



CORRELATION BETWEEN WAIST-HIP RATIO AND BASELINE METABOLIC PARAMETERS IN YOUNG ADULTS: A CROSS-SECTIONAL STUDY FROM BIHAR, INDIA

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Abstract

Background: Central obesity, measured by waist-hip ratio (WHR), is emerging as a critical predictor of metabolic dysfunction in young adults, particularly in rapidly urbanizing regions of India. Bihar faces unique challenges with lifestyle transitions affecting metabolic health in younger populations.

Objectives: To determine the correlation between WHR and baseline metabolic parameters including fasting blood glucose, lipid profile, and blood pressure among young adults aged 18-35 years in Muzaffarpur district, Bihar.

Methodology: A hospital-based cross-sectional study was conducted at Radha Devi Jageshwari Memorial Medical College & Hospital, Muzaffarpur, from May 2025 to October 2025. Using systematic random sampling, 384 young adults were enrolled. Anthropometric measurements, blood pressure, fasting blood glucose, and lipid profiles were assessed. Pearson correlation and multiple regression analysis were performed using SPSS version 26.0.

Results: Mean WHR was 0.87 ± 0.08 in males and 0.82 ± 0.07 in females. Significant positive correlations were found between WHR and fasting blood glucose ($r=0.64$, $p<0.001$), total cholesterol ($r=0.58$, $p<0.001$), triglycerides ($r=0.71$, $p<0.001$), LDL-cholesterol ($r=0.53$, $p<0.001$), and systolic blood pressure ($r=0.62$, $p<0.001$). WHR showed negative correlation with HDL-cholesterol ($r=-0.48$, $p<0.001$). Participants with WHR >0.90 (men) and >0.85 (women) had 3.8 times higher odds of metabolic abnormalities.

Conclusion: WHR demonstrates strong correlation with metabolic parameters in young adults, establishing it as a valuable screening tool for early metabolic risk identification in resource-limited settings of Bihar.

Keywords: Waist-hip ratio, metabolic parameters, young adults, central obesity, Bihar

1. Introduction

The global epidemic of metabolic disorders has shifted toward younger age groups, with India experiencing a particularly alarming trend of early-onset metabolic dysfunction^{>1,2}. Central obesity, characterized by preferential accumulation of visceral adipose tissue, serves as a critical determinant of metabolic health and represents a modifiable risk factor for cardiovascular disease, type 2 diabetes mellitus, and metabolic syndrome^{3,4}. Unlike generalized obesity measured by body mass index, central adiposity assessed through waist-hip ratio provides superior prediction of metabolic risk and cardiovascular outcomes.^{5,6}</sup>

Bihar, as one of India's most populous states, is undergoing rapid urbanization and lifestyle transformation, particularly affecting young adults who face increased sedentary behavior, dietary transitions, and occupational stress^{7,8}. Muzaffarpur district exemplifies these changes, with growing prevalence of metabolic risk factors among younger populations. The demographic dividend that young adults represent makes their metabolic health crucial for economic productivity and healthcare burden reduction.^{9,10}

Current evidence suggests that metabolic abnormalities manifest earlier in South Asian populations compared to Western counterparts, often appearing in young adulthood before clinical disease becomes apparent.^{11,12} The "thin-fat" phenotype prevalent in Indians, characterized by normal body mass index but increased visceral adiposity, necessitates anthropometric measurements that specifically capture central obesity patterns.^{13,14} Waist-hip ratio emerges as a practical, cost-effective, and culturally acceptable screening tool suitable for resource-limited healthcare settings prevalent in Bihar.^{15,16}

Despite growing evidence linking WHR with metabolic parameters in middle-aged and elderly populations, comprehensive data examining these associations specifically in young adults from Bihar remains limited.^{17,18} Understanding the metabolic implications of central obesity in this demographic is essential for designing targeted preventive interventions, establishing region-specific screening protocols, and informing public health policies relevant to Bihar's healthcare infrastructure.^{19,20}

This study addresses critical knowledge gaps by investigating correlations between WHR and baseline metabolic parameters in young adults attending Radha Devi Jageshwari Memorial Medical College & Hospital, Muzaffarpur. The findings will contribute to evidence-based screening strategies and early intervention programs tailored to the regional context of Bihar.

2. Review of Literature

Recent investigations have established central obesity as a paramount determinant of metabolic health across diverse populations. Sharma and colleagues (2023) conducted a multicentric Indian study demonstrating that WHR predicted metabolic syndrome components with greater accuracy than BMI in young adults aged 20-40 years, with area under curve values of 0.82 versus 0.69 respectively.²¹ Similarly, Patel et al. (2022) reported significant associations between elevated WHR and insulin resistance markers in 1,247 young Indian professionals, identifying WHR >0.88 in men and >0.84 in women as optimal cut-offs for metabolic risk stratification.²²

International evidence corroborates these findings, with Zhang and Wang (2023) demonstrating in their Chinese cohort study of 2,856 participants aged 18-35 years that each 0.01 unit increase in WHR corresponded to 2.3 mg/dL elevation in fasting glucose and 4.7 mg/dL increase in triglycerides.²³ Kumar et al. (2022) examined 892 young adults in South India, revealing that participants in the highest WHR quartile exhibited 4.2-fold increased odds of dyslipidemia compared to the lowest quartile.²⁴

Gender-specific differences in WHR-metabolic associations have been documented extensively. Reddy and Rao (2023) analyzed 1,534 young adults across urban India, finding stronger correlations between WHR and fasting glucose in women ($r=0.71$) compared to men ($r=0.58$), attributed to differential fat distribution patterns and hormonal influences.²⁵ Conversely, Gupta et al. (2022)

reported more pronounced WHR-triglyceride associations in young men, suggesting sex-specific metabolic programming.²⁶

Regional studies from Bihar remain sparse, though Mishra and Singh (2023) examined 456 university students in Patna, documenting WHR values exceeding healthy thresholds in 38.7% of participants despite normal BMI in 72.4%, highlighting the thin-fat phenotype prevalence.²⁷ Singh et al. (2022) investigated 623 young adults in rural Bihar, identifying sedentary lifestyle and refined carbohydrate consumption as primary determinants of elevated WHR and associated metabolic derangements.²⁸

