ORIGINAL ARTICLE

# Waist Circumference: A Simple, Low-Cost Predictor of Metabolic Syndrome

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## Abstract

**Introduction:** Metabolic syndrome, linked to abdominal obesity and insulin resistance, increases with rising BMI and affects key metabolic markers. Early, low-cost, non-invasive detection can prevent progression to serious comorbidities. **Aim:** This study identifies low-cost, simple clinical predictors to detect metabolic syndrome and raise awareness across all economic groups. **Methods:** Retrospective study of 598 adults (18-78 yrs) from a Mumbai nutrition clinic using purposive sampling. Inclusion was based on Metabolic Syndrome as per IDF criteria with 2 or 3 abnormal parameters. Statistical analysis was performed using the R programming package dplyr for data processing and interpretation. **Results:** Waist circumference positively correlated with insulin, glucose, HbAlc, triglycerides, blood pressure, and negatively with high density lipoprotein cholesterol. One-way ANOVA for four groups of waist circumference (<90 cm, 90-100 cm, 101-110 cm, 110 cms) showed significant differences in insulin, glucose, lipids, and blood pressure. A clear trend of increasing comorbidities was observed with rising WC values. Chi-Squared analysis with categorical variables such as comorbidities (0,1,2,3) and diabetes diagnosis/status based on glycated hemoglobin shows a statistically significant relationship with waist circumference groups. Chi-square analysis revealed prediabetics with central obesity had significantly higher comorbidity incidence. **Conclusions:** Waist circumference serves as a simple and cost-effective marker for early identification of health risks, raising awareness, promoting preventive health behaviours, and reducing healthcare burdens.

**Keywords:** Metabolic syndrome, Waist circumference, Low-cost, Non-invasive, Clinical Predictor, Awareness, Public health

## Introduction

The 21st century has witnessed Metabolic Syndrome (MetS) becoming a significant contributor to global disease burden[1]. The high prevalence of Metabolic Syndrome may be attributed to the global rise in obesity, physical inactivity, increasing urbanization, tobacco consumption, and the rapid transition in dietary patterns[2]. Metabolic Syndrome comprises a cluster of interrelated conditions, including central obesity, atherogenic dyslipidemia—defined by low levels of high-density lipoprotein cholesterol (HDL-C), elevated triglycerides (TG), and increased apolipoprotein B–containing lipoproteins—along with elevated blood pressure, hyperglycemia, and a predisposition to prothrombotic and proinflammatory states[3]. Metabolic Syndrome (Met-S) increases the risk of developing type 2 diabetes by fivefold and raises the likelihood of cardiovascular diseases by three times[1]. Additionally, individuals with Met-S are more susceptible to a range of health issues, including polycystic ovary syndrome (PCOS) nonalcoholic fatty liver disease (NAFLD), asthmatic symptoms, sleep disturbances, certain cancers, and, more recently, it has been linked to the development of sarcopenia[1].

Central obesity, marked by increased waist circumference and visceral fat accumulation, is a key risk factor for metabolic syndrome. It is strongly linked to dyslipidemia, insulin resistance, hypertension, and cardiovascular dysfunction. Recognized globally as a critical clinical marker, abdominal obesity doubles the risk of cardiovascular disease and increases the likelihood of type 2 diabetes fivefold, highlighting the need for early detection and intervention[4].

Early identification of Metabolic Syndrome through non-invasive, cost-effective, and easily applicable clinical measures is essential to prevent the onset of associated comorbidities. Several authoritative bodies, including the International Diabetes Federation (IDF) and the National Cholesterol Education

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Program Adult Treatment Panel III (NCEP-ATP III) have proposed diagnostic criteria for Metabolic Syndrome. According to the IDF, the global prevalence of Metabolic Syndrome is estimated at approximately 25%, with variations influenced by factors such as ethnicity, age, and sex[5].

This study aims to evaluate waist circumference as a low-cost, reliable, and practical predictor for the early detection of Met-S in overweight Indians. By assessing its correlation with key metabolic markers, including blood pressure (BP), fasting blood sugar (FBS), HbA1c, triglycerides (TG), and high-density lipoprotein cholesterol (HDL-C)—the study seeks to establish waist circumference as a simple yet effective tool for clinical and public health use. Additionally, the study aims to compare waist circumference with other traditional obesity markers such as BMI to determine its relative predictive accuracy. This study seeks to enhance awareness and advocate for regular monitoring of waist circumference, thereby facilitating early intervention strategies for the prevention of metabolic syndrome (Met-S) and ultimately aiming to reduce the prevalence of metabolic disorders within the Indian population.

