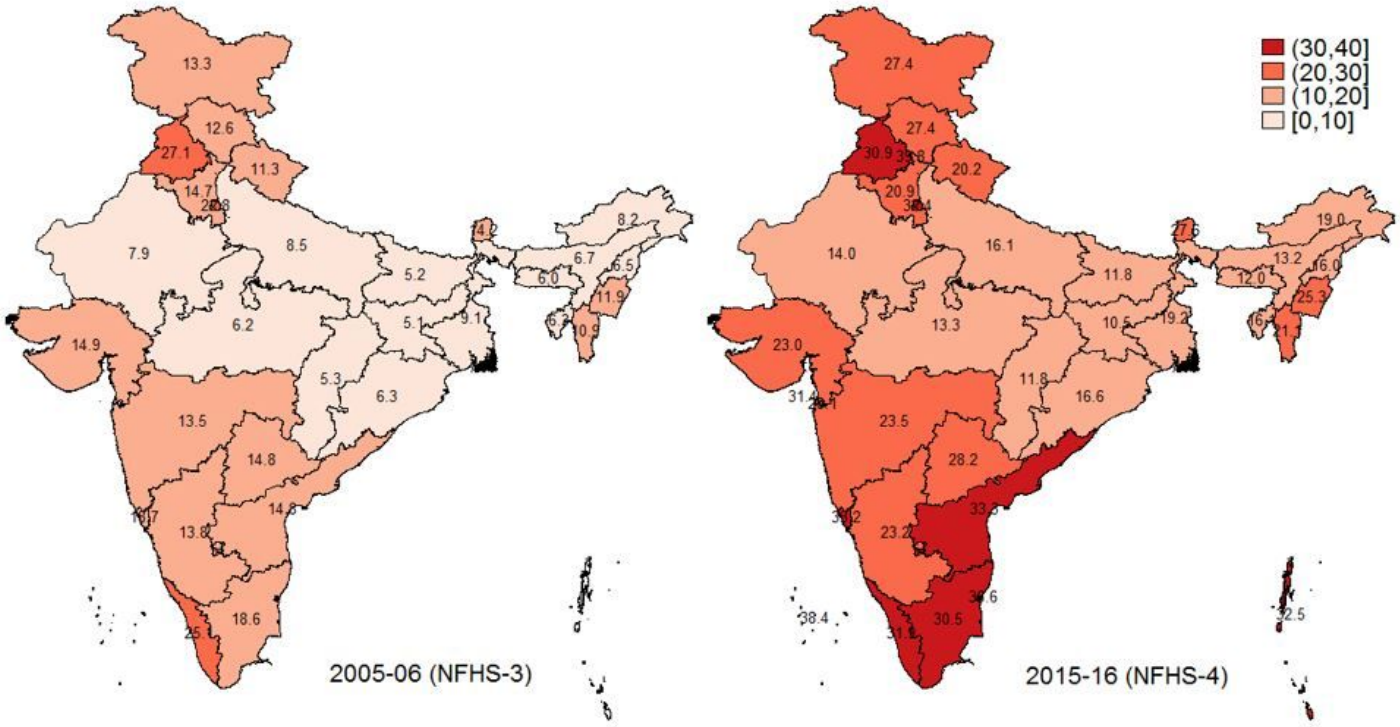


**Figure 1**

Percentage of overweight/obese adults across Indian states in 2005-06 and 2015-16