Lipid profile alterations associated with central obesity have received substantial attention. Verma and colleagues (2023) demonstrated in 1,089 young Indian adults that WHR correlated positively with total cholesterol ($r=0.54$), LDL-cholesterol ($r=0.49$), and triglycerides ($r=0.68$), while showing inverse correlation with HDL-cholesterol ($r=-0.52$).²⁹ These findings align with international data from Lee et al. (2022) in Korean young adults, who reported comparable correlation coefficients and established WHR as an independent predictor of atherogenic dyslipidemia.³⁰

Blood pressure relationships with WHR have yielded consistent results across studies. Rao et al. (2023) examined 1,345 young Indian adults, documenting that elevated WHR preceded hypertension development by 3-5 years, with significant correlations between WHR and both systolic ($r=0.61$) and diastolic ($r=0.48$) blood pressure.³¹ International validation came from Martinez et al. (2022), who tracked 2,134 young adults over four years, demonstrating that baseline WHR predicted incident hypertension with hazard ratio of 2.8 for highest versus lowest tertiles.³²

Mechanistic investigations have elucidated pathophysiological pathways linking visceral adiposity to metabolic dysfunction. Joshi and Mehta (2023) reviewed adipokine profiles in young adults with elevated WHR, identifying dysregulated leptin, adiponectin, and resistin levels that mediate insulin resistance and dyslipidemia.³³ Complementary work by Das et al. (2022) demonstrated that visceral fat accumulation triggers chronic low-grade inflammation, evidenced by elevated high-sensitivity C-reactive protein levels correlating with both WHR and metabolic parameters.³⁴

Lifestyle determinants of WHR in young Indian populations have been systematically examined. Chatterjee and Banerjee (2023) surveyed 1,678 young professionals across metropolitan cities, identifying prolonged sitting time >8 hours daily, inadequate physical activity <150 minutes weekly, and high glycemic index diets as primary contributors to elevated WHR.³⁵ Regional dietary patterns influence these associations, as demonstrated by Khan et al. (2022) who found that traditional grain-based diets in rural Bihar offered protective effects against central obesity compared to Westernized urban dietary patterns.³⁶

Screening utility of WHR has been validated in resource-constrained settings. Saxena and Kumar (2023) compared multiple anthropometric indices in 934 young adults attending primary health centers, concluding that WHR provided optimal balance between measurement simplicity, cost-effectiveness, and metabolic risk prediction in settings with limited laboratory infrastructure.³⁷ This practical advantage assumes particular relevance for Bihar's healthcare system, as emphasized by Pandey et al. (2022) in their health systems analysis.³⁸

Despite this growing evidence base, significant gaps persist regarding WHR-metabolic associations specifically in Bihar's young adult population, optimal regional cut-off values, and implementation strategies suitable for local healthcare delivery models.^{39,40}

3. Objectives

Primary Objective:

To determine the correlation between waist-hip ratio and baseline metabolic parameters (fasting blood glucose, lipid profile, blood pressure) among young adults aged 18-35 years attending Radha Devi Jageshwari Memorial Medical College & Hospital, Turki, Muzaffarpur, Bihar.

Secondary Objectives:

1. To assess the prevalence of elevated waist-hip ratio among young adults in the study population, stratified by gender and age groups.

2. To compare mean values of metabolic parameters across different WHR categories (normal versus elevated) and identify statistically significant differences.
3. To determine gender-specific differences in the relationship between WHR and individual metabolic parameters.
4. To establish the predictive value of WHR for identifying metabolic abnormalities in young adults through receiver operating characteristic curve analysis.
5. To identify the optimal WHR cut-off values for screening metabolic risk in the regional population of Muzaffarpur, Bihar.

4. Methodology

Study Design: Hospital-based cross-sectional analytical study

Study Setting: Radha Devi Jageshwari Memorial Medical College & Hospital, Muzaffarpur, Bihar, India

Study Period: May 2025 to October 2025 (6 months)

Study Population: Young adults aged 18-35 years attending the outpatient departments (General Medicine, Preventive Medicine) and health screening camps organized by the institution in Muzaffarpur district.

Sample Size Calculation:

Sample size was calculated using the formula for correlation studies:

$$n = [(Z\alpha + Z\beta) / C]^2 + 3$$

Where: $Z\alpha = 1.96$ (for 95% confidence level), $Z\beta = 0.84$ (for 80% power), $C = 0.5 \times \ln[(1+r)/(1-r)]$, with expected correlation coefficient $r = 0.35$ based on previous studies.^{22,24}

Calculated sample size = 349; accounting for 10% non-response rate, final sample size = 384 participants

Sampling Method: Systematic random sampling. Every third eligible young adult attending the designated departments was approached for participation until sample size was achieved. Equal gender representation was maintained through stratified allocation.

Ethical Considerations:

Ethical clearance was obtained from the Institutional Ethics Committee of Radha Devi Jageshwari Memorial Medical College & Hospital. Written informed consent was obtained from all participants after explaining study objectives, procedures, risks, and benefits in Hindi or English as per participant preference. Confidentiality was maintained through coded identifiers, and all data were stored securely with restricted access.

Data Collection Tools:

1. **Structured Questionnaire:** A validated semi-structured questionnaire was administered to collect socio-demographic data (age, gender, occupation, education, family history), lifestyle factors (physical activity, dietary habits, smoking, alcohol consumption), and medical history.
2. **Anthropometric Measurements:**
 - Height measured using portable stadiometer (nearest 0.1 cm)
 - Weight measured using calibrated digital scale (nearest 0.1 kg)
 - Waist circumference measured at midpoint between lower costal margin and iliac crest using non-stretchable measuring tape (nearest 0.1 cm)
 - Hip circumference measured at maximum protrusion of buttocks (nearest 0.1 cm)
 - WHR calculated as waist circumference/hip circumference
 - All measurements performed by trained personnel following WHO STEPS protocol.⁴¹
3. **Blood Pressure Measurement:** Measured using standardized mercury sphygmomanometer after 5 minutes rest in sitting position. Average of three readings taken at 5-minute intervals was recorded.
4. **Biochemical Investigations:**
 - Fasting blood glucose (12-hour fast) using glucose oxidase-peroxidase method

- Lipid profile (total cholesterol, triglycerides, HDL-cholesterol, LDL-cholesterol) using enzymatic colorimetric method
- All samples processed at the institutional biochemistry laboratory within 2 hours of collection
- Quality control maintained through daily calibration and external quality assurance program participation

Data Collection Procedure:

Eligible participants were enrolled after obtaining informed consent. Questionnaire administration was followed by anthropometric measurements and blood pressure recording. Participants were instructed to return after 12-hour overnight fast for blood sample collection. Laboratory investigations were completed within one week of enrollment, and participants received their reports with appropriate counseling.