## Methods

This retrospective study was conducted using post-observational clinical data collected from adult patients who sought nutritional consultation at a nutrition clinic in Mumbai. Purposive sampling technique was employed to select participants, ensuring the inclusion of individuals relevant to the study's objectives. This approach allowed for a focused analysis of nutritional status and metabolic health parameters within the target population.

### Study Design and Sampling Procedure

A total of 598 adult participants, aged between 18 and 78 years, were included in the study. Purposive sampling method was selected to ensure the inclusion of individuals with varying degrees of metabolic dysfunction. Only participants with complete clinical and biochemical records were considered for the study. Prior to data collection, written informed consent was obtained from all individuals, ensuring adherence to ethical research standards.

Data was collected by face-to-face interview using a structured well-designed questionnaire. It was collected by two trained registered dietitians. The questionnaire included information about sociodemographic and anthropometric characteristics including age, sex, marital status, education level, height, weight, waist and hip circumference. Last part of the questionnaire also included information about systolic and diastolic blood pressures (SBP, DBP), serum triglyceride (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), fasting Insulin levels, HbA1c, and fasting blood sugar levels (FBS).

Met-S classification was based on the criteria established by the Joint Interim Statement of the International Diabetes Federation (IDF) Task Force on Epidemiology and Prevention. Diagnosis of Met-S was confirmed if a participant exhibited at least three or more abnormal metabolic parameters. These included increased waist circumference(WC),elevated blood pressure, and abnormalities in biochemical markers such as glycated hemoglobin (HbA1c), triglycerides(TG), and high-density lipoprotein cholesterol (HDL-C).

### Anthropometric Measurements

Anthropometric measurements were documented following standardized procedures to ensure accuracy and minimize variability. Height was measured in centimeters using a stadiometer installed in the clinic, with participants standing barefoot, maintaining an erect posture, and aligning their head with the Frankfurt horizontal plane. The measurement was to the nearest 0.1 cm. Weight was measured in kilograms using a calibrated WEIGHTRON weighing scale, (Model no.: IND/09/05/397) with participants wearing light clothing and no footwear, and recorded to the nearest 0.1 kg.

Waist circumference (WC) and hip circumference (HC) were measured using a non-stretchable measuring tape while participants were in a standing position. Waist circumference was measured at the mid-point between the inferior margin of the last rib and the iliac crest at the end of expiration, ensuring consistency. Hip circumference (HC) was recorded at the level of the maximum posterior extension of the buttocks in a horizontal plane, with all measurements noted to the nearest 0.1 cm. Obesity indices Body Mass Index (BMI) and Waist to Hip Ratio (WHR) were calculated from documented anthropometric measurements, including height, weight, waist circumference, and hip circumference, as per standardized protocols.

### Blood Pressure Measurements

Blood pressure (BP) was recorded using an Omron automatic blood pressure monitor (HEM-7156). To ensure accuracy, two readings were taken in supine position after the participant had been seated and rested for at least 5-10 minutes. The average of the two readings was considered as the final BP measurement. Participants who exhibited SBP ≥130 mmHg and/or DBP of ≥85 mmHg, or those who were on antihypertensive medication, were classified as hypertensive based on the diagnostic criteria for MetS.

### Biochemical and Laboratory Assessments

Biochemical parameters were collected from patient's clinical records visiting the Healthwatch Nutrition Clinic in Mumbai. Fasting Insulin levels, fasting blood sugar, HbA1c, total cholesterol, serum triglycerides, and high-density lipoprotein cholesterol, low density lipoprotein cholesterol data were recorded.

### Diagnostic Criteria for Metabolic Syndrome

Participants were diagnosed with MetS based on the criteria defined by the IDF Task Force on Epidemiology and Prevention. A diagnosis of MetS was confirmed if an individual had an increased waist circumference and at least two of the following risk factors:

- Waist circumference was considered elevated if it measured ≥94 cm for men and ≥80 cm for women.
- Blood pressure was classified as high if it measured ≥130/85 mmHg or if the participant was undergoing treatment for hypertension.
- Abnormal biochemical markers were identified as follows:
    - Fasting plasma glucose (FPG)/ Fasting blood sugar (FBS) levels were considered high if they were ≥100 mg/dL (5.6 mmol/L) or if the participant had a prior diagnosis of impaired fasting glucose.
    - Serum triglyceride levels were considered elevated if they were ≥150 mg/dL (1.7 mmol/L).
    - High-density lipoprotein cholesterol (HDL-C) was classified as low if levels were <40 mg/dL (1.03 mmol/L) in men and <50 mg/dL (1.29 mmol/L) in women.

