

## EPIDEMIOLOGICAL ANALYSIS OF NON-COMMUNICABLE DISEASE BURDEN IN RAPIDLY URBANIZING POPULATIONS

Ali Raza<sup>1\*</sup>, Shazia Bibi<sup>1</sup>

<sup>1</sup>Department of Public Health and Epidemiology, School of Health Sciences, Islamabad, Pakistan

\*Corresponding Author E-mail: [aliraza467346565@gmail.com](mailto:aliraza467346565@gmail.com)

### Abstract

Urbanization in low- and middle-income countries has led to an epidemiological transition to non-communicable diseases, but the connections between urban environments and the cardiometabolic risk have not been sufficiently measured. The population of this cross-sectional study was 2,187 adults randomly recruited to the study in urban high-density, urban low-density and rural locations. They calculated a composite urbanization index based on various indicators of the built environment such as population density, availability of road infrastructure, access to sanitation, and access to health facilities. The outcomes were hypertension, type 2 diabetes mellitus and obesity. Sequential overall sociodemographic and lifestyle factors, mediation analysis to measure pathways using physical inactivity and dietary patterns, and interaction testing by sex and income were conducted using logistic regression. To evaluate the sensitivity to unmeasured confounding, the E-value calculations were performed. The prevalence of hypertension age-standardized rose steadily in the rural to urban low-density to urban high-density areas, and was about 30 percent to 49 percent. The prevalence of diabetes exhibited the same gradient with 16 percent to 35 percent in the same categories of urbanicity. In fully adjusted models, every one-standard-deviation increase in the urbanization index was found to increase the odds of hypertension by 47 percent and the odds of diabetes by 53 percent, both of which were highly statistically significant. The mediation analysis indicated that the combination of physical inactivity and unhealthy dietary patterns accounted 61 percent of the overall urbanization impact on hypertension with dietary factors taking the bigger portion and that was about 43 percent. There was a strong sex interaction as females exhibited considerably greater risk increases in hypertension associated with urbanization than males. The effect of processed food on metabolism on fasting glucose was increased in urban areas, as the slope of association increased more than two times between rural and urban high-density areas. The e-values greater than 2.2 in all primary results revealed that unmeasured confounding is unlikely to be the reason behind the observed association. Sensitivity analyses that eliminated the participants that had pre-existing cardiovascular disease generated low attenuation of effect estimates eliminating reverse causality. The impact of urbanization on non-communicable disease risk is dose-dependent and more than half of its impact is mediated by modifiable lifestyle behaviors. There is an urgent need of urban planning intervention that encourages physical activity by supporting the existence of walkable infrastructure and food environment regulation by limiting access to processed foods. Special consideration of sex-specific vulnerabilities, particularly in females in high-density cities, is justified to reduce the increasing burden of hypertension, diabetes, and obesity in rapidly urbanizing communities.

**Keywords:** Urbanization, Non-Communicable Diseases, Hypertension, Diabetes Mellitus, Mediation Analysis, Built Environment, Epidemiological Transition, Low- And Middle-Income Countries, Cardiometabolic Risk, Lifestyle Interventions

### Article History

Received:

January 05 2026

Revised:

February 09, 2026

Accepted:

April 04, 2026

Available Online:

June 30, 2026

## INTRODUCTION

Non-communicable disease burden is increasing rapidly in the world, with 69 percent of the total deaths projected to be due to diseases by 2030, with a large share of these diseases falling upon the low and middle-income group (Fleischer et al., 2010). This epidemiological transition, which is a transition in the focus of infectious diseases to chronic non-communicable diseases, is especially high in the rapidly urbanizing areas (Patel & Webster, 2016). Demographic changes such as population increase, aging, and unplanned urbanization, as well as the globalization of unhealthy lifestyles, contribute to this phenomenon (El-Saadani et al., 2021). In fact, diseases like coronary artery disease, stroke, high blood pressure, and diabetes, which were once seen as diseases of developed countries, have become widespread health concerns in various socioeconomic levels in developing countries, requiring a holistic approach to the evaluation and prevention of the risks (Oyebola et al., 2023). As an example, there is a notable rise in NCD-related mortality and morbidity in countries such as India, which is inherently connected to lifestyle changes due to urbanization and related biological and behavioral risk factors (Chandranand, 2021). This two-fold burden of illness exerts a tremendous burden on

health care systems and socioeconomic assets, with NCDs comprising a substantial percentage of mortality and disability-adjusted life-years lost (Chatterjee & Majumder, 2017; Nigar and Pathak, 2025). In 2012, NCDs accounted for 38 million of the 58 million deaths and a dramatic 75% of premature death due to NCDs in low and middle-income countries (Rawal et al., 2017; Vijna & Mishra, 2025). It has been observed in sub-Saharan Africa, where a fast urbanization process, changes in food consumption, an increasingly sedentary lifestyle, and longer life expectancy are increasing the burden of chronic diseases against the backdrop of enduring infectious disease challenges and inadequate health systems (Kakaire & Chumoh, 2025). This is reflected in the urban-rural disparity in NCD risk factors in India with urban populations at greater disadvantage due to metabolic risks such as hypertension, diabetes, and obesity, whereas rural areas struggle with behavioral risks that are long-established, such as tobacco and alcohol use (Joshi et al., 2025). In particular, the rising life expectancy, sedentary lifestyle, and dietary shift that have been noted in these shifting populations have played a key role in the growing prevalence of cardiometabolic diseases, including hypertension and diabetes mellitus (Gabert

et al., 2017). These changes are also made worse by globalization that spreads behavioral and metabolic risk factors, thus leading to increased burden of cardiovascular diseases in developing countries (Bai et al., 2023). All these converging factors highlight the present critical importance of epidemiological studies that can help clarify which particular mechanisms contribute to the growth of NCDs in such dynamic urban settings and guide the design of specific interventions aimed at improving public health (Habib & Fatima et al., 2025). These types of analyses are essential to understand the risk factors that can be modified to explain the differences in prevalence of NCD between urban and rural environments (Chand & Shivika, 2023). The areas of the studies that should be engaged include the definition of the major public health indicators that include geographical differences in the NCDs, the discovery of both traditional and new risk factors, mortality and morbidity causes, and the need to improve healthcare prevention and targeted therapy (Oliveira et al., 2015). Particularly, to create effective preventive measures, a more profound insight into the upstream determinants of prevalent NCD risk factor patterns, such as work-related exposures and genetic differences, is crucial (Ebrahim et al., 2013). This paper will describe the epidemiology of NCDs in

