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ORIGINAL ARTICLE

Community-Based Assessment of the Prevalence of Metabolic Syndrome and Its Association with Biochemical Markers among Rural and Urban Populations in Pakistan: A Comparative Study

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ABSTRACT

Background: Metabolic syndrome (MetS) is a cluster of metabolic abnormalities that predispose to the development of cardiovascular diseases and type 2 diabetes. Rapid urbanization and lifestyle changes in Pakistan are leading to a rise in MetS prevalence, especially in urban populations.

Aims and Objectives: This study compared the prevalence of MetS and its correlation with the major Biochemical markers in urban and rural populations of Pakistan. It also sought to find out which demographic and lifestyle factors, such as sedentary behavior and an increase in body mass index (BMI), are associated with the risk of MetS.

Methodology: The study was conducted from April 2022 to April 2023 in Al-Nafees Medical College, Islamabad, and the Pathology Department of Nishtar Medical University and Hospital, Multan, using a community-based cross-sectional study. Stratified random sampling was used to recruit 125 urban and 125 rural adults aged 25–65 years in a total of 250 adults. Age, gender, BMI, waist circumference, education, employment and income were collected in detailed demographic information. Fasting blood glucose, lipid profile (triglycerides, HDL-C, LDL-C, total cholesterol), fasting insulin (to calculate HOMA-IR), and high-sensitive C-reactive protein (hs CRP) were measured. The International Diabetes Federation criteria were used to diagnose MetS.

Results: Participants in the urban setting had significantly higher BMI, waist circumference, and a higher prevalence of sedentary lifestyles. Diagnosis of MetS was made in 35.2% of urban subjects versus 24.8% of rural subjects ($p = 0.03$). Elevated fasting blood glucose, triglycerides, fasting insulin, HOMA-IR, and hs-CRP were also observed in urban subjects.

Conclusion: Metabolic syndrome and adverse biochemical profiles are higher in the urbanized population of Pakistan. Urgent targeted public health interventions for promoting physical activity and a healthier dietary practice in urban communities are needed.

Keywords: Metabolic syndrome, urbanization, biochemical markers, Pakistan, cross-sectional study, sedentary lifestyle

INTRODUCTION

The pace of demographic and socioeconomic transformations is accelerating in Pakistan with rapid urbanization, changing lifestyle patterns, and population growth. With the modernization of the country, the traditional lifestyles, which include high physical activity and consumption of minimally processed foods, are being replaced with sedentary activities and diets with high intake of refined carbohydrates and unhealthy fats[1]. Now this has transitioned to a surge in noncommunicable diseases like cardiovascular disease and type 2 diabetes mellitus, which are the major contributors to the overall disease burden in Pakistan[2].

MetS is defined as a cluster of interrelated risk factors, like central obesity, dyslipidemia, hypertension, and impaired glucose regulation, that is known to be a precursor to these chronic conditions. MetS has gained prevalence in Pakistan, especially in urban areas where the effect of lifestyle changes is profound[3]. Strong associations of urban areas with higher rates of obesity, insulin resistance, and systemic inflammation have been observed. On the contrary, rural populations, which have traditionally been underrepresented for their lower risk because of their active lifestyles and traditional diet patterns, are now seeing these protective factors eroded by the same economic development and technological changes that have come to define life in urban settings[4].

Several studies have also reported on the prevalence of individual components of MetS in different regions of Pakistan, yet no studies have been conducted in the community on the prevalence of MetS in rural compared to urban populations. To understand how urbanization differentially affects metabolic health, such a comparative evaluation is essential[5]. In addition, the association between MetS and biochemical markers such as fasting blood glucose, lipid profiles, insulin resistance indices, and inflammatory markers such as high sensitivity C-reactive protein (hs-CRP) has not been explored in the Pakistani context. It is important to understand these associations as they reveal pathophysiological mechanisms and are important in identifying targets for early intervention[6].

The objective of the present study was to fill this gap by conducting a robust community-based comparative study of the prevalence of MetS and its biochemical correlates among adults in both urban and rural areas of Pakistan[7]. This study aimed to define how lifestyle factors and exposures may precipitate metabolic disturbance in various settings by using standardized diagnostic criteria and comprehensive biochemical profiling. The objective is to provide evidence to inform tailored public health strategies and clinical interventions that could help curb the rising tide of metabolic disorders in Pakistan[8].

Overall, this study investigates the occurrence of MetS and its relationship with biochemical markers in an urban versus rural setting in Pakistan, which is an important data void. The findings are expected to elicit improved understanding of the interplay between fast urbanization, transitions in lifestyle, and metabolic health, and will thus aid in the identification of effective, targeted interventions to manage the burden of MetS and its sequelae in the country[9].