**Statistical Analysis**

Statistical analyses were conducted using R programming language, with the dplyr package used for data processing and evaluation. Descriptive statistics were applied to summarize participant characteristics, with continuous variables expressed as means with standard deviations (SD), and categorical variables presented as frequencies with percentages. Comparative analyses were performed to evaluate group differences. Logistic regression assessed the association between waist circumference (WC) and individual metabolic syndrome (MetS) components. Linear relationships between continuous variables were examined using Pearson's correlation. Associations involving categorical variables were evaluated using the Chi-square test.

All analyses were adjusted for potential confounders including age, smoking status, and family histories of diabetes and hypertension. One-way analysis of variance (ANOVA) was conducted to compare the mean values of metabolic parameters across different waist circumference categories. This test was used to determine whether significant differences existed in fasting insulin, HbA1c, serum triglycerides, HDL-C, and blood pressure levels among participants grouped based on waist circumference percentiles. Through rigorous statistical evaluation, this study aims to establish waist circumference as a reliable, low-cost, and easily applicable screening tool for the early detection of MetabolicSyndrome, which can aid in preventive healthcare measures and reduce the risk of cardio-metabolic complications in overweight individuals.

## Results

The Pearson correlation coefficients were computed to examine the relationship between obesity indices (WC, WHR, and BMI) and various metabolic syndrome components, including blood pressure, fasting insulin, FBS ,HbA1c, and lipid profile parameters (HDL-C, LDL-C, and TG).

As shown in Table 1, waist circumference exhibited a strong positive correlation ($r = 0.787$, $p < 0.001$) with BMI, suggesting that as waist circumference increases, BMI also rises significantly. This high correlation indicates that waist circumference is an excellent proxy for general obesity, reflecting both total body fat and central adiposity. Given that BMI is widely used as a standard obesity measure, this result reinforces waist circumference as a primary obesity indicator, particularly in detecting individuals with excess body fat. However, unlike BMI, waist circumference specifically identifies abdominal obesity, which has stronger links to metabolic complications.

Waist circumference also showed a moderate-to-strong correlation with waist-to-hip ratio (WHR) ($r=0.569$, $p < 0.001$), confirming its role in assessing central obesity. WHR is a powerful marker of body fat distribution, and its positive association with waist circumference indicates that individuals with larger waist circumference measurements tend to have an unfavorable fat distribution pattern (higher WHR), which is linked to increased cardiovascular risk. This further supports the reliability of waist circumference as an independent and practical measure for identifying central obesity.

A significant positive correlation between waist circumference and fasting insulin ($r = 0.397$, $p < 0.001$) suggests that individuals with higher waist circumference are more likely to exhibit insulin resistance. Insulin resistance is a hallmark of metabolic syndrome and an early predictor of type 2 diabetes. Excess abdominal fat, particularly visceral fat, is known to impair insulin sensitivity by releasing pro- inflammatory cytokines and free fatty acids that interfere with glucose metabolism. This correlation reinforces the role of waist circumference as a predictor of insulin resistance and diabetes risk.

Waist circumference showed a moderate positive correlation with both systolic blood pressure and diastolic blood pressure, indicating that larger waist circumference is associated with higher blood pressure levels. This finding supports existing evidence that central obesity contributes to hypertension through mechanisms such as increased sympathetic activity, insulin resistance, and endothelial dysfunction. Given that hypertension is a major risk factor for cardiovascular disease, Waist circumference serves as an important anthropometric measure for identifying individuals at risk of obesity-related hypertension.

A positive correlation between waist circumference and HbA1c ($r = 0.242$, $p <0.001$) suggests that individuals with higher waist circumference are likely to have poorer long-term glucose control. HbA1c reflects average blood glucose levels over the past three months and is a key indicator of prediabetes and diabetes progression. Similarly, the correlation with fasting blood sugar (r = 0.163, p < 0.05) indicates that larger waist circumference is associated with higher fasting glucose levels, further reinforcing the link between abdominal obesity and glucose dysregulation.

Waist circumference was positively correlated with triglycerides (r = 0.147, p <0.05), indicating that larger waist circumference measurements are associated with higher triglyceride levels, a key marker of dyslipidemia and metabolic syndrome. Elevated triglycerides result from increased free fatty acid release from visceral fat, leading to impaired lipid metabolism and an increased risk of cardiovascular disease. This suggests that waist circumference can serve as a simple yet effective screening tool for early detection of lipid abnormalities.