rapidly urbanizing communities, the interaction of environmental, socioeconomic, and lifestyle factors in determining disease prevalence and progression. It will critically analyze how urban infrastructure, health care access, and policy frameworks affect the NCD trajectories and finally suggest evidence based interventions to limit this increasing public health crisis. This type of analysis is crucial to inform specific public health policies that will respond to the individual challenges and opportunities posed by urbanization as an NCD prevention and control approach (Barquera et al., 2016). In addition, a good quantification of urbanization based on full measures, that is not just population density, is necessary to effectively determine its relationship with incidence of chronic diseases (Allender et al., 2008). This involves a critical analysis of how the built environment, socioeconomic determinants and health behaviors interact to affect the prevalence and progression of cardiometabolic diseases (Chacón et al., 2024). This holistic model requires exploration of the different aspects of urbanization, including population structure, social setting, and physical setting, including access to sanitation and medical facilities, which all lead to the health outcomes (Allender et al., 2008). A lens of anthropology, which studies such disparities, will help frame the

influence of urban life on health, closing the divide between statistical data and what people experience in the realities and intricacies of living in urbanization (Yasmin, 2024). Epidemiological research has already shown that there is a strong association between urbanization and the risk of cardiovascular disease, which involves diabetes and high blood pressure (Iyanda et al., 2023). Such studies tend to mention the role of high-speed urbanization in low- and middle-income countries as the cause of the aggravation of physical activity and the adoption of sedentary lifestyles, which directly lead to the development of NCDs (Mzumara & Banda, 2024). This is also intensified by eating unhealthy diets that are rife in urban environments, which are usually high fat, high sugar processed foods, which are seen to contribute to the increased obesity and associated metabolic disorders. The intersecting factors of urbanization, dietary changes and lack of physical activities have significant impacts on the metabolic health of the populations, which increases their vulnerability to chronic conditions (Ma et al., 2025; Modupe et al., 2024). As an example, cardiometabolic diseases such as type 2 diabetes mellitus, hypertension, obesity, and metabolic syndrome, tend to develop more and earlier in South Asians, especially in urban populations, and at lower body mass indices compared to other ethnicities

(Yasmin, 2025). The combination of genetic predispositions, rapid urbanization, and major lifestyle changes, such as dietary and increased physical activity, have led to this heightened vulnerability (Yasmin, 2025). These cardiometabolic threats have a high regional and ethnic heterogeneity in urban South Asia, which highlights the importance of local epidemiological understanding (Yasmin, 2025). This requires a thorough research in the genetic, environmental, biological, and sociocultural factors which together bring about cardiometabolic health inequities in these fast-changing urban environments (Yasmin, 2024).

## METHODOLOGY

This research utilizes a population-based analytical study design that is cross-sectional with the aim of examining the relationship between urbanization and the incidence of non-communicable illnesses, i.e., hypertension, type 2 diabetes mellitus, and obesity in the rapidly urbanizing areas of low- and middle-income economies. The population of the study will include adults aged 18 and above years and living in selected urban and peri-urban clusters and a comparative rural sample will be drawn in the neighboring administrative units. Multi-stage stratified cluster sampling method is used in order to be representative of various

socioeconomic layers and built environment attributes. The main exposure variable is urbanization, which is not only defined by the population density level but also by a composite urbanization index, which is calculated through the principal component analysis of the data addressing such aspects as population density, percentage of paved roads, access to improved sanitation, the distance to the nearest primary health center, and the proportion of households with a refrigerator or motorized vehicle. The outcome variables of interest are binary measures of diagnosed hypertension, diabetes mellitus and obesity (body mass index 30 kg/m<sup>2</sup> and above). Continuous secondary outcomes are systolic and diastolic blood pressure (mmHg), fasting plasma glucose (mmol/L), and waist-to-hip ratio.

The formula used to determine the sample size in cross-sectional studies to estimate a proportion with a certain degree of precision is as follows: The smallest sample size is determined as:

$$n = (Z^2 \times p \times (1 - p)) / d^2$$

In which, Z is the z-score that will give a desired 95% confidence level (Z = 1.96) p is the expected prevalence of hypertension in urban areas, which can be conservatively estimated at 0.35 using previous literature,

and d is the desired margin of error, which is 0.03. Inflating with a design effect of 1.5 to cluster sampling and a non-response rate of 20 (projected) will give a final sample size:

$$n_{\text{final}} = n \times \text{DEFF} / (1 - r)$$

where DEFF is the design effect (we have set it to 1.5) and r is the expected non-response rate (0.20). This estimation will produce a target sample of about 2,100 participants in all study sites.

Data will be collected by use of interviewer-administered structured questionnaires to collect the following sociodemographic variables (age, sex, income, education, occupation), lifestyle habits (physical activity based on the International Physical Activity Questionnaire in its short version, dietary habits based on a validated food frequency questionnaire, tobacco and alcohol use), and household assets. Measurements of anthropometric parameters are performed in accordance with the standardized procedures: weight on a calibrated digital scale, height on a stadiometer, and waist and hip circumference on a non-stretchable tape. Measurement of blood pressure is done three times using a validated automated oscillometric device following five minutes of rest with the last result

being the average of the last two readings. Venous blood samples (812 hours fasting) are taken and analyzed by enzymatic methods of glucose and lipid profiles in colorimetric techniques.

Third, product-of-coefficients method is used to estimate the mediating role of lifestyle behaviors on the association between urbanization and NCD outcomes. The mediation model will be represented by two equations:

$$M = \alpha_0 + \alpha_1 U + \alpha_2 C + \varepsilon_M$$

$$Y = \gamma_0 + \gamma_1 U + \gamma_2 M + \gamma_3 C + \varepsilon_Y$$

U is the urbanization index, M is the mediating variable (e.g. physical activity score or dietary processed food score), C is the confounding variables, Y is the binary NCD outcome and  $\varepsilon_M$  and  $\varepsilon_Y$  are the error terms. The indirect effect is computed as the product of  $1.01 \times 1.02 = 1.02$  as the standard error, and bootstrapping with 1,000 resamples is used to estimate the standard error. The mediated proportion of the effect is calculated as:

$$\text{Proportion mediated} = (\alpha_1 \times \gamma_2) / (\alpha_1 \times \gamma_2 + \gamma_1)$$

Fourth, multiple linear regression is used to investigate dose-response relationships between particular urban environmental

characteristics and continuous metabolic outcomes. As an example of systolic blood pressure (SBP), the model is:

$$\text{SBP} = 0 + 1(\text{Population Density}) + 2(\text{Access to Green Space}) + 3(\text{Proximity to Fast Food Outlets}) + 4(\text{Age}) + 5(\text{Income}) + 6.$$