METHODOLOGY

Study Design and Setting: The present community-based cross-sectional study was carried out from April 2022 to April 2023 at two major institutions of Pakistan, namely Al Nafees Medical College, Islamabad, and the Pathology Department, Nishtar Medical University and Hospital, Multan. The study at hand was meant to assess the prevalence of metabolic syndrome (MetS) and its

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association with key biochemical markers of urban and rural populations of Pakistan.

Participants and Inclusion/Exclusion Criteria: The study enrolled 250 adults aged 25 to 65 years with approximately equal distribution in urban and rural areas. To obtain stable environmental and lifestyle exposures, participants had to have a minimum 5 year residency in their respective areas. Adults who were within the specified age range and had given informed consent, and also met the residency requirement, were included. Exclusion criteria included being pregnant, having preexisting chronic inflammatory disease (e.g., rheumatoid arthritis, Crohn's disease, ulcerative colitis), or current use of medications known to change lipid or glucose metabolism. To avoid confounding factors, these criteria were applied to ensure a representative sample.

Sampling Technique: To obtain a representative balance of both urban and rural populations, a stratified random sampling method was adopted. The sampling frame used was first local health centers and community registries, and demographic data were collected from them. Therefore, participants were selected at random from each stratum based on their eligibility, so that the final sample of 250 people accurately represented the demographic diversity of the target population.

Data Collection and Measurements: Trained personnel collected the data following standardized protocols. Structured questionnaires were used to obtain detailed demographic and clinical information on medical history, lifestyle factors (dietary habits and physical activity levels), and socioeconomic status. Calibrated instruments were used to measure anthropometric measurements, including height, weight, and waist circumference, with the body mass index calculated accordingly. A minimum rest period of 10 minutes in a seated position was allowed then blood pressure was measured using a digital sphygmomanometer.

Biochemical Analysis: All participants were fasted overnight for 12 hours, and venous blood samples were drawn. The samples were processed in the central laboratories of Al Nafees Medical College and Nishtar Medical University. Biochemical analyses included fasting blood glucose by enzymatic methods, full lipid profile (triglycerides, total cholesterol, HDL cholesterol, LDL cholesterol), insulin levels, measured by immunoassay techniques, and the calculation of the Homeostasis Model Assessment for Insulin Resistance (HOMA-IR). The marker of systemic inflammation was also determined as high-sensitivity C-reactive protein (hs-CRP).

Definition of Metabolic Syndrome: The definition of metabolic syndrome was according to the International Diabetes Federation (IDF) criteria. Central obesity (waist circumference ≥ 94 cm for men and ≥ 80 cm for women, adjusted for race), any 2 of the following: elevated triglycerides (> 150 mg/dL), low HDL (> 40 mg/dL for men or > 50 mg/dL for women), elevated blood pressure (≥ 130/85 mmHg), or elevated fasting plasma glucose (≥ 100 mg/dL) were also required for diagnosis.

Statistical Analysis: SPSS version 26.0 was used for the analysis of data. Means ± standard deviations (SD) were used to express continuous variables and compared with the Student's t test, while categorical variables were presented as percentages and analyzed with the chi-square test. To determine independent predictors of metabolic syndrome, multivariate logistic regression analysis was used to adjust for potential confounders that could have influenced the results: age, gender, BMI, physical activity, and area of residence. Statistically significant was assumed to occur if the p-value was less than 0.05.

Ethical Considerations: The study was performed by the ethical standards of the World Medical Association Declaration of Helsinki. Both the Institutional Review Boards (IRBs) of Al-Nafees Medical College and Nishtar Medical University approved this study. Before enrollment, all of the participants provided written informed consent. Personal information was strictly kept confidential during the study. The study objectives, procedures, potential risks, and benefits, and the right of the participants to withdraw at any time without any consequence for their medical care were explained to the participants, and they were assured that their participation in the study was voluntary. Anonymized data were used, and all laboratory analyses were performed according to standardized safety protocols.