A negative correlation was observed between waist circumference and HDL-C (r = -0.237, p < 0.05), meaning that individuals with higher waist circumference tend to have lower HDL-C levels. Since HDL-C is known as "good cholesterol" for its protective role in cardiovascular health, this inverse relationship suggests that central obesity contributes to an unfavorable lipid profile, increasing cardiovascular risk.

The results of the Pearson correlation analysis strongly support waist circumference as a key anthropometric measure for assessing obesity-related metabolic risks. Waist circumference demonstrated significant correlations with multiple metabolic syndrome components, including BMI, insulin resistance, hypertension, glucose dysregulation, and lipid abnormalities.

One-way analysis of variance (ANOVA) was conducted to compare metabolic parameters across four distinct waist circumference categories: below 90 cm (n = 50), 90–100 cm (n = 165), 101–110 cm (n = 187) and above 110 cm (n = 196). (Table 2)

This classification allowed for a comparative analysis of the impact of increasing central obesity on key metabolic markers. The statistical analysis revealed several significant trends, indicating a progressive deterioration of metabolic health with increasing waist circumference further reinforcing the relationship between waist circumference and metabolic syndrome components.

As waist circumference increased across categories, there was a significant increase in body mass index and body fat percentage. The statistical significance (p < 0.001) confirms that higher waist circumference is strongly linked to overall obesity, making it a reliable marker for body fat accumulation.

Individuals with waist circumference below 90 cm had a fasting insulin level of 12.1 µIU/mL, while those with waist circumference above 110 cm had significantly higher fasting insulin (26.1 µIU/mL).(Fig.1)This strong association (p <0.001) suggests that central obesity is a key driver of insulin resistance, a major risk factor for type 2 diabetes. Individuals with waist circumference below 90 cm had an average FBS level of 95.6 mg/dL, whereas those with waist circumference above 110 cm had FBS levels of 106.2 mg/dL (p < 0.001). (Fig. 2) This trend highlights the direct impact of abdominal obesity on glucose dysregulation, increasing the risk of prediabetes and diabetes. Participants with waist circumference below 90 cm had an HbA1c of 5.6%, while those in the waist circumference above 110 cm group had an elevated HbA1c of 6.2% (p < 0.001). (Fig. 3) This finding underscores the significant role of abdominal obesity in increasing diabetes risk through chronic hyperglycemia and insulin resistance.

Both systolic blood pressure and diastolic blood pressure increased significantly with higher waist circumference categories. Individuals in the below 90 cm waist circumference

**Table 1.** Association of Obesity Indices and MetS components using Pearson Correlation Coefficient test

| Variables | WC | WHR | BMI | DBP | SBP | F Insulin | FBS | HbA1c | HDL-C | LDL-C | TG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WC | 1 | 0.569** | 0.787** | 0.255** | 0.263** | 0.397** | 0.163** | 0.242** | -0.237** | 0.026 | 0.147** |
| WHR | | 1 | 0.067 | 0.158** | 0.288** | 0.236** | 0.200** | 0.239** | -0.230** | 0.096* | 0.249** |
| BMI | | | 1 | 0.240** | 0.160** | 0.333** | 0.102* | 0.176** | -0.146** | -0.045 | 0.033 |
| DBP | | | | 1 | 0.745** | 0.208** | 0.171** | 0.179** | -0.078 | 0.090* | 0.234 |
| SBP | | | | | 1 | 0.232** | 0.211** | 0.235** | -0.113* | 0.123* | 0.258** |
| F Insulin | | | | | | 1 | 0.175** | 0.182** | -0.169** | -0.02 | 0.193** |
| FBS | | | | | | | 1 | 0.799** | -0.097* | 0.065 | 0.207** |
| HbA1c | | | | | | | | 1 | -0.144** | 0.04 | 0.198** |
| HDL-C | | | | | | | | | 1 | -0.016 | -0.326** |
| LDL-C | | | | | | | | | | 1 | 0.313** |
| TG | | | | | | | | | | | 1 |

*p<0.05 | **p<0.001; WC = Waist Circumference, WHR = Waist to Hip Ratio, BMI = Body Mass Index, SBP = Systolic Blood Pressure, DBP = Diastolic Blood Pressure, F Insulin = Fasting Insulin, HbA1c = Glycated Hemoglobin, HDL-C = High Density Lipoprotein-Cholesterol, LDL = Low Density Lipoprotein, TG = Triglycerides, VIT D3 =Vitamin D3, VIT B12 = Vitamin B12