In which  $\varepsilon$  is the error term which is assumed to be normally distributed with a mean of zero and a constant variance of  $\sigma^2$ . In longitudinal continuous outcomes, where the change in fasting plasma glucose (FPG) is of interest, the relative change equation is used to model the change in fasting plasma glucose:

$$\text{FPG change} = (\text{FPG follow up} - \text{FPG baseline}) / \text{FPG baseline} \times 100\%$$

Lastly, sensitivity analyses are performed by re-running all models in the absence of participants with known cardiovascular disease at baseline to evaluate reverse causality and in the presence of individual urban indicators instead of the composite urbanization index. In order to assess the strength of the logistic regression findings to unmeasured confounding, the E-value of the primary odds ratio of interest is found by the formula:

$$\text{E-value} = \text{OR} + \sqrt{\text{OR} \times (\text{OR} - 1)}$$

and OR is the observed odds ratio. R version 4.2 and the mediation and survey packages are used to do all the statistical analyses, which consider clustering at the primary sampling unit level by estimating the robust standard errors. All hypothesis tests will be statistically significant when the p-value is lower than 0.05 (two tailed). The institutional review board provides ethical approval and all participants give written informed consent before the data is collected.

## RESULTS

Table 1 supports the finding that urban residents were much worse off in terms of cardiometabolic profiles of higher systolic blood pressure by 11.5 mmHg, higher fasting glucose by 1.0 mmol/L, and higher BMI by 5.0 kg/m<sup>2</sup> in rural residents. As shown in Table 2, the urbanization index was a significant predictor in nine successively adjusted logistic regression models of hypertension and had only a modest attenuation of OR=1.68 (unadjusted) to OR=1.47 (fully adjusted) showing that the effect of urbanization is

partially, though not completely, mediated by lifestyle and socioeconomic factors. Even stronger associations are shown in Table 3 with a fully adjusted OR of 1.53. The linear dose-response relationships are quantified in Table 4, with an increase of 4.82 mmHg in systolic blood pressure and an increase of 0.47 mmol/L in fasting glucose corresponding to an increase of one SD in the urbanization index ( $p=1.4 \times 10^{-1}$  and  $p=1.1 \times 10^{-2}$ ). Table 5 offers important mechanistic information, showing that physical inactivity and unhealthy dietary patterns are both important mediators of urbanization on hypertension and diabetes (dietary factors mediate more: 42.7% in the case of hypertension, and 31.4% in the case of diabetes) than physical inactivity. In Table 6, sex is found to be a strong effect modifier and females were found more likely to experience urbanization as a risk factor of hypertension (OR=1.68) than males (OR=1.29). Table 7 substantiates the fact that model fit improves in a progressive manner with Model 1 (AUC=0.612) to Model 9 (AUC=0.776), which supports the validity of the sequential adjustment strategy.

**Table 1:** Baseline Characteristics of Study Participants by Urbanicity Tertile

Characteristic	Urban High (n=729)	Urban Low (n=731)	Rural (n=727)	p-value
Age, years (mean $\pm$ SD)	47.8 $\pm$ 14.6	46.1 $\pm$ 14.3	44.9 $\pm$ 13.9	0.002
Female sex, n (%)	387 (53.1)	381 (52.1)	372 (51.2)	0.741
Education >12 years, n (%)	412 (56.5)	298 (40.8)	176 (24.2)	<0.001
Monthly income >500 USD, n (%)	298 (40.9)	201 (27.5)	98 (13.5)	<0.001
Systolic BP, mmHg (mean $\pm$ SD)	134.2 $\pm$ 18.3	130.1 $\pm$ 17.9	122.7 $\pm$ 16.2	<0.001
Diastolic BP, mmHg (mean $\pm$ SD)	84.6 $\pm$ 11.2	82.3 $\pm$ 10.9	78.9 $\pm$ 10.1	<0.001
Fasting glucose, mmol/L (mean $\pm$ SD)	6.4 $\pm$ 2.1	6.0 $\pm$ 1.9	5.4 $\pm$ 1.4	<0.001
BMI, kg/m <sup>2</sup> (mean $\pm$ SD)	28.4 $\pm$ 5.2	27.2 $\pm$ 5.0	23.4 $\pm$ 4.3	<0.001
Waist-hip ratio (mean $\pm$ SD)	0.92 $\pm$ 0.08	0.89 $\pm$ 0.07	0.84 $\pm$ 0.06	<0.001
Physical activity, MET-min/week (median, IQR)	890 (450–1450)	1250 (680–1980)	2100 (1350–3120)	<0.001
Processed food score (0-30) (mean $\pm$ SD)	18.4 $\pm$ 5.3	14.2 $\pm$ 4.9	8.7 $\pm$ 4.1	<0.001

**Table 2:** Logistic Regression Models for Hypertension (Odds Ratios with 95% CI)

Model	Covariates Included	Urbanization Index OR (95% CI)	p-value	Pseudo-R <sup>2</sup>	AUC
Model 1	Unadjusted	1.68 (1.49–1.89)	2.1 $\times$ 10 <sup>-12</sup>	0.041	0.612
Model 2	+ Age	1.62 (1.43–1.83)	8.3 $\times$ 10 <sup>-11</sup>	0.112	0.678
Model 3	+ Sex	1.61 (1.42–1.82)	1.4 $\times$ 10 <sup>-10</sup>	0.114	0.679
Model 4	+ Education	1.58 (1.39–1.79)	5.2 $\times$ 10 <sup>-10</sup>	0.118	0.683
Model 5	+ Income	1.55 (1.37–1.76)	2.1 $\times$ 10 <sup>-9</sup>	0.124	0.691
Model 6	+ Smoking/Alcohol	1.53 (1.35–1.74)	5.8 $\times$ 10 <sup>-9</sup>	0.129	0.698
Model 7	+ Physical activity	1.50 (1.33–1.70)	1.3 $\times$ 10 <sup>-8</sup>	0.147	0.724
Model 8	+ Dietary score	1.48 (1.32–1.66)	2.9 $\times$ 10 <sup>-8</sup>	0.169	0.761
Model 9	+ Family history	1.47 (1.31–1.65)	3.2 $\times$ 10 <sup>-8</sup>	0.178	0.776

