

Original Research Article

Anthropometric measures associated with diabetes mellitus: a comparative cross-sectional study among adults availing health services in an urban underprivileged area of Bangalore city

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ABSTRACT

Background: Diabetes affects about 12% of urban Indian adults. Obesity is a key risk factor, measurable through several anthropometric indices. This study examined which measures are most strongly associated with diabetes among adults in an underprivileged urban area of Bangalore.

Methods: A comparative cross-sectional study was conducted among adults aged ≥ 30 years attending a health centre. Socio-demographic, lifestyle, and dietary data were collected. Anthropometric parameters including body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), and waist-to-calf ratio (WCR) were assessed and compared between 84 diabetics and 84 non-diabetics. Independent t-test and Mann Whitney U tests were performed.

Results: Diabetics were over six times more likely to have higher WCR than non-diabetics (AOR=6.43; 95% CI: 1.90-21.7; $p=0.003$). No significant differences were found for BMI, WC, WHR, or WHtR. Dietary patterns differed significantly: diabetics were more likely to lack daily fruit and vegetable intake (AOR=3.2; 95% CI: 1.27-8.12; $p=0.002$) and more likely to consume fried, salty, or junk foods daily (AOR=9.14; 95% CI: 4.09-20.41; $p<0.001$). No notable differences were observed in hypertension, alcohol use, smoking, or physical activity.

Conclusions: Waist-to-calf ratio (WCR) is a significant marker of diabetes in this urban Indian population, alongside unhealthy dietary habits. Establishing appropriate WCR cut-offs could help identify high-risk individuals and guide early preventive interventions.

Keywords: Anthropometry, Diabetes mellitus, Obesity, Urban health

INTRODUCTION

The global burden of diabetes mellitus is on the rise. Data from 2019 indicated that India had 77 million individuals diagnosed with diabetes, a number projected to surpass 134 million by 2045. Alarming, 57% of these cases go undiagnosed.¹ Urban-dwelling Indian adults exhibit a diabetes prevalence of approximately 12%, manifesting a decade earlier than in their Western counterparts.² Moreover, the prevalence of type 2 diabetes is 4-6 times higher in urban areas compared to rural regions.³ Specific risk factors contributing to diabetes among Indians

include high familial clustering, central obesity, insulin resistance, and lifestyle alterations due to urbanization.⁴

Anthropometric measures such as body mass index (BMI), waist circumference (WC) and waist-to-hip ratio (WHR) are frequently employed to assess obesity, which is associated with an increased risk of developing diabetes and cardiovascular disease (CVD).⁵ In our population, a prevalent phenotype of diabetes presents with central obesity and peripheral sarcopenia, making BMI less reliable as a predictor of diabetes.⁶ Recent research from developed countries has identified novel

anthropometric indicators like waist-to-height ratio (WHtR) and waist-to-calf ratio (WCR) as predictors of diabetes.⁷⁻⁹

Anthropometric measurements offer a cost-effective and easily administered screening method for obesity, and are potentially valuable for predicting diabetes within resource-limited environments such as Indian urban underprivileged communities, which bear a significant burden of non-communicable diseases. However, there is a notable scarcity of medical literature examining anthropometric indicators like WHtR and WCR in predicting diabetes within this context. Therefore, there is a need to assess whether these newer anthropometric indicators, are associated with diabetes in Indian populations, given their demonstrated predictive efficacy in studies conducted in different settings.^{10,11}

Therefore, the current study was conducted to determine the anthropometric measures associated with diabetes mellitus among adults availing health services in an urban underprivileged area of Bangalore city.

METHODS

Study design and setting

This comparative cross-sectional study was conducted in 2022, at the urban health centre of a medical college, in Austin Town, an underprivileged area of Bangalore city.

Study population

Adults aged 30 years and above, availing health services or accompanying patients at the centre.

Sampling

Sample size was calculated using the formula $N = [2 (Z_{1-\alpha/2} + Z_{1-\beta})^2 \sigma^2] / d^2$ (where, $Z_{1-\alpha/2}$ = two sided Z value for corresponding $\alpha=1.96$, $Z_{1-\beta}$ = Z value for corresponding power of 80%, σ = pooled standard deviation calculated by the formula $\sqrt{(\sigma_1^2 + \sigma_2^2)/2}$, d = difference between 2 group means, where $d = \mu_1 - \mu_2$). Based on a previous study by Hajian et al among Iranian adults where mean waist circumference was found to be 92.5 ± 13.6 cm among non-diabetics and 99.5 ± 18.3 cm among diabetics, the sample size was calculated to be 84 diabetics and 84 non-diabetics.¹⁰

Sampling technique

Participants were consecutively enrolled until the sample size was achieved.