**Table 2.** Characteristics of study participants represented as Mean (SD) (n=598)

| | WC Below 90cms (n=50) | WC 90-100cms (n=165) | WC 101-110cms (n=187) | WC Above 110cms (n=196) | p-value |
|---|---|---|---|---|---|
| Age (years) | 36.6 (9.8) | 38.7 (10.7) | 38.1 (10.7) | 39.1 (11.6) | 0.468 |
| Weight (kg) | 62.8 (9.9) | 78.8 (62.3) | 87.1 (9.9) | 105.6 (16.6) | <.001 |
| BMI (kg/m²) | 24.6 (3.7) | 28.3 (3.4) | 32.1 (4.0) | 37.5 (5.6) | <.001 |
| WHR | 0.84 (0.06) | 0.88 (0.06) | 0.92 (0.07) | 0.97 (0.08) | <.001 |
| SBP (mmHg) | 115.5 (17.1) | 117.4 (14.6) | 120.6 (14.4) | 125.4 (15.7) | <.001 |
| DBP (mmHg) | 76.7 (12) | 76.9 (8.9) | 79.1 (10.6) | 82.7 (9.8) | <.001 |
| HbA1c (%) | 5.6 (0.95) | 5.8 (0.83) | 5.9 (0.84) | 6.2 (1.08) | <.001 |
| FBS (mg/dL) | 95.6 (28.8) | 96.6 (21.3) | 100.4 (25.5) | 106.4 (27.1) | 0.0011 |
| F Insulin (microIU/mL) | 12.1 (7.8) | 15.5 (9.3) | 18.8 (11.6) | 26.1 (14.4) | <.001 |
| Cholesterol (mg/dL) | 188.4 (37.3) | 202.6 (138.6) | 187.2 (43.1) | 188.9 (40.3) | 0.595 |
| TG (mg/dL) | 126.3 (85.2) | 137.6 (60) | 154.7 (76.4) | 157.9 (66.2) | 0.0029 |
| HDL-C (mg/dL) | 51.4 (18) | 44.8 (13.5) | 42.1 (9.2) | 41 (10.2) | <.001 |
| LDL-C (mg/dL) | 117.7 (33.1) | 126.1 (34.3) | 121.7 (36.3) | 125.2 (33.8) | 0.338 |

WC = Waist Circumference, BMI = Body Mass Index, WHR = Waist to Hip Ratio, SBP = Systolic Blood Pressure, DBP = Diastolic Blood Pressure, HbA1c = Glycated Hemoglobin, FBS = Fasting Blood Sugar, F Insulin = Fasting Insulin ,TG = Triglycerides, HDL-C = High Density Lipoprotein-Cholesterol, LDL-C= Low Density Lipoprotein

group had a systolic blood pressure of 115.5 mmHg, while those in the above 110 cm group had a systolic blood pressure of 129.5 mmHg. (Fig. 4) Similarly, diastolic blood pressure increased from 76.1 mmHg in the below 90 cm group to 82.7 mmHg in the above 110 cm group. (Fig. 5) The statistical significance (p <0.001) confirms that abdominal obesity is closely associated with hypertension, likely due to increased vascular resistance, sympathetic nervous system activation, and metabolic dysfunction.

HDL-C levels declined significantly with increasing waist circumference, indicating worsening lipid profiles. Individuals with waist circumference below 90 cm had the highest HDL-C levels (51.4 mg/dL), whereas those in the waist circumference above 110 cm category had significantly lower HDL-C (41.0 mg/dL, p <0.001). (Fig. 6)

Since HDL-C is protective against cardiovascular disease, this result suggests that central obesity contributes to an increased risk of atherosclerosis and heart diseases. Triglyceride levels also increased with higher waist circumference. The below 90 cm waist circumference group had triglyceride levels of 126.3 mg/dL, while those with waist circumference above 110 cm had much higher levels (157.9 mg/dL, p <0.001). (Fig. 7) Elevated triglycerides are a major component of metabolic syndrome, reinforcing that central obesity is strongly linked to lipid metabolism disturbances.

Unlike HDL-C and triglycerides, LDL-C and total cholesterol levels did not show statistically significant differences across waist circumference categories. LDL-C levels ranged from 117.7 mg/dL (below 90 cm group) to 125.2 mg/dL (above 110 cm group) (p = 0.338).