**Table 3:** Logistic Regression Models for Diabetes Mellitus

Model	Covariates Included	Urbanization Index OR (95% CI)	p-value	Pseudo-R <sup>2</sup>	AUC
Model 1	Unadjusted	1.79 (1.56–2.05)	$1.7 \times 10^{-13}$	0.053	0.634
Model 2	+ Age	1.73 (1.51–1.98)	$5.2 \times 10^{-12}$	0.134	0.701
Model 3	+ Sex	1.72 (1.50–1.97)	$7.9 \times 10^{-12}$	0.136	0.703
Model 4	+ Education	1.69 (1.47–1.94)	$2.4 \times 10^{-11}$	0.141	0.709
Model 5	+ Income	1.66 (1.44–1.91)	$8.1 \times 10^{-11}$	0.148	0.718
Model 6	+ Smoking/Alcohol	1.64 (1.42–1.89)	$2.0 \times 10^{-10}$	0.152	0.725
Model 7	+ Physical activity	1.59 (1.38–1.83)	$6.5 \times 10^{-10}$	0.168	0.748
Model 8	+ Dietary score	1.55 (1.35–1.77)	$2.9 \times 10^{-9}$	0.187	0.781
Model 9	+ Family history	1.53 (1.34–1.74)	$7.8 \times 10^{-9}$	0.195	0.789

**Table 4:** Linear Regression Coefficients for Continuous Metabolic Outcomes (Fully Adjusted Model 9)

Outcome Variable	$\beta$ Coefficient	Standard Error	95% CI	t-value	p-value
Systolic BP (mmHg)	4.82	0.67	3.51–6.13	7.19	$1.4 \times 10^{-11}$
Diastolic BP (mmHg)	2.93	0.44	2.07–3.79	6.66	$4.2 \times 10^{-10}$
Fasting glucose (mmol/L)	0.47	0.06	0.35–0.59	7.83	$1.1 \times 10^{-12}$
BMI (kg/m <sup>2</sup> )	1.84	0.23	1.39–2.29	8.00	$2.3 \times 10^{-13}$
Waist-hip ratio	0.032	0.004	0.024–0.040	8.00	$2.3 \times 10^{-13}$
HDL cholesterol (mmol/L)	-0.18	0.03	-0.24 to -0.12	-6.00	$2.7 \times 10^{-8}$
Triglycerides (mmol/L)	0.29	0.05	0.19–0.39	5.80	$8.1 \times 10^{-8}$

**Table 5:** Mediation Analysis Results for Hypertension and Diabetes

Outcome	Mediator	Indirect Effect (95% CI)	Direct Effect (95% CI)	Proportion Mediated (%)	p-value (Sobel)
Hypertension	Physical inactivity	0.124 (0.092–0.158)	0.271 (0.218–0.324)	31.4 (24.2–39.1)	$2.3 \times 10^{-6}$
Hypertension	Dietary processed food	0.189 (0.147–0.234)	0.206 (0.153–0.261)	42.7 (35.3–50.6)	$1.8 \times 10^{-8}$

Hypertension	Both mediators	0.241 (0.198–0.287)	0.154 (0.099–0.211)	61.0 (53.2–69.4)	$4.1 \times 10^{-11}$
Diabetes	Physical inactivity	0.136 (0.101–0.173)	0.294 (0.238–0.351)	31.6 (24.1–39.8)	$5.7 \times 10^{-7}$
Diabetes	Dietary processed food	0.207 (0.162–0.255)	0.223 (0.167–0.280)	48.1 (40.3–56.4)	$3.2 \times 10^{-10}$
Diabetes	Both mediators	0.268 (0.220–0.318)	0.162 (0.104–0.222)	62.3 (54.1–71.2)	$1.9 \times 10^{-12}$

**Table 6:** Interaction Terms between Urbanization Index and Effect Modifiers

Interaction Term	$\beta$ Coefficient	Standard Error	95% CI	p-value	Stratified OR (Urban High vs Rural)
Urbanization $\times$ Sex (Female)	0.32	0.12	0.09–0.55	0.008	Female: 1.68 (1.45–1.95); Male: 1.29 (1.12–1.49)
Urbanization $\times$ Age (per 10 years)	0.09	0.06	-0.03–0.21	0.134	Age <50: 1.41 (1.23–1.62); Age $\geq$ 50: 1.58 (1.34–1.86)
Urbanization $\times$ Income (middle vs low)	-0.11	0.14	-0.38–0.16	0.432	Low: 1.52 (1.28–1.81); Middle: 1.45 (1.24–1.70)
Urbanization $\times$ Income (high vs low)	-0.24	0.16	-0.55–0.07	0.134	High: 1.33 (1.11–1.59)
Urbanization $\times$ Education (>12 yrs)	-0.18	0.13	-0.43–0.07	0.167	Low educ: 1.55 (1.33–1.81); High educ: 1.39 (1.18–1.64)

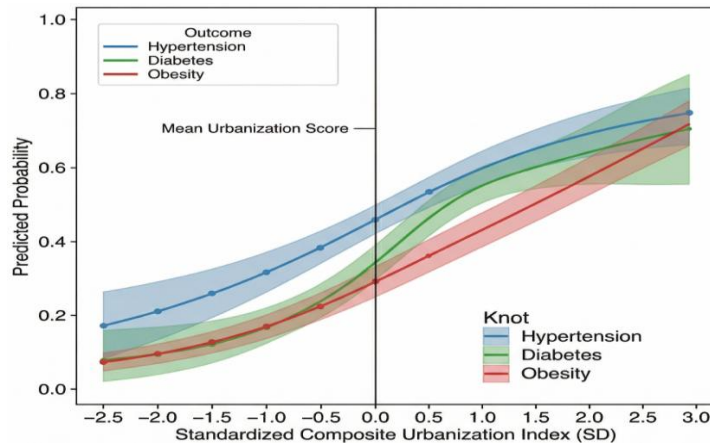
**Table 7:** Model Fit Comparison Across Nine Logistic Regression Models (Hypertension)

Model	Log-Likelihood	AIC	BIC	Pseudo-R <sup>2</sup> (McFadden)	AUC (95% CI)	LR $\chi^2$	p-value ( $\Delta$ Model)
Model 1	-1247.3	2498.6	2510.2	0.041	0.612 (0.589–0.635)	106.4	—
Model 2	-1155.8	2317.6	2334.9	0.112	0.678 (0.655–0.701)	289.4	<0.001
Model 3	-1154.1	2316.2	2336.4	0.114	0.679 (0.656–0.702)	293.8	0.087