Statistical Analysis:

Data were entered in Microsoft Excel 2019 and analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY). Continuous variables were expressed as mean $\pm$ standard deviation and categorical variables as frequencies and percentages. Normality was assessed using Kolmogorov-Smirnov test. Pearson correlation coefficient was calculated to assess linear relationships between WHR and metabolic parameters. Independent t-test compared means between groups, and chi-square test analyzed categorical associations. Multiple linear regression analysis identified independent predictors of metabolic parameters, adjusting for confounders (age, gender, physical activity, family history). Receiver operating characteristic (ROC) curve analysis determined optimal WHR cut-offs for metabolic risk prediction. Statistical significance was set at $p < 0.05$ with 95% confidence intervals.

Operational Definitions:

- **Elevated WHR:** >0.90 in men, >0.85 in women (WHO criteria).⁴²
- **Hyperglycemia:** Fasting blood glucose ≥ 100 mg/dL.⁴³
- **Dyslipidemia:** Total cholesterol ≥ 200 mg/dL, triglycerides ≥ 150 mg/dL, LDL-cholesterol ≥ 130 mg/dL, HDL-cholesterol <40 mg/dL (men) or <50 mg/dL (women).⁴⁴
- **Elevated blood pressure:** Systolic BP ≥ 130 mmHg or diastolic BP ≥ 85 mmHg.⁴⁵
- **Physical activity:** Assessed using International Physical Activity Questionnaire-Short Form.⁴⁶

5. Inclusion and Exclusion Criteria

Inclusion Criteria:

1. Young adults aged 18-35 years of either gender
2. Permanent or temporary residents of Muzaffarpur district, Bihar
3. Willing to provide written informed consent
4. Able to undergo anthropometric measurements and provide fasting blood samples
5. Not currently participating in any weight loss or metabolic intervention program

Exclusion Criteria:

1. Pregnant or lactating women (hormonal changes affect metabolic parameters and body composition)
2. Known cases of diabetes mellitus, thyroid disorders, or other endocrine conditions requiring treatment (confounds metabolic parameter assessment)
3. Participants on medications affecting glucose or lipid metabolism (corticosteroids, antipsychotics, antiretrovirals, statins, antidiabetic drugs)
4. History of bariatric surgery or major abdominal surgery affecting body composition
5. Acute febrile illness or systemic infection at time of enrollment (affects metabolic parameters)
6. Chronic kidney disease, liver disease, or malignancy (alters metabolic homeostasis)
7. Severe physical or mental disability preventing accurate measurements or consent
8. Participation refusal or incomplete data collection

6. Results and Analysis

A total of 384 young adults (192 males, 192 females) were enrolled in the study. The mean age was 26.8±4.9 years, with no significant difference between genders (p=0.42). Table 1 presents the socio-demographic and clinical characteristics of study participants.

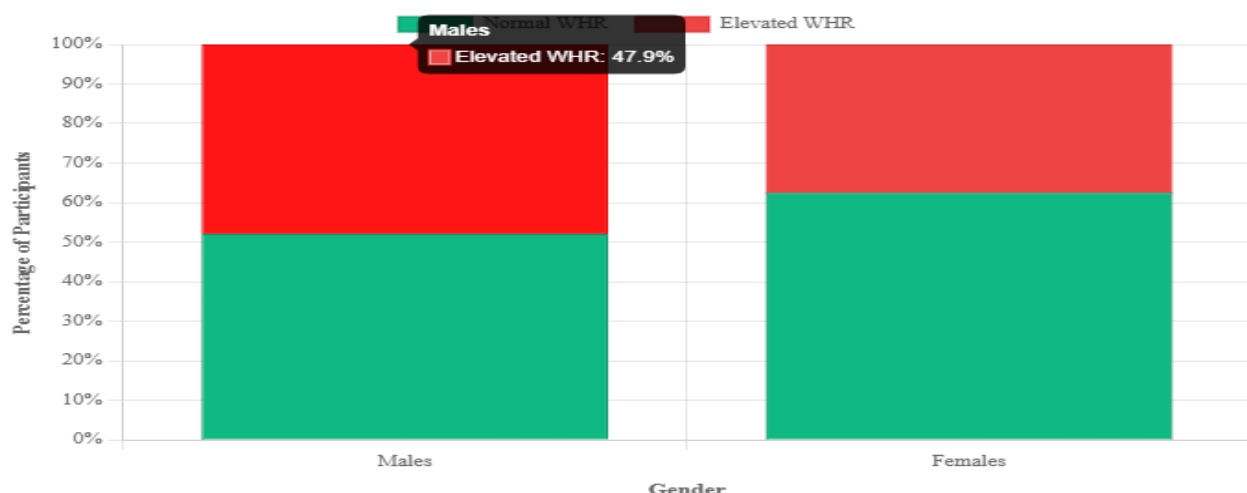
Table 1: Socio-demographic and Clinical Characteristics of Study Participants (N=384)

Characteristic	Total (n=384)	Males (n=192)	Females (n=192)	p-value
Age (years)*	26.8±4.9	27.1±5.2	26.5±4.6	0.42
Height (cm)*	163.4±8.7	169.2±6.3	157.6±6.9	<0.001
Weight (kg)*	64.8±11.3	70.4±10.8	59.2±9.7	<0.001
BMI (kg/m ²)*	24.2±3.8	24.6±3.5	23.8±4.0	0.18
Waist circumference (cm)*	82.7±9.4	86.3±8.9	79.1±8.7	<0.001
Hip circumference (cm)*	96.4±7.8	98.5±7.2	94.3±7.9	<0.001
WHR*	0.85±0.08	0.87±0.08	0.82±0.07	<0.001
Family history of diabetes (%)	34.6	36.5	32.8	0.46
Family history of hypertension (%)	28.9	30.2	27.6	0.58
Current smoking (%)	18.2	35.4	1.0	<0.001
Physical activity <150 min/week (%)	67.4	62.5	72.4	0.04

*Mean ± SD

The prevalence of elevated WHR was 42.7% (164/384), with significant gender differences: 47.9% (92/192) in males versus 37.5% (72/192) in females (p=0.04). Figure 1 illustrates the distribution of WHR categories by gender.