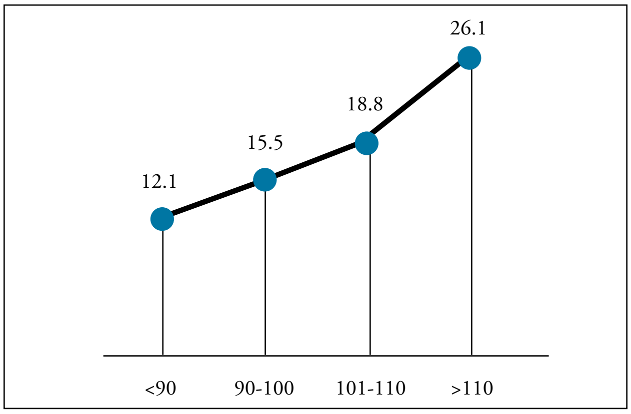


**Figure 1.** Increase in Fasting Insulin with increasing waist circumference,

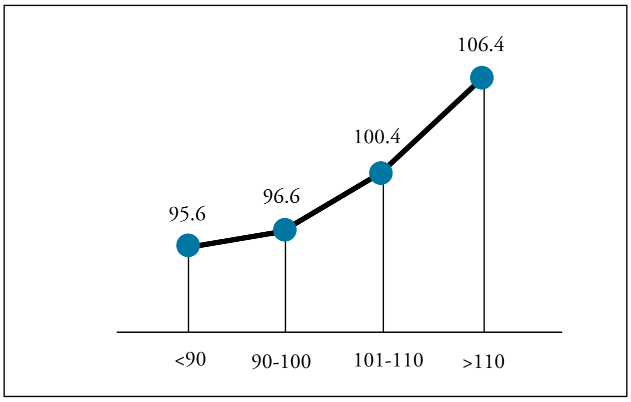


**Figure 2.** Increase in FBS values with increasing waist circumference.

Total cholesterol levels varied between 188.4 mg/dL (below 90 cm) and 189.8 mg/dL (above 110 cm) (p = 0.595). While LDL-C is traditionally considered a key cardiovascular risk marker,