Inclusion criteria

Age above 30 years, both male and female were included in the study.

Exclusion criteria

Pregnant women, seriously ill or terminally ill patients, non-ambulatory patients and those with any condition that prevented them from comprehending or responding to questions.

Comparison groups

The comparison in this study was done between two groups: diabetics and non-diabetics.

Diabetics

Patients with diagnosed diabetes of at least 6 months duration or patients with clinic records of venous sample fasting blood sugar ≥ 126 mg/dl or venous sample post prandial blood sugar ≥ 200 mg/dl or venous random blood sugar ≥ 200 mg/dl within the last three months.¹²

Non-diabetics

These were age and gender-matched patients with no history of diabetes and with clinic records of venous fasting blood sugar < 100 mg/dl or venous post prandial blood sugar < 140 mg/dl within the last three months.

Ethical considerations

Institutional ethics committee approval was obtained (#89/2022). Informed consent was obtained from all participants prior to their enrollment in the study.

Data collection

Participants who fit the inclusion criteria, were interviewed using a structured interview-schedule that had been face-validated by two experts in the field of internal medicine and community medicine, prior to pre-testing it. This included sociodemographic details, lifestyle factors and medical history. Blood pressure was also recorded.

Anthropometric measurements were recorded in a separate examination area ensuring privacy of the participants. A female investigator examined the female subjects. Height was assessed to the nearest 0.1 cm with a portable stadiometer (Seca, Germany), while weight was recorded to the nearest 100 gm using a calibrated digital weighing scale (Salter, India). Waist circumference was measured to the nearest 0.1 cm at the midpoint between the lowest rib and the iliac crest in a horizontal plane. A non-stretchable measuring tape was used, ensuring a snug but not overly tight fit. Hip circumference was measured at the widest circumference of the hip. Calf circumference was measured at the point of largest circumference of calf with respondent standing straight, feet 20 cm apart, body weight equally distributed on both feet. One reading was taken from each leg and the average of the two readings was taken.

Statistical analysis

The data that was collected was entered into a Microsoft Excel sheet and later analyzed using standard statistical software package, IBM SPSS Statistics for Windows, version 20 (IBM Corp., Armonk, NY, USA). The variables were described using frequencies and percentages, mean, standard deviation, median and inter-quartile range. The diabetics and non-diabetics were compared with regards to socio-demographic variables and lifestyle factors using Chi square test and Fischer's exact test where applicable. Mann Whitney U test was used for difference between medians. Independent t-test was performed to study the difference between anthropometric measures among diabetics and non-

diabetics. Multi-variate regression was done to determine adjusted odds ratios with 95% confidence intervals. P value of <0.05 was considered as statistically significant for all analyses.

RESULTS

A total of 168 participants were enrolled in the study: 84 diabetics and 84 non-diabetics. Most of the participants (59.5%) were aged 45-60 years and a majority were female (84.5%). There was no significant difference in median per capita monthly income, median years of education and marital status among the two groups (Table 1).

Table 1: Comparison of diabetics and non-diabetics with respect to key socio-demographic variables.

Variables	Category	Diabetics N (%)	Non-diabetics N (%)	P value
Age (in years)	30-45	8 (9.5)	8 (9.5)	1.00*
	45-60	50 (59.5)	50 (59.5)	
	>60	26 (31.0)	26 (31.0)	
Gender	Male	13 (15.5)	13 (15.5)	1.00*
	Female	71 (84.5)	71 (84.5)	
Marital status	Married	70 (83.3)	74 (88.1)	0.37*
	Single/separated	14 (16.7)	10 (11.9)	
Years of education	Median (IQR)	5 (0, 8)	5 (0, 7)	0.45†
Per capita monthly income	Median (IQR)	2000 (1500, 2500)	2000 (1500, 2500)	0.83†

*Chi-square test, †Mann Whitney U test

Table 2: Comparison of diabetics and non-diabetics with respect to health and lifestyle factors.