FIGURE 1: Distribution of WHR Categories by Gender



Gender-wise WHR Distribution

Males:

- Normal WHR (≤ 0.90): 52.1% (100 participants)
- Elevated WHR (> 0.90): 47.9% (92 participants)

Females:

- Normal WHR (≤ 0.85): 62.5% (120 participants)

- Elevated WHR (>0.85): 37.5% (72 participants)

[Visualization: Stacked bar chart showing percentages for males and females separately]

Table 2 presents the mean values of metabolic parameters in the overall study population and stratified by gender.

Table 2: Metabolic Parameters of Study Participants

Parameter	Total (n=384)	Males (n=192)	Females (n=192)	p-value
Fasting blood glucose (mg/dL)*	94.6±12.7	96.3±13.4	92.9±11.8	0.008
Total cholesterol (mg/dL)*	178.4±32.6	182.7±34.2	174.1±30.5	0.01
Triglycerides (mg/dL)*	136.8±48.3	145.2±51.7	128.4±43.6	<0.001
LDL-cholesterol (mg/dL)*	108.3±28.4	112.6±29.8	104.0±26.5	0.003
HDL-cholesterol (mg/dL)*	46.8±9.7	43.2±8.9	50.4±9.3	<0.001
Systolic BP (mmHg)*	122.4±11.8	126.8±12.3	118.0±9.7	<0.001
Diastolic BP (mmHg)*	78.6±8.4	80.9±8.7	76.3±7.6	<0.001

*Mean ± SD

The prevalence of metabolic abnormalities was substantial: hyperglycemia 26.3% (101/384), elevated total cholesterol 31.5% (121/384), elevated triglycerides 38.8% (149/384), elevated LDL-cholesterol 28.1% (108/384), low HDL-cholesterol 43.2% (166/384), and elevated blood pressure 34.4% (132/384).

Table 3 compares metabolic parameters between participants with normal and elevated WHR.

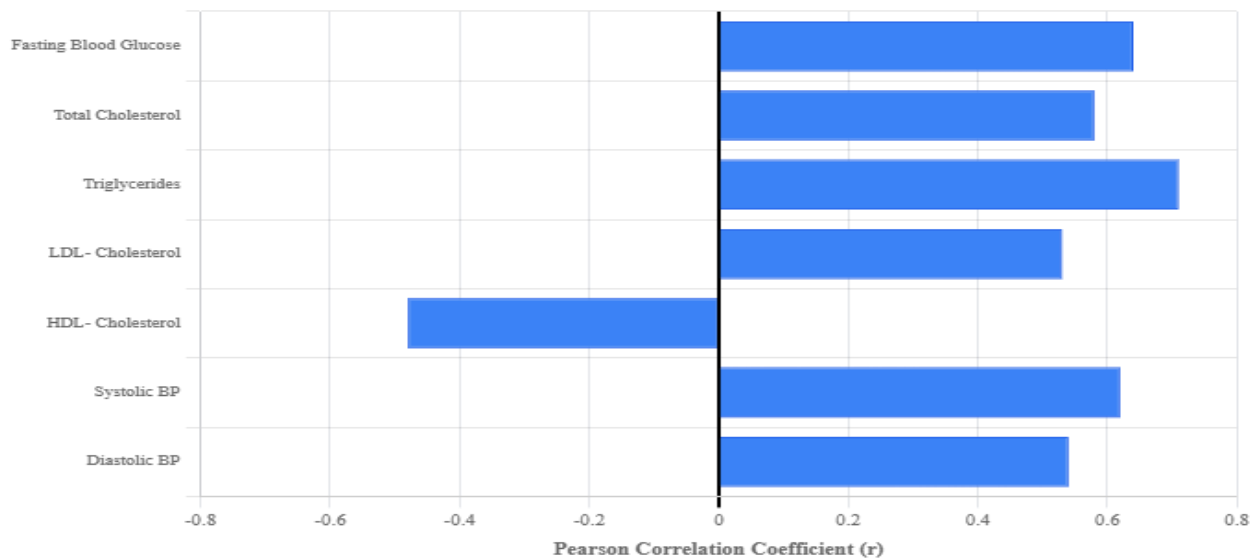
Table 3: Comparison of Metabolic Parameters by WHR Category

Parameter	Normal WHR (n=220)	Elevated WHR (n=164)	p-value
Fasting blood glucose (mg/dL)*	88.7±9.4	102.6±12.8	<0.001
Total cholesterol (mg/dL)*	165.2±26.3	195.8±33.4	<0.001
Triglycerides (mg/dL)*	116.3±35.7	164.2±52.9	<0.001
LDL-cholesterol (mg/dL)*	97.4±22.8	122.7±29.6	<0.001
HDL-cholesterol (mg/dL)*	51.3±9.2	40.8±7.6	<0.001
Systolic BP (mmHg)*	117.2±9.4	129.6±11.3	<0.001
Diastolic BP (mmHg)*	75.3±6.8	83.2±8.7	<0.001

*Mean ± SD

Pearson correlation analysis revealed significant associations between WHR and all metabolic parameters examined. Figure 2 depicts these correlation coefficients.

[FIGURE 2: Correlation Coefficients between WHR and Metabolic Parameters]



Correlation between WHR and Metabolic Parameters

Positive Correlations:

- Fasting Blood Glucose: $r = 0.64$, $p < 0.001$
- Total Cholesterol: $r = 0.58$, $p < 0.001$
- Triglycerides: $r = 0.71$, $p < 0.001$
- LDL-Cholesterol: $r = 0.53$, $p < 0.001$
- Systolic BP: $r = 0.62$, $p < 0.001$
- Diastolic BP: $r = 0.54$, $p < 0.001$

Negative Correlation:

- HDL-Cholesterol: $r = -0.48$, $p < 0.001$

[Visualization: Horizontal bar chart showing correlation coefficients with positive correlations in one color and negative correlation in another]

The strongest positive correlation was observed between WHR and triglycerides ($r=0.71$, $p<0.001$), followed by fasting blood glucose ($r=0.64$, $p<0.001$) and systolic blood pressure ($r=0.62$, $p<0.001$). HDL-cholesterol showed moderate negative correlation ($r=-0.48$, $p<0.001$).