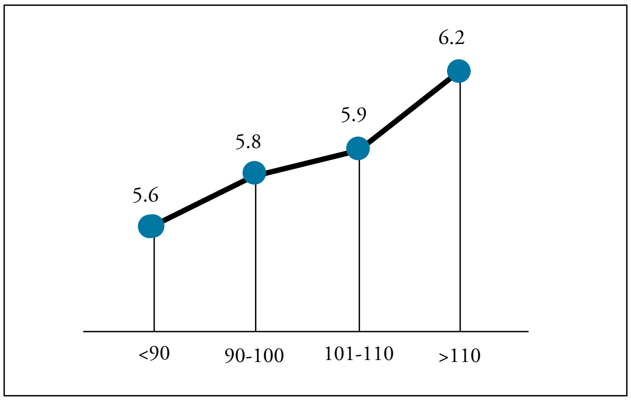


**Figure 3.** Increase in HbA1c values with increasing waist circumference.

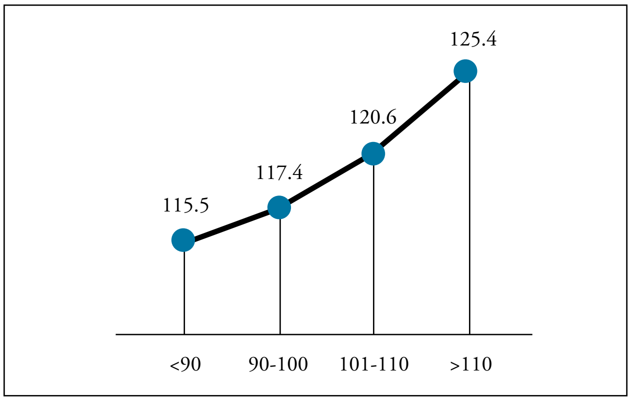


**Figure 4.** Increase in SBP values with increasing waist circumference.

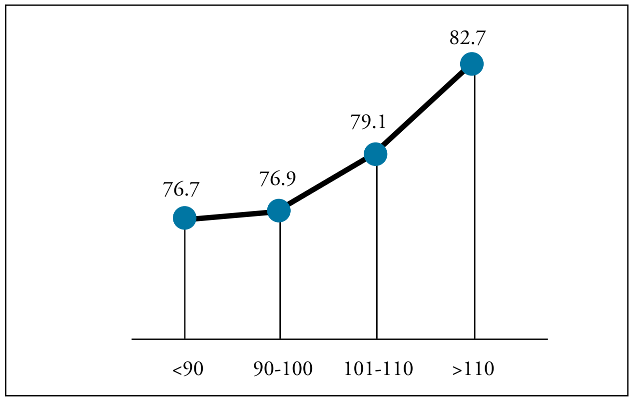


**Figure 5.** Increase in DBP values with increasing waist circumference.

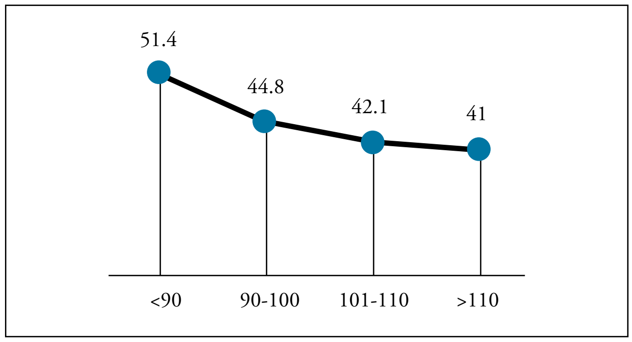


**Figure 6.** Decrease in HDL-C values with increasing waist circumference.

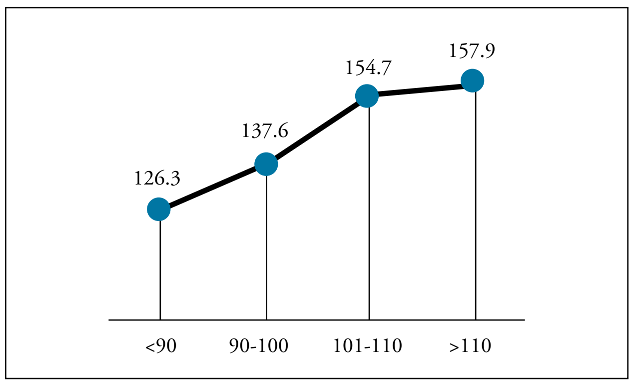


**Figure 7.** Increase in TG values with increasing waist circumference.

this finding suggests that central obesity may influence lipid metabolism primarily through lowering HDL-C and increasing triglycerides rather than significantly impacting LDL-C levels.

The ANOVA results provide strong statistical evidence that higher waist circumference is associated with progressive metabolic deterioration, particularly in glycemic control, insulin resistance, hypertension, and lipid imbalances. Given these findings, waist circumference should be prioritized in clinical assessments and public health interventions for obesity-related health risks, particularly for preventing metabolic syndrome and cardiovascular diseases.

Chi-Squared analysis with categorical variables as comorbidities (Zero, 1, 2 or 3) and DM status (Normal, Prediabetes & T2DM based on HbA1c) shows a statistically significant relationship ($p<0.05$) with Waist circumference (WC) categories (<90cms, 90-100cms, 101-110cms & >110cms). Prediabetes with central obesity were observed to have higher incidence of comorbidities.

## Discussion

With rising incidence of cardiometabolic complications in obese across all economic strata: our study attempts to identify simple , low-cost and clinically predictive risk factors for ease in detecting MetS and creating awareness for MetS prevention.

Our study showed that increased waist circumference was associated with impaired blood sugar regulation. Participants with waist circumference <90 cm had an average FBS of 95.6 mg/dL, while those above 110 cm had a higher FBS of 106.2 mg/dL ($p < 0.001$). HbA1c levels also increased from 5.6% to 6.2% across the same groups ($p < 0.001$). These results suggest that abdominal obesity may contribute to a higher risk of prediabetes and diabetes. Similarly, another study conducted by Liu, Y.et al.[4] determined the relationship between physical activity , abdominal obesity and metabolic markers in postmenopausal women and found that waist circumference positively correlates with metabolic markers diastolic blood pressure, triglycerides, and fasting glucose ($p<0.05$).

In our study, we found a positive correlation between waist circumference and triglyceride levels ($r = 0.147$, $p < 0.05$). This indicates that individuals with larger waist circumferences tend to have higher triglyceride levels, a key feature of dyslipidemia and metabolic syndrome. Since elevated triglycerides are linked to visceral fat and increased cardiovascular risk, waist circumference may serve as a simple and useful tool for identifying early lipid abnormalities. Xing Z. et al[6] have reported higher waist circumference to be associated with increased risks of Major Adverse Cardiovascular Events (MACEs) in males.

In our cohort, waist circumference showed a strong correlation with BMI ($r = 0.787$) and WHR ($r = 0.569$), both $p < 0.001$. Among these measures, waist circumference was most closely linked to metabolic risk, highlighting its value as a simple and effective tool for identifying central obesity and predicting metabolic syndrome. Shen W. et al.[7] examined the association between waist circumference and metabolic syndrome in a large cohort study; with findings predicting waist circumference as the strongest predictor of Metabolic Syndrome compared to BMI and WHR, reinforcing its clinical utility in metabolic risk assessment.