RESULTS

Baseline Characteristics of the Study Population: The study included a total of 250 participants, 125 urban and 125 rural. The total mean age was 44.7 ± 9.8 years, which did not differ significantly between the urban (44.2 ± 9.5 years) and rural (45.1 ± 10.2 years, p = 0.30). The detailed baseline demographic and clinical characteristics, now including gender distribution and additional demographic data are presented in Table 1. There were significant differences in the body mass index (BMI) (28.1 ± 4.0 kg/m² vs. 26.0 ± 3.5 kg/m², p < 0.001) and mean waist circumference (92.5 ± 8.7 cm vs. 87.0 ± 9.0 cm, p < 0.001) between urban and rural participants. In addition, 70% of urban respondents were sedentary (p < 0.001 compared to 50% in the rural group). Education status was different between rural subjects (30%) and urban ones (65%; p < 0.001). Among participants, 80% of urban and 85% of rural were married (p = 0.20). We also found that employment status was significantly different, with 75% of urban participants employed and 60% of rural participants (p = 0.01). There was no significant difference in smoking status (35% urban, 30% rural, p = 0.30), but a much higher proportion of urban subjects reported incomes above the median (60% vs. 25%, p < 0.001). Moreover, gender distribution was similar between the groups, with 52% and 48% of participants in the urban group being male and female (p = 0.50) and 48% and 52% in the rural group.

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants (n = 250)

Characteristic	Urban (n = 125)	Rural (n = 125)	p-value
Age (years)	44.2 ± 9.5	45.1 ± 10.2	0.30
Gender			
Male (%)	52%	48%	0.50
Female (%)	48%	52%	
BMI (kg/m²)	28.1 ± 4.0	26.0 ± 3.5	<0.001
Waist Circumference (cm)	92.5 ± 8.7	87.0 ± 9.0	<0.001
Sedentary Lifestyle (%)	70%	50%	<0.001
Tertiary Education (%)	65%	30%	<0.001
Married (%)	80%	85%	0.20
Employed (%)	75%	60%	0.01
Smoking Status (%)	35%	30%	0.30
Income Above Median (%)	60%	25%	<0.001

Prevalence of Metabolic Syndrome: According to the International Diabetes Federation (IDF) criteria, 75 out of 250 participants (30.0%) fulfilled the criteria for metabolic syndrome (MetS). Nevertheless, there was one big difference between the two groups: 44 of 125 urban participants (35.2%) had MetS compared to 31 of 125 rural participants (24.8%; p = 0.03).

Table 2: Prevalence of Metabolic Syndrome

Group	n	MetS Cases	Prevalence (%)	p-value
Urban	125	44	35.2	
Rural	125	31	24.8	0.03
Total	250	75	30.0	

Biochemical Profile of Participants with Metabolic Syndrome: Biochemical analyses were performed on 44 urban and 31 rural participants diagnosed with MetS. Fasting blood glucose levels were significantly higher in urban subjects with MetS (110.0 ± 12 mg/dL) than in rural subjects (105.0 ± 10 mg/dL, p = 0.01). In like manner, triglyceride levels were higher in the urban subjects (180 ± 35 mg/dL vs. 165 ± 30 mg/dL, p = 0.02) and high density lipoprotein cholesterol (HDL-C) levels were lower (urban: 38 ± 7 mg/dL vs. 42 ± 8 mg/dL, p = 0.03). Little higher were also other lipid parameters like total cholesterol and low density lipoprotein cholesterol (LDL-C) in urban participants (LDL-C: 130 ± 20 mg/dL

vs. 125 ± 18 mg/dL, p = 0.10; Total Cholesterol: 210 ± 25 mg/dL vs. 205 ± 23 mg/dL, p = 0.08), but these differences were not statistically significant. Insulin levels, fasting (15 ± 4 vs 13 ± 3 µIU/mL, p = 0.04) and HOMA-IR (3.5 ± 1.0 vs 3.0 ± 0.8, p = 0.04) were elevated in the urban group. Urban participants were significantly elevated for the inflammatory marker high sensitivity C-reactive protein (hs CRP) (4.5 ± 1.2 mg/L vs. 3.8 ± 1.0 mg/L, p = 0.04). Also, systolic and diastolic blood pressure were marginally higher in urban subjects (Systolic: 138 ± 10 mmHg vs. 135 ± 8 mmHg, p = 0.05; Diastolic: 88 ± 6 mmHg vs. 86 ± 5 mmHg, p = 0.05).