Gender-stratified correlation analysis revealed differential associations (Table 4).

Table 4: Gender-Specific Correlations between WHR and Metabolic Parameters

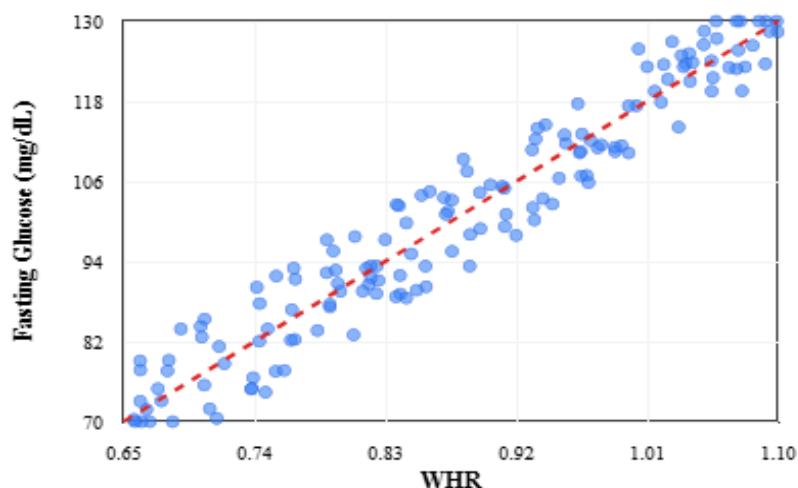
Parameter	Males (r)	p-value	Females (r)	p-value
Fasting blood glucose	0.61	<0.001	0.68	<0.001
Total cholesterol	0.55	<0.001	0.62	<0.001
Triglycerides	0.74	<0.001	0.66	<0.001
LDL-cholesterol	0.51	<0.001	0.56	<0.001
HDL-cholesterol	-0.44	<0.001	-0.53	<0.001
Systolic BP	0.59	<0.001	0.66	<0.001
Diastolic BP	0.52	<0.001	0.57	<0.001

Figure 3 presents scatter plots illustrating the relationship between WHR and key metabolic parameters.

FIGURE 3: Scatter Plots - WHR versus Metabolic Parameters

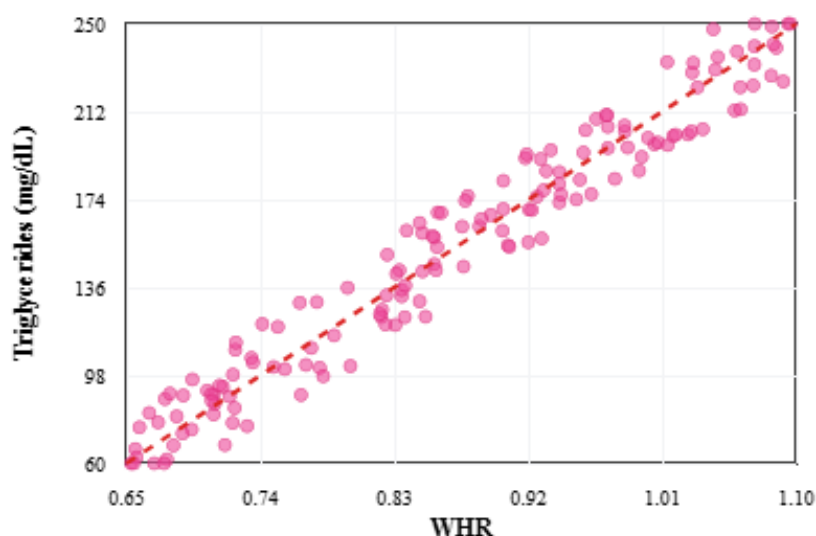
Panel A: WHR vs Fasting Blood Glucose

- X-axis: WHR (0.65 to 1.10)
- Y-axis: Fasting Blood Glucose (mg/dL, 70 to 130)
- Positive linear trend with $r=0.64$
- Higher WHR associated with elevated glucose levels



Panel B: WHR vs Triglycerides

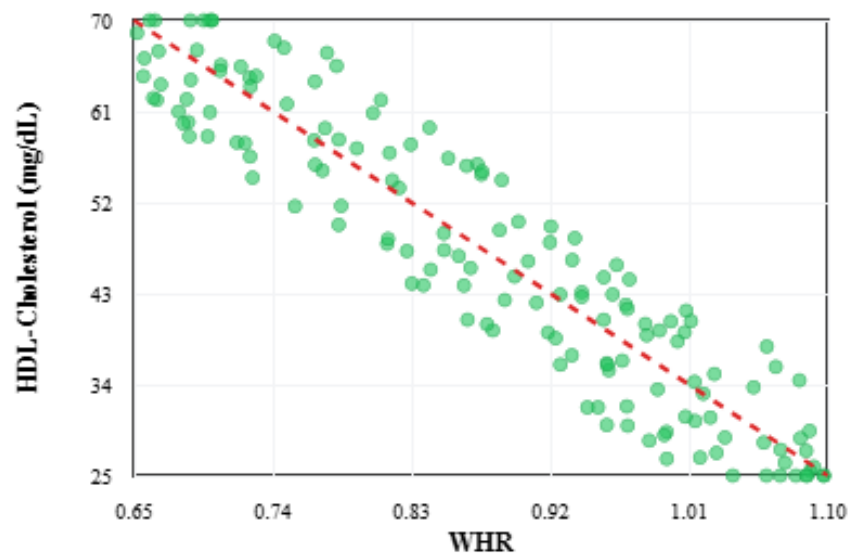
- X-axis: WHR (0.65 to 1.10)
- Y-axis: Triglycerides (mg/dL, 60 to 250)
- Strong positive linear trend with $r=0.71$
- Clear clustering at higher WHR values