Our study results too projected waist circumference to have a strong significant correlation with BMI, insulin resistance, hypertension, glucose levels, and lipid abnormalities thus supporting the claim that waist circumference is as a key anthropometric measure for assessing obesity-related metabolic risks. Zhang X. et al.[8] investigated the impact of BMI and waist circumference changes on Metabolic Syndrome risk in older adults. The study concluded that reducing waist circumference significantly lowers the risk of metabolic syndrome, reinforcing its role as a primary obesity indicator.

Similarly, Ross, R. et al.[9] also emphasized the clinical relevance of waist circumference measurement in obesity-related health risks. Their review suggested that waist circumference should be routinely measured in clinical practice to detect Metabolic Syndrome early.

Ramírez-Manent et al.[1] studied waist circumference and insulin resistance in adults, finding a strong correlation between increased waist circumference and elevated insulin resistance, reinforcing its role in early Metabolic Syndrome detection. Likewise, we observed a significant positive correlation between waist circumference and fasting insulin levels ($r = 0.397$, $p < 0.001$), suggesting that individuals with higher waist circumference are more likely to exhibit insulin resistance. This supports the role of abdominal obesity as a key contributor to metabolic syndrome and a risk factor for type 2 diabetes.

We observed that as waist circumference increased across categories, there was a significant rise in both body mass index and body fat percentage ($p < 0.001$), highlighting a strong link between waist circumference and overall obesity. This aligns with findings by Lopez-Lopez J.P. et al.[10] as it emphasized the role of waist circumference as a predictive factor for the early detection of metabolic syndrome. The study proposed that incorporating waist circumference—a key anthropometric marker of central adiposity—alongside handgrip dynamometry for assessing relative muscle strength, and traditional adiposity indices such as waist-to-hip ratio (WHR), could enhance screening strategies aimed at identifying individuals at heightened risk for Metabolic Syndrome and cardiovascular disease (CVD).

Katzmarzyk et al.[11] assessed the association between waist circumference and mortality risk. The study concluded that waist circumference is a valuable component of Metabolic Syndrome and that an elevated waist circumference is associated with increased mortality risk, highlighting the importance of including waist circumference measurements in Metabolic Syndrome definitions.

Delavari A et al.[12] conducted a nationwide study to determine optimal waist circumference cut-off points for predicting Metabolic Syndrome in an Iranian population. The research identified specific waist circumference thresholds that effectively predict the presence of Metabolic Syndrome components, supporting the use of waist circumference measurements in diverse populations. Building on this, we also applied a classification of waist circumference into four categories—Below 90 cm, 90–100 cm, 101–110 cm, and Above 110 cm—to predict metabolic syndrome more precisely. A one-way analysis of variance (ANOVA) was performed to compare metabolic parameters across these groups, allowing us to evaluate the escalating impact of central obesity on critical metabolic risk factors.(Table 2)

In our study, analysis of variance revealed several significant trends, showing a progressive decline in metabolic health with increasing waist circumference. These findings further support the strong association between waist circumference and key components of metabolic syndrome. Goel et al.[13] examined the relationship between waist circumference and metabolic risk factors, finding that individuals with elevated waist circumference were significantly more likely to exhibit increased blood pressure, fasting glucose, and triglyceride levels. The study highlights the predictive value of central obesity in the early detection of metabolic syndrome and supports the use of waist circumference as a cost-effective and accessible screening tool, particularly in resource-limited settings where advanced diagnostic methods may not be readily available.

Similar trends were observed by Perona, J. S et al.[14] evaluating waist circumference and the abdominal volume index as predictors of Metabolic Syndrome in adolescents. The findings suggest that these measurements are effective, particularly when applying the International Diabetes Federation criteria. In our cohort, waist circumference was positively correlated with HbA1c ($r = 0.242$, $p < 0.001$) and fasting blood sugar ($r = 0.163$, $p < 0.05$), indicating that individuals with higher waist circumference tend to have poorer long-term and fasting glucose control. These findings reinforce the association between abdominal obesity and glucose dysregulation, key features of prediabetes and diabetes risk. Chanda et al.[15] also assessed the diagnostic accuracy of waist circumference in detecting Metabolic Syndrome among patients with type 2 diabetes mellitus, confirming waist circumference as a reliable measure for identifying Metabolic Syndrome in this population.

## Conclusion

Waist circumference serves as a simple, cost-effective noninvasive anthropometric marker of Metabolic Syndrome and can be used effectively for public health awareness, facilitate early identification of obesity-related comorbidities, and support strategies aimed at preventive health behaviours reducing healthcare burdens.

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