Table 3: Biochemical Markers in Participants with Metabolic Syndrome

Biochemical Parameter	Urban (n = 44)	Rural (n = 31)	p-value
Fasting Blood Glucose (mg/dL)	110.0 ± 12	105.0 ± 10	0.01
Triglycerides (mg/dL)	180 ± 35	165 ± 30	0.02
HDL-C (mg/dL)	38 ± 7	42 ± 8	0.03
LDL-C (mg/dL)	130 ± 20	125 ± 18	0.10
Total Cholesterol (mg/dL)	210 ± 25	205 ± 23	0.08
Fasting Insulin (µIU/mL)	15 ± 4	13 ± 3	0.04
HOMA-IR	3.5 ± 1.0	3.0 ± 0.8	0.04
hs-CRP (mg/L)	4.5 ± 1.2	3.8 ± 1.0	0.04
Systolic BP (mmHg)	138 ± 10	135 ± 8	0.05
Diastolic BP (mmHg)	88 ± 6	86 ± 5	0.05

Multivariate Analysis of Predictors for Metabolic Syndrome: Independent predictors of metabolic syndrome were identified by performing a multivariate logistic regression analysis. This analysis showed that urban residence was associated with a 1.70 increase in the risk of MetS (adjusted OR = 1.70; 95% CI: 1.10–2.60; p = 0.02). Additionally, a sedentary lifestyle predicted MetS (adjusted OR = 1.60; 95% CI: 1.00–2.50; p = 0.04) and each unit increase in BMI was associated with a 15% increased odds of MetS (adjusted OR = 1.15; 95% CI: 1.08–1.23; p < 0.001). After adjusting for confounders, age, gender, marital status, tertiary education, and smoking status did not remain statistically significant.

Table 4: Multivariate Logistic Regression Analysis for Predictors of Metabolic Syndrome

Predictor	Adjusted OR	95% CI	p-value
Urban Residence	1.70	1.10 – 2.60	0.02
Sedentary Lifestyle	1.60	1.00 – 2.50	0.04
BMI (per unit increase)	1.15	1.08 – 1.23	<0.001
Age (per year increase)	1.02	0.98 – 1.06	0.30
Male Gender	0.95	0.65 – 1.40	0.80

The main study results revealed that BMI, waist circumference, and sedentary behavior were higher in urban versus rural participants in Pakistan, and they also had higher education and income levels. Although urban residents had these advantages, they were much more likely to have metabolic syndrome (35.2% vs. 24.8% in rural areas). In addition, urban subjects with MetS had adverse biochemical profiles (higher fasting blood glucose, triglycerides, fasting insulin, HOMA-IR, and hs-CRP, and slightly elevated blood pressure). In this population, urban residence, sedentary lifestyle, and higher BMI were independent significant predictors of the metabolic syndrome by multivariate analysis. The findings here underscore the importance of addressing MetS in urban settings in Pakistan, where the burden of this condition is growing, and emphasize the impact of urbanization on metabolic health.

DISCUSSION

It was demonstrated in the present study that urban residents in Pakistan are more likely to have metabolic syndrome (MetS) compared to rural residents, with 35.2 percent of the urban subjects meeting the IDF criteria and 24.8 percent of the rural subjects[10]. Significantly adverse biochemical profiles were also found in urban subjects, characterized by elevated fasting blood glucose, fasting triglycerides, fasting insulin, higher HOMA-IR and hs-CRP levels consistent with greater insulin resistance and systemic inflammation. This is consistent with previous reports of an increased risk of metabolic disorders associated with urbanization, possibly as a consequence of sedentary lifestyles and dietary transition, and psychosocial stress[11, 12].

Although urban participants have higher education and income levels, the lifestyle factor in metabolic health (in particular, lower physical activity) has a more pronounced effect[13]. The elevated risk observed in urban residents may result from the greater BMI and waist circumference seen in urban residents, which together underscore the importance of central obesity as a central driver of MetS. Rural populations considered to have a lower risk of developing type 2 diabetes typically enjoy more physically active routines and less processed diets, but they are starting to lose these protective factors as they increasingly adopt modern lifestyles[14, 15].

This study has some limitations, such as cross cross-sectional design, which prevents causation inferences, and a small sample size that may affect the generalizability of results. Future longitudinal studies with larger and more diverse populations are needed to explore causal relationships and assess the effectiveness of targeted interventions[16, 17].

CONCLUSION

This study shows that metabolic syndrome and adverse biochemistry are prevalent with urbanization in Pakistan. In comparison with rural residents, urban residents had higher BMI, larger waist circumference, higher fasting blood glucose, triglycerides, insulin, and hs-CRP. These findings indicate that even in the urban areas with better socioeconomic indicators, lifestyle factors, often sedentary behavior and poor dietary habits dominate in increasing metabolic risk. The results emphasize the importance of targeted public health interventions to encourage physical activity and healthy eating in urban settings to combat the increase in the burden of metabolic syndrome. Future research with larger, longitudinal studies is indicated to further elucidate causative factors and to assess the impact of community-based prevention programs.

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