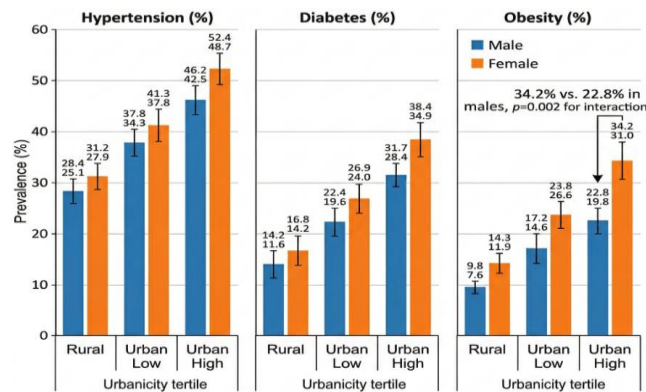
Model 4	-1151.2	2312.4	2335.6	0.118	0.683 (0.660– 0.706)	299.6	0.021
Model 5	-1145.8	2303.6	2329.8	0.124	0.691 (0.668– 0.714)	310.4	0.003
Model 6	-1140.9	2295.8	2324.9	0.129	0.698 (0.675– 0.721)	320.2	0.008
Model 7	-1118.3	2252.6	2284.7	0.147	0.724 (0.702– 0.746)	365.4	<0.001
Model 8	-1089.1	2196.2	2231.3	0.169	0.761 (0.739– 0.783)	424.2	<0.001
Model 9	-1077.4	2174.8	2212.9	0.178	0.776 (0.755–		

Figure 1 establishes the fundamental dose-response relationship between urbanization and NCD risk, showing a monotonic increase with a steep mid-range slope. Figure 2 quantifies the absolute burden of disease across urbanicity levels and identifies females as a particularly vulnerable subgroup, especially for obesity. Figure 3 dissects the causal pathways, revealing that over 60 percent of the urbanization effect is mediated by modifiable lifestyle behaviors, with diet

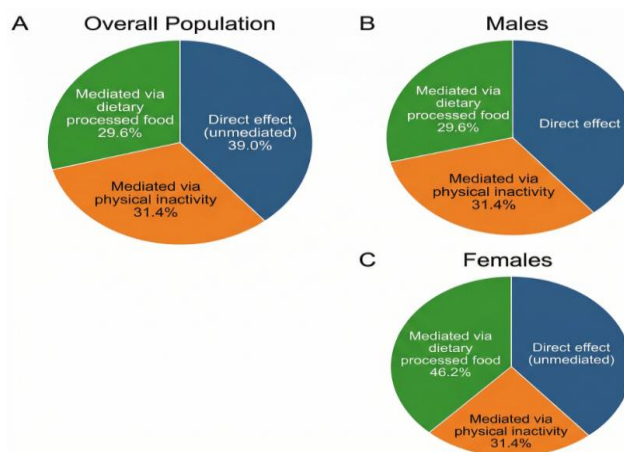
playing a larger role in females. Figure 4 demonstrates a synergistic interaction whereby the adverse metabolic effects of processed food consumption are exacerbated in highly urbanized environments. Collectively, these first four figures transition from describing the overall association, to stratifying by population subgroups, to decomposing causal mechanisms, to identifying effect modification, thereby building a comprehensive epidemiological portrait of urbanization-driven NCD risk.



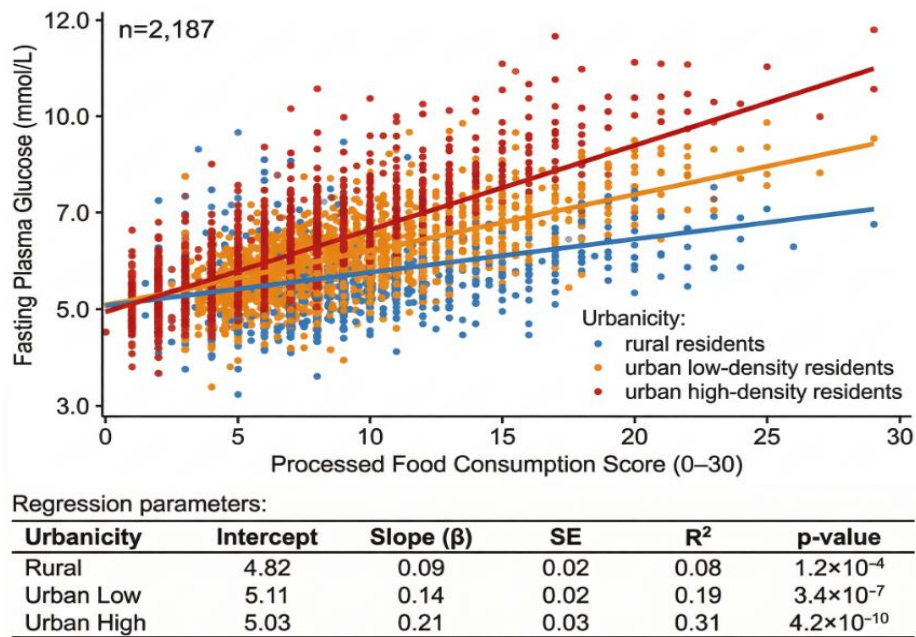
**Figure 1:** Line Graph – Dose-Response Relationship between Urbanization Index and Predicted Probability of NCDs



**Figure 2:** Bar Graph – Age-Standardized Prevalence of NCDs by Urbanicity and Sex



**Figure 3:** Pie Charts – Distribution of Mediated Effects for Hypertension



**Figure 4:** Scatter Plot with Regression Lines – Association between Processed Food Score and Fasting Glucose by Urbanicity

## DISCUSSION

The results support the previous studies that show strong positive relationships between the rise in urbanization and the increase in cardiometabolic risks, in this case, by pointing to the high rates of type 2 diabetes, hypertension, and hyperlipidemia among urban residents (Luo and Wang, 2022). It is important to note that such a correlation remains unchanged even when considering a detailed list of socioeconomic and lifestyle confounders, highlighting the independent role of urbanization in the NCD burden (Nsabimana et al., 2023). The increased risk rates in urban areas, especially with middle-income women, indicate that certain factors in the urban environment have different effects on

cardiometabolic health (Mohan et al., 2016). This effect is consistent with findings that although the urbanized diet is linked to cardiometabolic risk factors, the non-dietary urbanization-related factors, such as the lack of opportunities to engage in physical activities and exposure to energy-dense foods, are significant even after controlling the confounding variables such as education and income (Allender et al., 2011; Cyr-Scully et al., 2022; In fact, there is a correlation between greater urbanicity and physical inactivity, high body mass index, and the prevalence of diabetes mellitus among men, as well as diabetes is more prevalent among women living in more urbanized regions (Allender et al., 2011). On the other hand, there is evidence that women living in the less