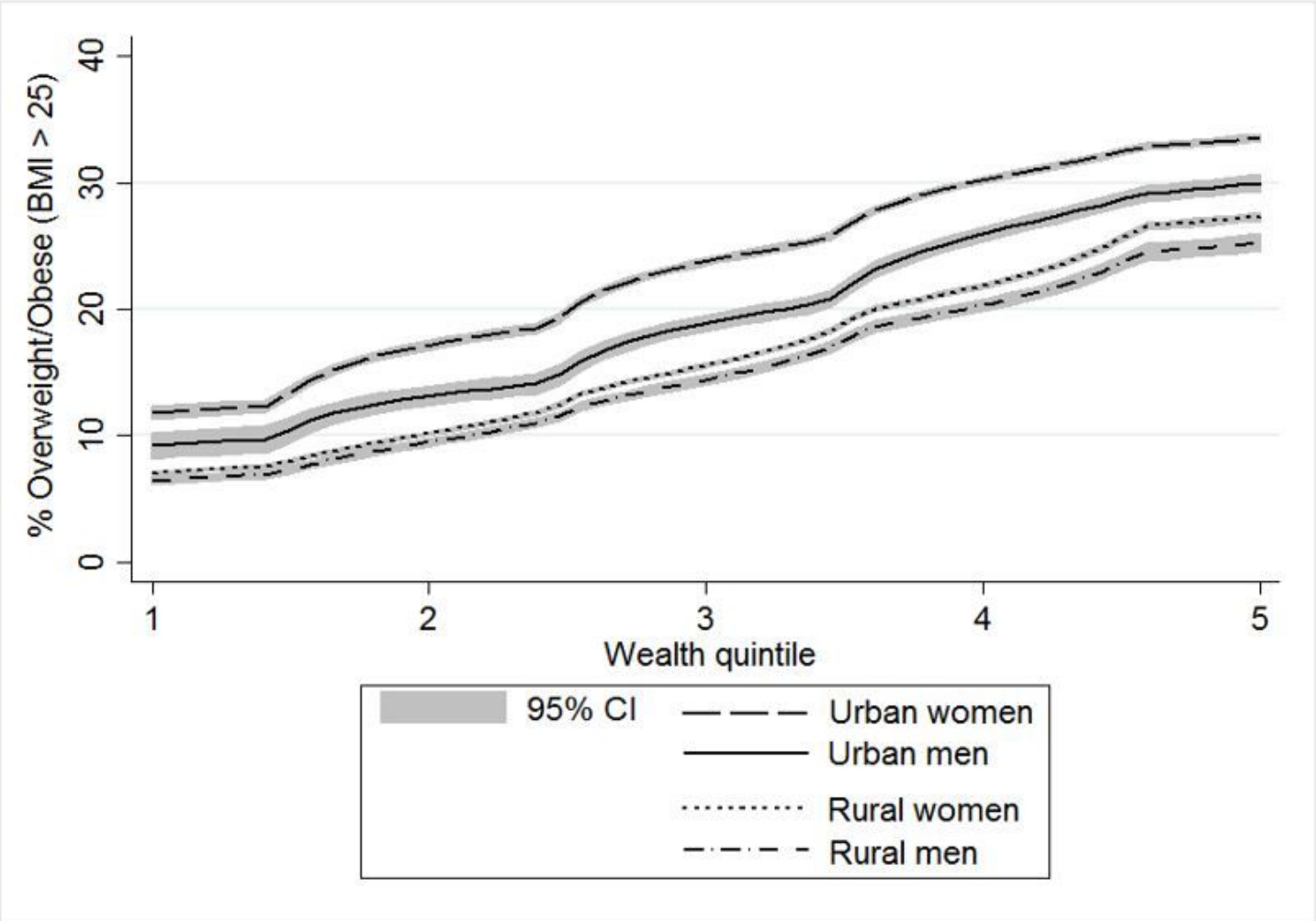


**Figure 2**

Local polynomial regression of overweight/obesity on wealth by urban and rural men and women

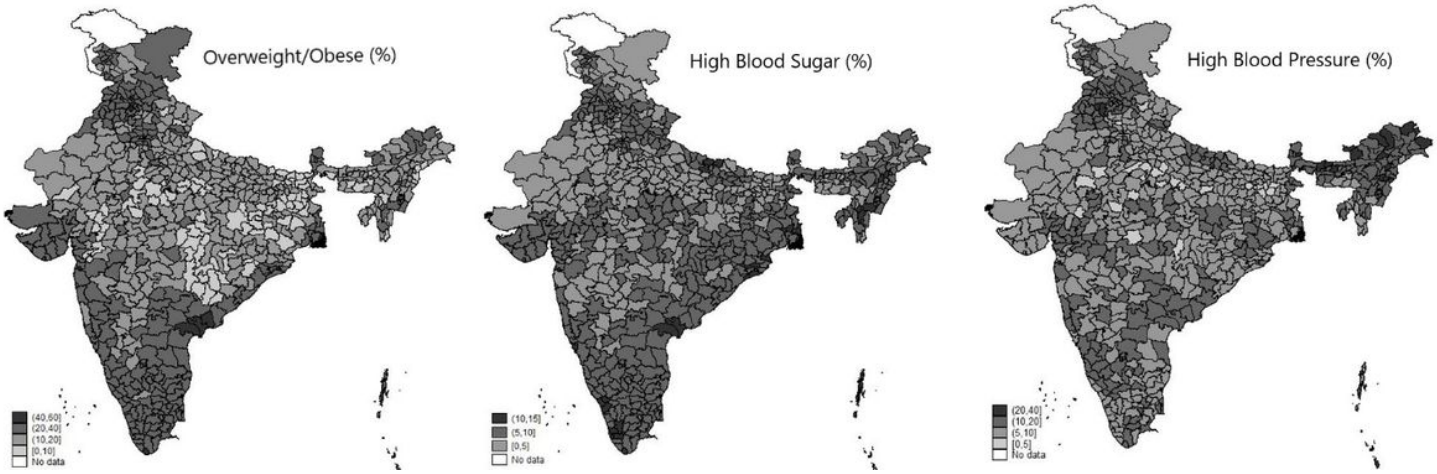


**Figure 3**

Overweight/obesity, high blood sugar, and high blood pressure across districts of India in 2015-16