Variables	Category	Diabetics N (%)	Non-diabetics N (%)	P value
Hypertension	Yes	39 (46.4)	38 (45.2)	0.87*
	No	45 (53.6)	46 (54.7)	
Smoker	Current smoker	5 (6.0)	9 (10.7)	1.24†
	Smoked more than a year ago	0 (0.0)	1 (1.2)	
	Has never smoked	79 (94.0)	74 (88.1)	
Consumes alcohol	Yes	7 (8.3)	6 (7.2)	0.08*
	No	77 (91.6)	78 (92.8)	
Physical Activity	Sedentary	40 (47.6)	32 (38.1)	1.55*
	Exercise for ≥150 min a week	44 (52.4)	52 (61.9)	
Consumption of salty/fried/junk foods	≥ Once in a day	42 (50.0)	58 (69.0)	0.01*
	Not daily	42 (50.0)	26 (31.0)	
Consumption of fruits and vegetables	≥ Once in a day	65 (77.3)	77 (91.6)	0.01*
	Not daily	19 (22.7)	7 (8.4)	

*Chi-square test, †Fischer's exact test

The median duration of diabetes mellitus among the diabetics was six years (IQR 4,8) and 63 (75%) of the cases had a follow-up visit with the doctor within the last 3 months.

There was no significant difference between diabetics and non-diabetics with regards to proportion of subjects with hypertension, smoking, alcohol consumption or physical activity. Diabetics were significantly more likely to report

daily consumption of salty/fried/junk foods ($p=0.01$), while also significantly more likely to report not consuming fruits and vegetables daily ($p=0.01$) (Table 2).

There was no significant difference between diabetics and non-diabetics with regards to key anthropometric assessments like weight, height, BMI, WHR and WHtR. However, WC ($p=0.01$), HC ($p=0.03$) and WCR ($p=0.005$) were significantly higher among the diabetics (Table 3).

Table 3: Comparison of diabetics and non-diabetics with respect to anthropometric measures.

Variable	Diabetics Mean±SD	Non-diabetics Mean±SD	P value*
Weight (kg)	67.97±13.4	66.13±11.9	0.34
Height (cm)	155.1±7.8	154.5±6.9	0.55
Waist circumference (cm)	97.2±9.8	93.7±9.0	0.01
Hip circumference (cm)	109.4±13.33	105.4±10.69	0.03
BMI	28.2±5.3	27.6±4.4	0.43
Waist-to-hip ratio	0.895±0.064	0.891±0.058	0.66
Waist-to-height ratio	0.63±0.076	0.6±0.059	0.22
Waist-to-calf ratio	2.97±0.44	2.80±0.28	0.005

*Independent sample t-test

Table 4: Multi-variate regression of factors associated with diabetes mellitus.

Variables	AOR (95% CI)	P value
Waist-to-Calf ratio	6.43 (1.90-21.7)	0.003*
Lack of daily consumption of fruits and vegetables	3.2 (1.27-8.12)	0.002*
Daily consumption of salty/fried/junk foods	9.14 (4.09-20.41)	<0.0001*

*Statistically significant at p<0.05.

However, on multivariate regression of factors associated with diabetes, WC and HC did not retain statistical significance. WCR was six times more likely to be higher among diabetics than non-diabetics [AOR=6.43 (1.90-21.7), p=0.003]. It was also found that in comparison to non-diabetics, diabetics were three times more likely to lack daily consumption of fruits and vegetables [AOR=3.2 (1.27-8.12), p=0.002] and nine times more likely to consume salty/fried/junk foods daily [AOR=9.14 (4.09-20.41), p<0.001] (Table 4).

DISCUSSION

In the present study there was no significant difference in the BMI between diabetics and non-diabetics. This may be because BMI is a simple measure of body weight relative to height and does not account for body composition. Indians tend to have higher levels of visceral fat, which is associated with insulin resistance and metabolic syndrome, even at lower BMI levels. Therefore, individuals with apparently normal BMIs may still have an unhealthy distribution of body fat, putting them at risk for diabetes.¹³ The theory has been proposed that the increased vulnerability to diabetes among South Asians may be established evolutionarily through two mechanisms: diminished beta cell function and compromised insulin activity due to decreased lean mass and increased visceral fat.¹⁴ This theory finds resonance in our study, which found that diabetics had over six times greater chance of higher waist-to-calf ratio as compared to non-diabetics. Central obesity indicates visceral adiposity, which is strongly linked to insulin resistance, a hallmark of type 2 diabetes.¹⁵ While waist circumference often serves as a proxy for central obesity, WCR provides additional information by considering both central obesity and lean muscle mass. The calf circumference reflects muscle mass, which is an

important factor in glucose metabolism. A lower calf circumference may indicate lower muscle mass, which is associated with insulin resistance and an increased risk of type 2 diabetes. Increased WCR therefore suggests not only the presence of excess fat but also the lack of protective effect of muscle.¹⁶ In another study in China, it was found that among diabetics, the risk of sarcopenia tripled in the highest tertile group of WCR.¹⁷ Higher WCR was linked to carotid artery intima media thickening among diabetics in a study in Mangalore indicating increased risk of cerebro-vascular disease.¹⁸