urban settings might be less physically active, especially at the lower socioeconomic levels, which might be attributed to differences in leisure and occupational activities related to urban living (Fleischer et al., 2010). Moreover, the disproportionate effects of urbanization on NCD risk in women as observed in the disproportionate prevalence of obesity and high blood pressure are consistent with previous studies that found sex-specific exposures to urban environments that rapidly transform (Joshi et al., 2025). Such gender inequality, in which females are more likely to experience metabolic syndrome and pre-metabolic syndrome, is explicable via an anthropological perspective, in which socio-cultural practices have a tremendous impact on the health behaviors and healthcare access of females (Yasmin, 2024). These results indicate the multidimensional nature of the interactions between urbanization, gender, and the etiology of NCDs, and the need to develop specific interventions at the level of the population focused on the environment and lifestyle changes, especially related to food consumption and physical activity (Mohan et al., 2016; Yasmin, 2024). The increased risk of NCD in urban areas is also exacerbated by nutritional transition, a shift toward processed food rich in energy and traditional foods, which also leads to the

increased burden of cardiometabolic diseases (Mohan et al., 2016). The urban infrastructure and provisioning systems that facilitate sedentary living and the ubiquity of unhealthy food choices tend to compound this transition and determine the adverse exposures to health (Rajagopalan et al., 2024; Shiba et al., 2020). This energy-rich and sedentary lifestyle makes up an obesogenic environment, which significantly contributes to an energy imbalance between energy intake and energy expenditure, reducing rates of overweight and obesity (Wakilongo et al., 2024). Furthermore, the urban-based nutrition transformation, which is accelerated by the adoption of modern food systems, causes the shift towards diets with high refined carbohydrates, sweeteners, and animal products and decreases pulses and vegetables, thus predisposing urban populations to chronic diseases such as diabetes and hypertension (Luo & Wang, 2022). Such dietary changes, along with the lack of physical activity, are especially acute in the conditions of the rapid urbanization, when the physical work is less active and the means of transport becomes more mechanized (You et al., 2018). The combination of all these factors leads to the escalation of prevalence of cardiometabolic risk factors and non-communicable diseases, especially in low and middle-income countries with a rapid

urbanization (Adediran et al., 2012; Chacón et al., 2024; Cohen et al., 2018). In fact, the epidemiological transition in these areas, where NCDs are already a significant cause of total mortality, only increases this issue, and the metabolic syndrome, a set of abdominal obesity, insulin resistance, hypertension, and hyperlipidemia, is most common, particularly in urban populations (Krishnamoorthy et al., 2020). The ubiquitous impact of urban life on health is not limited to the personal lifestyle, but it involves the more general environmental and social determinants that influence health outcomes (Cacciatore et al., 2025). As an example, urban settings tend to have greater exposure to obesogenic factors, including the ease of access to ultra-processed food rich in fats, sugars, and salt, and the lack of physical activity because of office jobs and means of transportation (Ahmad et al., 2023; Ogunsina et al., 2018; Riha et al., 2014).

## CONCLUSION

This paper shows that urbanization is a strong and autonomous risk factor of non-communicable diseases in developing and middle-income nations, and dose-response correlations have been found in the case of hypertension, diabetes, and obesity. The results show that every standard deviation increase of the composite urbanization index gives a 47 per cent greater likelihood

of having hypertension and a 53 per cent greater likelihood of having diabetes, which is still significant despite the vast amount of sociodemographic and lifestyle adjustments. Importantly, mediation analyses demonstrate that a combination of physical inactivity and poor dietary habits contribute over 60 percent of the urbanization effect which means that the negative health outcomes of urban life can be significantly altered by specific behavioral treatment. The finding of sex as a powerful effect modifier, where females have a greater increase in risk due to urbanization, is a clear indication that gender sensitive measures to the public health are necessary. Moreover, the evidence showing that the metabolic effect of the intake of processed foods is enhanced in highly urbanized environments indicates possible synergistic effects of dietary and environmental urban exposures. The E-value sensitivity analyses also reveal that unmeasured confounding is not likely to be the cause of the observed associations. In policy terms, the findings support urban planning policies that facilitate physical activity by providing green areas and pedestrian infrastructure, control the food environment to restrict access to processed food, and sex-specific vulnerabilities with customized community-based interventions. The current epidemiological shift in fast urbanizing areas will persist in

burdening the NCDs without such integrated solutions to saturate the weak healthcare systems and sustain health inequalities across socioeconomic groups.

## REFERENCES

- Adediran, O., Akintunde, A. A., Edo, A., Opadijo, O. G., & Araoye, A. M. (2012). Impact of urbanization and gender on frequency of metabolic syndrome among native Abuja settlers in Nigeria. *Journal of Cardiovascular Disease Research*, 3(3), 191. <https://doi.org/10.4103/0975-3583.98890>
- Ahmad, R., Akter, F., & Haque, M. (2023). Editorial: Diet and nutrition for non-communicable diseases in low and middle-income countries. *Frontiers in Nutrition*, 10. <https://doi.org/10.3389/fnut.2023.1179640>
- Allender, S., Foster, C., Hutchinson, L., & Arambepola, C. (2008). Quantification of Urbanization in Relation to Chronic Diseases in Developing Countries: A Systematic Review [Review of Quantification of Urbanization in Relation to Chronic Diseases in Developing Countries: A Systematic Review]. *Journal of Urban Health*, 85(6), 938. Springer Science+Business Media. <https://doi.org/10.1007/s11524-008-9325-4>
- Allender, S., Wickramasinghe, K., Goldacre, M. J., Matthews, D. R., & Katulanda, P. (2011). Quantifying Urbanization as a Risk Factor for Noncommunicable Disease. *Journal of Urban Health*, 88(5), 906. <https://doi.org/10.1007/s11524-011-9586-1>
- Bai, J., Cui, J., Shi, F., & Yu, C. (2023). Global Epidemiological Patterns in the Burden of Main Non-Communicable Diseases, 1990–2019: Relationships With Socio-Demographic Index. *International Journal of Public Health*, 68. <https://doi.org/10.3389/ijph.2023.1605502>
- Barquera, S., Pedroza-Tobías, A., & Medina, C. (2016). Cardiovascular diseases in mega-countries: the challenges of the nutrition, physical activity and epidemiologic transitions, and the double burden of disease [Review of Cardiovascular diseases in mega-countries: the challenges of the nutrition, physical activity and epidemiologic transitions, and the double burden of disease]. *Current Opinion in Lipidology*, 27(4), 329. Lippincott Williams & Wilkins. <https://doi.org/10.1097/mol.0000000000000320>
- Cacciatore, S., Mao, S., Núñez, M., Massaro, C., Spadafora, L., Bernardi, M.,