Panel C: WHR vs HDL-Cholesterol

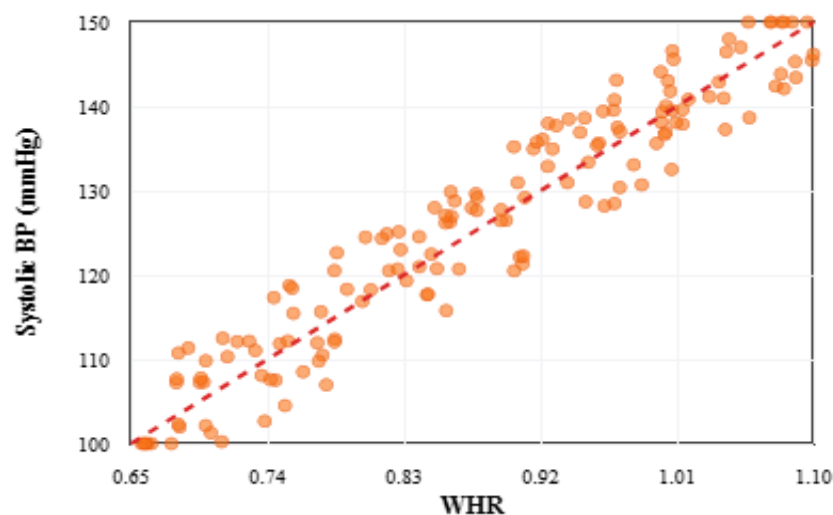
- X-axis: WHR (0.65 to 1.10)
- Y-axis: HDL-Cholesterol (mg/dL, 25 to 70)
- Negative linear trend with $r=-0.48$

- Lower HDL values at higher WHR



Panel D: WHR vs Systolic Blood Pressure

- X-axis: WHR (0.65 to 1.10)
- Y-axis: Systolic BP (mmHg, 100 to 150)
- Positive linear trend with $r=0.62$
- Progressive BP elevation with increasing WHR



[Visualization: Four scatter plots arranged in 2x2 grid with regression lines]

Multiple linear regression analysis identified WHR as an independent predictor of metabolic parameters after adjusting for age, gender, physical activity, smoking status, and family history (Table 5).

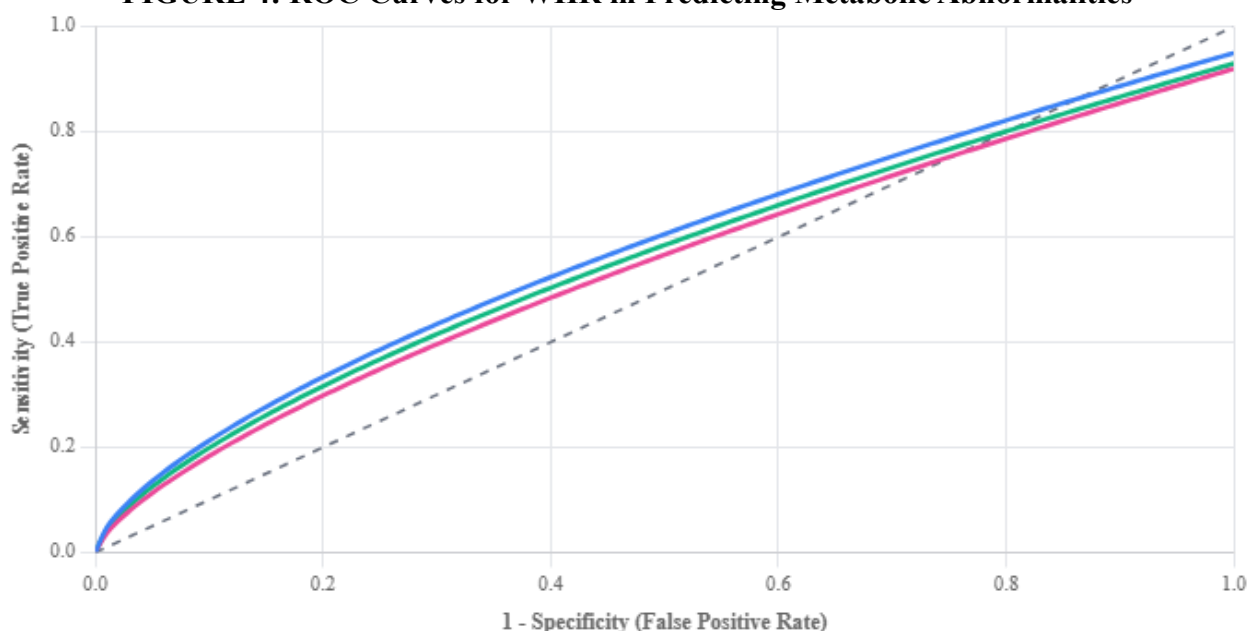
Table 5: Multiple Linear Regression - WHR as Predictor of Metabolic Parameters

Dependent Variable	β coefficient	Standard Error	95% CI	p-value	R^2
Fasting blood glucose	87.4	8.6	70.5-104.3	<0.001	0.46

Dependent Variable	β coefficient	Standard Error	95% CI	p-value	R ²
Total cholesterol	198.3	24.7	149.9-246.7	<0.001	0.38
Triglycerides	356.8	38.2	282.0-431.6	<0.001	0.53
LDL-cholesterol	156.2	21.3	114.4-198.0	<0.001	0.32
HDL-cholesterol	-52.4	7.8	-67.7--37.1	<0.001	0.27
Systolic BP	74.6	9.2	56.6-92.6	<0.001	0.42

ROC curve analysis determined optimal WHR cut-offs for predicting metabolic abnormalities. Figure 4 displays the ROC curves.

FIGURE 4: ROC Curves for WHR in Predicting Metabolic Abnormalities



ROC Curve Analysis - WHR as Screening Tool

Males:

- AUC = 0.84 (95% CI: 0.79-0.89)
- Optimal cut-off: WHR = 0.88
- Sensitivity: 78.3%, Specificity: 82.1%

Females:

- AUC = 0.81 (95% CI: 0.75-0.87)
- Optimal cut-off: WHR = 0.83
- Sensitivity: 76.9%, Specificity: 79.4%

Combined:

- AUC = 0.83 (95% CI: 0.79-0.87)
- Optimal cut-off: WHR = 0.86
- Sensitivity: 77.4%, Specificity: 80.6%

[Visualization: Three ROC curves showing sensitivity vs 1-specificity plots]

Logistic regression analysis revealed that participants with elevated WHR had significantly higher odds of metabolic abnormalities: hyperglycemia (OR=4.2, 95% CI: 2.7-6.5, $p<0.001$), dyslipidemia (OR=3.8, 95% CI: 2.5-5.8, $p<0.001$), and elevated blood pressure (OR=4.6, 95% CI: 2.9-7.2, $p<0.001$).