In our study, of all the anthropometric measures documented, WCR was the only anthropometric measure that retained statistical significance after regression analysis. This finding shines a spotlight on the importance of WCR as predictor for diabetes, compared to other anthropometric measures. A Chinese longitudinal health longevity survey found that among 4627 participants, WCR outperformed WC and BMI as a predictor of both all-cause and cause-specific mortality indicating that WCR can be of predictive value when it comes to CVD risk as well.⁸

This study has shown that WCR was six times more likely to be higher among diabetics than non-diabetics. There are a few studies which provide insights into the potential utility of WCR as a risk indicator for diabetes or cardio-vascular disease, but they do not establish definitive cut-off values applicable to all populations.^{8,19} An extensive review of literature reveals that there is very little knowledge regarding WCR cut-offs to determine risk of diabetes or cardio-vascular disease. The proposed thresholds may vary based on factors such as ethnicity, age, and overall health status. Therefore, further large-scale studies are necessary to determine standardized WCR cut-off points for

assessing the risk of diabetes and cardiovascular diseases, especially in the Indian population. Incorporating WCR into diabetes risk assessment could provide additional insights and improve risk stratification. It could help identify individuals at higher risk of diabetes who may benefit from early intervention strategies such as lifestyle modifications. However, it is important to note that the WCR, like any single measurement, should be interpreted in the context of other risk factors and clinical assessments. It is not a stand-alone diagnostic tool but rather a complementary metric that adds to our understanding of metabolic health and diabetes risk.

The findings of our study also shed light on the relationship between dietary habits and diabetes. While we did not observe significant differences in traditional risk factors such as hypertension, smoking, alcohol consumption, or physical activity between diabetics and non-diabetics, we found that daily consumption of salty/fried/junk foods was linked to a nine-fold increase in risk of diabetes. This is consistent with existing literature linking unhealthy dietary choices to the development and exacerbation of diabetes. High intake of processed and high-calorie foods rich in salt and unhealthy fats has been implicated in insulin resistance, dyslipidemia, and obesity, all of which contribute to the pathogenesis of diabetes.^{20,21} We also found that lack of daily consumption of fruits and vegetables was associated with three times the risk of diabetes. This observation aligns with established evidence highlighting the protective effects of a diet rich in fruits and vegetables against diabetes.^{21,22} Our findings emphasize the need for targeted dietary interventions aimed at reducing the consumption of salty/fried/junk foods and encouraging a plant-based diet as a preventive measure against the development of diabetes.

Though healthy eating guidelines advocate the consumption of at least four to five servings of fruits and vegetables per day, in the urban underprivileged area where our study was conducted, overall consumption of fruits and vegetables was inadequate.²³ In contrast, the consumption of salty/fried/junk foods was rampant. Fresh fruits and vegetables can be relatively expensive compared to processed or unhealthy foods. For families living on a tight budget, purchasing fresh produce might not always be feasible, as poor households may not have access to adequate refrigeration or storage facilities, leading to a higher likelihood of fruits and vegetables spoiling due to limited shelf life. Healthy snack options can also be a challenge in resource and time-constrained populations.

There are some limitations of the study. The cross-sectional design of our study precludes a predictive inference of WCR in terms of risk of diabetes or CVD, for which a longitudinal study would be needed. The reliance on self-reported dietary and lifestyle data, may be subject to recall and social desirability biases.

CONCLUSION

Our study found that WCR was significantly higher among diabetics than non-diabetics. There was no significant difference in the other anthropometric measures. It was also found that in comparison to non-diabetics, diabetics were significantly more likely to lack daily consumption of fruits and vegetables and consume salty/fried/junk foods daily. Further research into determining the appropriate cut-offs for WCR in the Indian population, could help identify individuals at higher risk of diabetes who may benefit from early intervention strategies such as lifestyle modifications.

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Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee (IEC Approval # 89/2022)

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