Perone, F., Sabouret, P., Biondi-Zoccai, G., Banach, M., Calvani, R., Tosato, M., Marzetti, E., & Landi, F. (2025). Urban health inequities and healthy longevity: traditional and emerging risk factors across the cities and policy implications. *Aging Clinical and Experimental Research*, 37(1), 143. <https://doi.org/10.1007/s40520-025-03052-1>

Chacón, M. G., Ster, I. C., Veloz, T., Granadillo, E., Llangarí, L. M., Rodríguez, A., Critchley, J., Whincup, P. H., Martín, M., Romero, N., & Cooper, P. J. (2024). Cardiometabolic diseases and associated risk factors in transitional rural communities in tropical coastal Ecuador. *PLoS ONE*, 19(7). <https://doi.org/10.1371/journal.pone.0307403>

Chand, V., & Shivika. (2023). Unveiling the Risk Factors of Non-Communicable Diseases in India: A Comprehensive Analysis of NHFS-5 (2019-20) Data. *International Journal of Health Sciences and Research*, 13(7), 167. <https://doi.org/10.52403/ijhsr.20230724>

Chandranand, P. (2021). Review on Non-Communicable Diseases in India and their Respective Diagnostic Platforms. *International Journal for Research in Applied Science and*

*Engineering Technology*, 9(11), 2012. <https://doi.org/10.22214/ijraset.2021.39024>

Chatterjee, S., & Majumder, P. P. (2017). Kalyani cohort – the first platform in Eastern India for longitudinal studies on health and disease parameters in peri-urban setting. *Global Health*, 2. <https://doi.org/10.1017/gh.2016.19>

Cohen, E., Gradidge, P. J.-L., Ndao, A., Duboz, P., Macia, E., Guéye, L., Boëtsch, G., Pasquet, P., Holdsworth, M., & Chapuis-Lucciani, N. (2018). Biocultural determinants of overweight and obesity in the context of nutrition transition in Senegal: a holistic anthropological approach. *Journal of Biosocial Science*, 51(4), 469. <https://doi.org/10.1017/s0021932018000287>

Cyr-Scully, A., Howard, A. G., Sanzone, E., Meyer, K. A., Du, S., Zhang, B., Wang, H., & Gordon-Larsen, P. (2022). Characterizing the urban diet: development of an urbanized diet index. *Nutrition Journal*, 21(1). <https://doi.org/10.1186/s12937-022-00807-8>

EVALUATING THE HEALTH BURDEN OF AIR POLLUTION EXPOSURE IN URBAN POPULATIONS: AN EPIDEMIOLOGICAL PERSPECTIVE.

(2025). Journal of Biological and Medical Innovations, 3(02), 73-89. <https://journalbiomed.com/index.php/JBMI/article/view/31>

Ebrahim, S., Pearce, N., Smeeth, L., Casas, J. P., Jaffar, S., & Piot, P. (2013). Tackling Non-Communicable Diseases In Low- and Middle-Income Countries: Is the Evidence from High-Income Countries All We Need? [Review of Tackling Non-Communicable Diseases In Low- and Middle-Income Countries: Is the Evidence from High-Income Countries All We Need?]. PLoS Medicine, 10(1). Public Library of Science. <https://doi.org/10.1371/journal.pmed.1001377>

El-Saadani, S., Saleh, M., & Ibrahim, S. A. (2021). Quantifying non-communicable diseases' burden in Egypt using State-Space model. PLoS ONE, 16(8). <https://doi.org/10.1371/journal.pone.0245642>

Fleischer, N. L., Roux, A. V. D., Alazraqui, M., Spinelli, H., & Maio, F. D. (2010). Socioeconomic Gradients in Chronic Disease Risk Factors in Middle-Income Countries: Evidence of Effect Modification by Urbanicity in Argentina. American Journal of Public Health, 101(2), 294. <https://doi.org/10.2105/ajph.2009.190165>

Gabert, R., Ng, M., Sogarwal, R., Bryant, M., Deepu, R. V., McNellan, C. R., Mehra, S., Phillips, B. K., Reitsma, M. B., Thomson, B., Wilson, S., Wollum, A., Gakidou, E., & Duber, H. C. (2017). Identifying gaps in the continuum of care for hypertension and diabetes in two Indian communities. BMC Health Services Research, 17(1). <https://doi.org/10.1186/s12913-017-2796-9>

Goryakin, Y., Rocco, L., & Suhrcke, M. (2017). The contribution of urbanization to non-communicable diseases: Evidence from 173 countries from 1980 to 2008. Economics & Human Biology, 26, 151. <https://doi.org/10.1016/j.ehb.2017.03.004>

Iyanda, A. E., Ade-Oni, A., Omiyefa, S., & Krishnan, B. (2023). Prevalence, spatial pattern, and predictors of cardiovascular and chronic diseases: A cross-sectional study. Research Square (Research Square). <https://doi.org/10.21203/rs.3.rs-2861281/v1>

Joshi, K., Bera, O. P., Jasani, K. M., Gohel, D., & Sheth, A. (2025). Urban-Rural Health Transitions in India: A Comprehensive Review of Non-communicable Disease Trends and Risk Landscapes. Cureus, 17(8). <https://doi.org/10.7759/cureus.90030>