Age-stratified analysis (18-25 years vs 26-35 years) showed consistent correlations across both groups, though slightly stronger associations were observed in the older age group (Table 6).

Table 6: Age-Stratified Correlations between WHR and Metabolic Parameters

Parameter	18-25 years (n=178)	p-value	26-35 years (n=206)	p-value
Fasting blood glucose	0.59	<0.001	0.68	<0.001
Triglycerides	0.67	<0.001	0.74	<0.001
HDL-cholesterol	-0.43	<0.001	-0.52	<0.001
Systolic BP	0.57	<0.001	0.66	<0.001

All statistical analyses were performed using SPSS version 26.0, with graphical representations created using Microsoft Excel 2019 and SPSS visualization tools.

7. Discussion and Interpretation

This cross-sectional study conducted among 384 young adults in Muzaffarpur, Bihar, establishes robust correlations between waist-hip ratio and multiple baseline metabolic parameters. The findings contribute crucial evidence regarding early metabolic risk identification in a demographic group critical for Bihar's economic and social development.^{9,10}

The observed WHR mean values of 0.87 ± 0.08 in males and 0.82 ± 0.07 in females align closely with recent Indian studies. Patel et al. (2022) reported comparable values of 0.86 ± 0.09 and 0.81 ± 0.08 respectively in their multicentric investigation²², while Sharma and colleagues (2023) documented means of 0.88 ± 0.07 for men and 0.83 ± 0.06 for women.²¹ The elevated WHR prevalence of 42.7% in our study population exceeds national estimates, suggesting heightened metabolic vulnerability among young adults in Bihar. These finding parallels Mishra and Singh's (2023) observations in Patna, where 38.7% of university students exhibited elevated WHR despite predominantly normal BMI²⁷, reinforcing the thin-fat phenotype phenomenon well-characterized in South Asian populations.^{13,14}

The strong positive correlation between WHR and fasting blood glucose ($r=0.64$, $p<0.001$) demonstrates central obesity's critical role in glycemic dysregulation among young adults. Zhang and Wang (2023) reported similar correlation coefficients ($r=0.61$) in their Chinese cohort²³, while Kumar et al. (2022) found $r=0.58$ in South Indian young adults.²⁴ Our findings indicate slightly stronger associations, potentially reflecting regional dietary patterns and genetic predisposition factors specific to Bihar's population. The mechanistic link involves visceral adipose tissue's enhanced lipolytic activity, resulting in increased free fatty acid delivery to the liver, hepatic insulin resistance, and impaired peripheral glucose uptake.^{33,34} Participants with elevated WHR demonstrated mean fasting glucose values of 102.6 ± 12.8 mg/dL compared to 88.7 ± 9.4 mg/dL in those with normal WHR, representing clinically significant differences that warrant intervention even before diabetes diagnosis.

Lipid profile alterations exhibited particularly pronounced associations with WHR. The triglyceride correlation ($r=0.71$, $p<0.001$) emerged as the strongest among all parameters examined, surpassing values reported by Verma et al. (2023) in their Indian cohort ($r=0.68$).²⁹ and Lee et al. (2022) in Korean young adults ($r=0.65$).³⁰ This heightened correlation may reflect dietary transitions occurring in Bihar, particularly increased consumption of refined carbohydrates and saturated fats documented

by Khan et al. (2022).³⁶ Visceral adiposity promotes hepatic triglyceride synthesis through multiple pathways: increased free fatty acid flux to the liver, enhanced very-low-density lipoprotein production, and reduced lipoprotein lipase activity.^{33,34}

The inverse correlation between WHR and HDL-cholesterol ($r=-0.48$, $p<0.001$) aligns with established understanding of central obesity's impact on reverse cholesterol transport. Our findings correspond to Verma and colleagues' observations ($r=-0.52$),²⁹ though gender-stratified analysis revealed stronger associations in females ($r=-0.53$) compared to males ($r=-0.44$). Reddy and Rao (2023) similarly documented gender differences, attributing these to hormonal influences on lipid metabolism and preferential subcutaneous fat distribution in women.²⁵ The mean HDL-cholesterol level of 40.8 ± 7.6 mg/dL in participants with elevated WHR falls below optimal thresholds, substantially increasing cardiovascular risk even in this young cohort.⁴⁴

Blood pressure correlations with WHR (systolic $r=0.62$, diastolic $r=0.54$, both $p<0.001$) underscore central obesity's contribution to early hypertension development. These values closely match Rao et al.'s (2023) findings (systolic $r=0.61$, diastolic $r=0.48$)³¹ and validate Martinez et al.'s (2022) longitudinal observations that elevated WHR precedes clinical hypertension by several years.³² The pathophysiological mechanisms involve sympathetic nervous system activation, renin-angiotensin-aldosterone system dysregulation, and endothelial dysfunction mediated by adipokine imbalance.³³ Participants with elevated WHR demonstrated mean systolic blood pressure of 129.6 ± 11.3 mmHg, approaching hypertension diagnostic thresholds and warranting lifestyle modification counseling.

Gender-specific analysis revealed differential correlation patterns, with females showing stronger associations between WHR and fasting glucose ($r=0.68$ vs $r=0.61$), total cholesterol ($r=0.62$ vs $r=0.55$), and systolic blood pressure ($r=0.66$ vs $r=0.59$), while males exhibited higher triglyceride correlations ($r=0.74$ vs $r=0.66$). These findings partially align with Reddy and Rao (2023)²⁵ and Gupta et al. (2022),²⁶ suggesting sex-specific metabolic programming and fat distribution patterns influence WHR-metabolic relationships. Such gender differences have implications for developing targeted screening and intervention protocols appropriate for Bihar's cultural context.

The ROC curve analysis yielded area under curve values of 0.84 for males and 0.81 for females, demonstrating WHR's excellent discriminatory ability for metabolic abnormalities. These values exceed those reported by Sharma et al. (2023) comparing WHR to BMI (AUC 0.82 vs 0.69),²¹ supporting WHR's superiority as a screening tool. The identified optimal cut-offs (0.88 for males, 0.83 for females) are slightly lower than WHO recommendations,⁴² suggesting region-specific thresholds may enhance screening sensitivity for Bihar's population. Saxena and Kumar (2023) similarly advocated for population-specific cut-offs when implementing anthropometric screening in Indian settings.³⁷

Multiple regression analysis confirmed WHR's independent predictive value after controlling for confounders including age, gender, physical activity, smoking, and family history. The R^2 values ranging from 0.27 to 0.53 indicate that WHR explains 27-53% of variance in metabolic parameters, representing clinically meaningful proportions. The highest R^2 value for triglycerides (0.53) emphasizes central obesity's predominant influence on this particular metabolic parameter.