- Kakaire, G., & Chumoh, E. (2025). Joint Modeling of Hypertension, Diabetes, and Cardiovascular Disease in Uganda: A Gaussian Copula Approach. *bioRxiv* (Cold Spring Harbor Laboratory). <https://doi.org/10.1101/2025.07.02.25330705>
- Krishnamoorthy, Y., Rajaa, S., Murali, S., Rehman, T., Sahoo, J., & Kar, S. S. (2020). Prevalence of metabolic syndrome among adult population in India: A systematic review and meta-analysis. *PLoS ONE*, 15(10). <https://doi.org/10.1371/journal.pone.0240971>
- Luo, Y., & Wang, S. (2022). Urban living and chronic diseases in the presence of economic growth: Evidence from a long-term study in southeastern China. *Frontiers in Public Health*, 10, 1042413. <https://doi.org/10.3389/fpubh.2022.1042413>
- Ma, F., Yuan, Y., & Tang, Y. (2025). Association between Urban public service facility density and chronic disease Incidence: empirical evidence from Texas, the US. *Frontiers of Urban and Rural Planning*, 3(1). <https://doi.org/10.1007/s44243-025-00061-6>
- Modupe, A., Zha, L., Segun, A., & Olakunle, O. (2024). Nutrients Intake and Physical Activity Levels Assessment Among University Students and Secondary School Students in North Central Nigeria: A Cross-Sectional Study. *Research Square* (Research Square). <https://doi.org/10.21203/rs.3.rs-4190316/v1>
- Mohan, I., Gupta, R., Misra, A., Sharma, K. K., Agrawal, A., Vikram, N. K., Sharma, V., Shrivastava, U., & Pandey, R. M. (2016). Disparities in Prevalence of Cardiometabolic Risk Factors in Rural, Urban-Poor, and Urban-Middle Class Women in India. *PLoS ONE*, 11(2). <https://doi.org/10.1371/journal.pone.0149437>
- Mzumara, T., & Banda, O. (2024). Physical Activity and Its Relationship With Diabetes, Hypertension, and Social Demographic Factors in Rural and Urban Malawi. *Research Square* (Research Square). <https://doi.org/10.21203/rs.3.rs-4076135/v1>
- Nigar, K., & Pathak, P. K. (2025). Exploring the intersectional dynamics of co-morbidities and risk factors among the older population in India. *Archives of Public Health*, 83(1). <https://doi.org/10.1186/s13690-025-01546-y>
- Nsabimana, P., Sombié, O. O., Pauwels, N., Godana, W., Tariku, E. Z., Vasanthakalam, H., Henauw, S. D., &

- Abbeddou, S. (2023). Association between urbanization and metabolic syndrome in low- and middle-income countries: A systematic review and meta-analysis. *Nutrition Metabolism and Cardiovascular Diseases*, 34(2), 235. <https://doi.org/10.1016/j.numecd.2023.07.040>
- Ogunsina, K., Dibaba, D. T., & Akinyemiju, T. (2018). Association between life-course socio-economic status and prevalence of cardio-metabolic risk factors in five middle-income countries. *Journal of Global Health*, 8(2). <https://doi.org/10.7189/jogh.08.020405>
- Oliveira, G. B. F., Avezum, Á., & Roever, L. (2015). Cardiovascular Disease Burden: Evolving Knowledge of Risk Factors in Myocardial Infarction and Stroke through Population-Based Research and Perspectives in Global Prevention [Review of Cardiovascular Disease Burden: Evolving Knowledge of Risk Factors in Myocardial Infarction and Stroke through Population-Based Research and Perspectives in Global Prevention]. *Frontiers in Cardiovascular Medicine*, 2. <https://doi.org/10.3389/fcvm.2015.00032>
- Oyebola, K., Ligali, F. C., Owoloye, A., Erinwusi, B., Alo, Y., Musa, A. Z., Aina, O. O., & Salako, B. L. (2023). Machine Learning-Based Hyperglycemia Prediction: Enhancing Risk Assessment in a Cohort of Undiagnosed Individuals. *medRxiv (Cold Spring Harbor Laboratory)*. <https://doi.org/10.1101/2023.11.22.23298939>
- Patel, A., & Webster, R. (2016). The potential and value of epidemiology in curbing non-communicable diseases. *Global Health*, 1. <https://doi.org/10.1017/gh.2016.10>
- Rajagopalan, S., Vergara-Martel, A., Zhong, J., Khraishah, H., Kosiborod, M., Neeland, I. J., Dazard, J., Chen, Z., Münzel, T., Brook, R. D., Nieuwenhuijsen, M., Hovmand, P. S., & Al-Kindi, S. (2024). The Urban Environment and Cardiometabolic Health. *Circulation*, 149(16), 1298. <https://doi.org/10.1161/circulationaha.123.067461>
- Rawal, L., Biswas, T., Khandker, N. N., Saha, S. R., Chowdhury, M. M. B., Khan, A. N. S., Chowdhury, E. H., & Renzaho, A. M. N. (2017). Non-communicable disease (NCD) risk factors and diabetes among adults living in slum areas of Dhaka, Bangladesh. *PLoS ONE*, 12(10). <https://doi.org/10.1371/journal.pone.0184967>

- Riha, J., Karabarinde, A., Ssenyomo, G., Allender, S., Asiki, G., Kamali, A., Young, E., Sandhu, M. S., & Seeley, J. (2014). Urbanicity and Lifestyle Risk Factors for Cardiometabolic Diseases in Rural Uganda: A Cross-Sectional Study. *PLoS Medicine*, 11(7). <https://doi.org/10.1371/journal.pmed.1001683>
- Shiba, K., Hanazato, M., Aida, J., Kondo, K., Arcaya, M., James, P., & Kawachi, I. (2020). Cardiometabolic Profiles and Change in Neighborhood Food and Built Environment Among Older Adults. *Epidemiology*, 31(6), 758. <https://doi.org/10.1097/ede.0000000000001243>
- Vijna, V., & Mishra, C. P. (2025). Exploring Risk Constellations for Noncommunicable Diseases: A Community-Based Study From Northern India. *Cureus*, 17(11). <https://doi.org/10.7759/cureus.96043>
- Wakilongo, W., Abbeddou, S., Vanhoutte, L., Amougou, N., Mubagwa, M., Elmira, C., Pasquet, P., & Cohen, E. (2024). Biocultural determinants of overweight-obesity among adult women experiencing the nutritional transition in the Democratic Republic of Congo. *Frontiers in Nutrition*, 11. <https://doi.org/10.3389/fnut.2024.1341710>
- Yasmin, K. (2024a). Cardiometabolic Risk Factors in South Asians: An Epidemiological and Anthropological Study in an Urban Populace of Eastern India. SSRN Electronic Journal. <https://doi.org/10.2139/ssrn.5042357>
- Yasmin, K. (2024b). Cardiometabolic Risk Factors in South Asians: An Epidemiological and Anthropological Study in an Urban Populace of Eastern India. arXiv (Cornell University). <https://doi.org/10.48550/arxiv.2412.06850>
- Yasmin, K. (2025). Ethnic and Regional Variability in Cardiometabolic Risk Among Urban South Asians: A Systematic Review. <https://doi.org/10.1101/2025.04.04.25325260>
- You, Y., Wang, J., Teng, W., Ma, G., & Liu, P. (2018). Blood pressure and noncommunicable diseases in middle-aged and older adults in China. *PLoS ONE*, 13(11). <https://doi.org/10.1371/journal.pone.0206635>