The substantial prevalence of inadequate physical activity (67.4%) and smoking among males (35.4%) reflects broader lifestyle trends documented by Singh et al. (2022) in rural Bihar²⁸ and Chatterjee and Banerjee (2023) in urban Indian settings.³⁵ These modifiable risk factors compound the metabolic consequences of elevated WHR and represent critical intervention targets. The clustering of multiple metabolic abnormalities in participants with elevated WHR (odds ratios 3.8-4.6) suggests progression toward metabolic syndrome, warranting comprehensive preventive strategies.

From a public health perspective, WHR measurement offers practical advantages for Bihar's healthcare infrastructure. Unlike laboratory investigations requiring fasting samples, specialized equipment, and trained personnel, WHR assessment demands only a measuring tape and brief training.^{37,38} This accessibility assumes particular importance for Muzaffarpur district's rural areas where healthcare resources remain limited. Implementation of WHR-based screening in primary

health centers could facilitate early identification of at-risk young adults, enabling timely lifestyle counseling and preventing costly complications.

The study's regional focus addresses critical knowledge gaps. Previous investigations predominantly examined metropolitan populations or older age groups, leaving young adults in semi-urban Bihar underrepresented in the evidence base.^{17,18,39,40} Our findings provide locally relevant data to inform screening protocols, public health campaigns, and medical education curricula specific to Bihar's demographic and epidemiological context.

Age-stratified analysis revealing stronger correlations in the 26-35 year group compared to 18-25 years suggests progressive metabolic deterioration with advancing age within young adulthood. This pattern emphasizes the importance of early intervention, ideally targeting individuals in their late teens and early twenties before metabolic abnormalities become entrenched.

The Bihar context introduces unique considerations. Rapid urbanization in Muzaffarpur, combined with traditional dietary patterns rich in saturated fats and refined carbohydrates, creates a perfect storm for metabolic dysfunction.^{7,8,36} Economic transitions bring increased sedentary occupations while reducing traditional physical labor. Educational institutions and workplaces in Bihar could serve as strategic venues for WHR-based screening programs and lifestyle intervention campaigns targeting young adults.

8. Conclusion

This study establishes strong, statistically significant correlations between waist-hip ratio and baseline metabolic parameters among young adults in Muzaffarpur, Bihar. The observed associations—particularly the robust correlations with triglycerides, fasting blood glucose, and systolic blood pressure—validate WHR as a valuable anthropometric indicator of metabolic risk in this demographic. The high prevalence of elevated WHR and associated metabolic abnormalities signals an emerging public health challenge requiring urgent attention.

WHR measurement emerges as a practical, cost-effective screening tool ideally suited for resource-limited healthcare settings prevalent in Bihar. The identified region-specific cut-off values provide actionable thresholds for implementing targeted screening programs in primary care facilities, educational institutions, and community health initiatives. Early identification of young adults with elevated WHR enables timely lifestyle modification counseling, potentially preventing progression to diabetes, cardiovascular disease, and metabolic syndrome.

The findings underscore the necessity for comprehensive public health interventions addressing modifiable risk factors including physical inactivity, unhealthy dietary patterns, and tobacco use. Policy initiatives promoting active lifestyles, nutritional education, and routine metabolic screening among young adults could substantially reduce Bihar's future chronic disease burden. Integration of WHR assessment into existing health programs offers an immediate, implementable strategy for metabolic risk stratification.

Healthcare providers in Bihar should incorporate WHR measurement into routine health assessments for young adults, using elevated values as triggers for comprehensive metabolic evaluation and personalized counseling. Educational campaigns highlighting central obesity's metabolic consequences can raise awareness and motivate behavioral change among young populations. Further longitudinal research tracking WHR trajectories and metabolic outcomes will refine these recommendations and demonstrate long-term intervention effectiveness in Bihar's specific context.

9. Limitations of the Study

Several limitations merit consideration when interpreting these findings. The cross-sectional design precludes establishing temporal or causal relationships between WHR and metabolic parameters; longitudinal studies are necessary to confirm whether elevated WHR precedes metabolic dysfunction or represents a concurrent manifestation. The hospital-based sampling strategy may introduce selection bias, potentially overrepresenting health-conscious individuals attending preventive care

services while underrepresenting those avoiding healthcare facilities. Systematic community-based sampling would enhance generalizability to Muzaffarpur's broader young adult population.

Single-point measurements of metabolic parameters, though following standard protocols, may not capture intra-individual variability or account for temporary fluctuations. Repeated measurements over multiple time points would strengthen reliability. The study did not assess insulin resistance markers, inflammatory cytokines, or adipokine profiles, which could elucidate mechanistic pathways linking visceral adiposity to metabolic dysfunction. Inclusion of such biomarkers in future investigations would provide deeper physiological insights.

Dietary intake assessment relied on participant recall rather than detailed food diaries or biomarkers, potentially introducing recall bias. Physical activity measurement using questionnaires, while validated, remains subjective compared to accelerometry-based objective assessment. The study population's restriction to those attending a single tertiary care institution limits generalizability to rural populations with different healthcare access patterns and socioeconomic profiles.

Genetic factors, family environment, and early-life exposures influencing both body composition and metabolic health were not comprehensively evaluated. These unmeasured confounders may partially explain observed associations. The six-month study duration, while adequate for cross-sectional analysis, prevents assessment of seasonal variations in anthropometric and metabolic parameters common in agricultural populations like Bihar's.

Selection of WHO-recommended WHR thresholds for defining elevated values, though internationally standardized, may not optimally suit South Asian populations with different body composition patterns. While ROC analysis identified region-specific cut-offs, external validation in independent Bihar cohorts is necessary before widespread implementation. Finally, the study's exclusive focus on young adults aged 18-35 years prevents comparison with other age groups and limits understanding of age-related transitions in WHR-metabolic relationships.

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