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Waist-to-Calf Ratio as a Novel Anthropometric Marker of Carotid Atherosclerosis in Patients with Type 2 Diabetes Mellitus: A Cross-Sectional Study.

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Abstract

Background: Type 2 diabetes mellitus (T2DM) is associated with an increased risk of cardiovascular disease due to accelerated atherosclerosis. Carotid intima–media thickness (CIMT) measured by B-mode ultrasonography is a reliable non-invasive marker for early detection of atherosclerosis. Anthropometric indicators reflecting body fat distribution, particularly the waist-to-calf ratio (WCR), may help identify individuals at higher cardiovascular risk. ***Material and Methods***: This observational cross-sectional study was conducted in the Department of General Medicine, NRI General Hospital, Chinakakani, Guntur, from April 2022 to March 2024. A total of 100 patients with type 2 diabetes mellitus were included. Anthropometric measurements such as waist circumference and calf circumference were recorded and WCR was calculated. CIMT was assessed using carotid Doppler ultrasonography. Statistical analysis was performed using SPSS version 20, and a p-value <0.05 was considered statistically significant. ***Results***: Abnormal CIMT was observed in 22% of patients. Duration of diabetes (p = 0.001) and abnormal ECG findings (p = 0.001) showed significant associations with CIMT. Waist circumference (p = 0.04), calf circumference (p = 0.03), and waist-to-calf ratio (p = 0.001) were also significantly associated with carotid atherosclerosis. ***Conclusion***: Waist-to-calf ratio showed a significant association with carotid atherosclerosis in patients with type 2 diabetes mellitus. It may serve as a simple and useful anthropometric marker for identifying diabetic patients at increased risk of subclinical cardiovascular disease.

Keywords: Type 2 diabetes mellitus; carotid intima-media thickness; waist-to-calf ratio; central obesity; carotid atherosclerosis.

INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of morbidity and mortality worldwide and is strongly associated with metabolic disorders such as type 2 diabetes mellitus (T2DM). Individuals with diabetes have a significantly increased risk of developing atherosclerotic cardiovascular disease due to mechanisms including chronic hyperglycemia, insulin resistance, endothelial dysfunction, oxidative stress, and systemic inflammation. Early identification of markers that can predict atherosclerosis in diabetic patients is therefore essential for risk stratification and implementation of preventive strategies (1).

Obesity is a well-recognized risk factor for cardiovascular disease; however, recent evidence suggests that body fat distribution plays a more critical role than total body mass alone in determining cardiometabolic risk. Central obesity, typically assessed by waist circumference (WC), reflects visceral fat accumulation and is strongly associated with insulin resistance, dyslipidemia, hypertension, and increased risk of cardiovascular events. Numerous epidemiological studies have demonstrated that increased waist circumference is closely linked with higher incidence of coronary artery disease and stroke, particularly among individuals with diabetes (2).

While the harmful effects of central adiposity are well established, the role of peripheral body composition, especially skeletal muscle mass, has gained increasing attention. Peripheral muscle mass may exert protective metabolic effects by enhancing insulin sensitivity and improving glucose metabolism. Anthropometric measures that reflect peripheral body composition may therefore provide additional insight into cardiovascular risk beyond traditional indices such as body mass index (BMI). However, the clinical significance of such measurements has not been extensively explored (3).

Among these measurements, calf circumference (CC) is a simple and practical anthropometric parameter that reflects peripheral muscle mass and subcutaneous fat stores. It has long been used in geriatric medicine as an indicator of nutritional status and sarcopenia. Reduced calf circumference is often associated with muscle loss, decreased functional capacity, and increased risk of adverse health outcomes, whereas larger calf circumference generally indicates better muscle mass and improved metabolic health (4).

Recent studies have suggested a potential relationship between peripheral anthropometric measures and cardiovascular disease. Lower calf or thigh circumference has been associated with increased insulin resistance, metabolic syndrome, and subclinical atherosclerosis. In particular, several investigations have reported an inverse relationship between calf circumference and carotid artery plaque formation, indicating that reduced peripheral muscle mass may contribute to vascular pathology (5).

The waist-to-calf ratio (WCR) has recently been proposed as a novel anthropometric index that combines measures of central adiposity and peripheral muscle mass. While waist circumference reflects visceral fat accumulation, calf circumference represents peripheral body composition. A higher waist-to-calf ratio may therefore indicate an unfavorable combination of increased abdominal fat and reduced peripheral muscle mass, which could contribute to elevated cardiovascular risk. However, limited data are available regarding the association between WCR and subclinical atherosclerosis, particularly among patients with type 2 diabetes mellitus (6).

Assessment of early vascular changes is important for preventing cardiovascular complications in high-risk populations. B-mode ultrasonography of the carotid arteries is a widely used non-invasive technique for detecting subclinical atherosclerosis. Measurement of carotid intima-media thickness (CIMT) and identification of carotid plaques using ultrasound provide valuable information about early atherosclerotic changes and have been shown to predict future cardiovascular events (7).

In view of these considerations, the present study was undertaken to evaluate the association between waist-to-calf ratio and carotid atherosclerosis in patients with type 2 diabetes mellitus. The study aims to measure the waist-to-calf ratio in patients with type 2 diabetes mellitus, to screen these patients for carotid atherosclerosis using carotid Doppler ultrasonography, and to analyze the correlation between waist-to-calf ratio and the presence of carotid atherosclerosis in this population.

MATERIALS AND METHODS

Study Design and Setting

This observational cross-sectional study was conducted in the Department of General Medicine at NRI General Hospital, Chinakakani, Guntur, Andhra Pradesh, India. The study was carried out over a period of two years, from April 2022 to March 2024.

Study Population and Sample Size

The study included patients diagnosed with type 2 diabetes mellitus attending the outpatient and inpatient departments of General Medicine during the study period. A total sample size of 100 patients was selected using consecutive non-probability sampling.

Inclusion Criteria

Adult patients diagnosed with type 2 diabetes mellitus according to the American Diabetes Association (ADA) criteria (2016) were included in the study. Patients were considered to have diabetes mellitus if any of the following criteria were met:

1. Fasting plasma glucose (FPG) ≥126 mg/dL (7.0 mmol/L) after at least 8 hours of fasting.
2. Two-hour plasma glucose ≥200 mg/dL (11.1 mmol/L) during an oral glucose tolerance test (OGTT) using 75 g of anhydrous glucose dissolved in water.
3. Glycated hemoglobin (HbA1c) ≥6.5% (48 mmol/mol).
4. Random plasma glucose ≥200 mg/dL (11.1 mmol/L) in a patient with classic symptoms of hyperglycemia or hyperglycemic crisis.

For all selected patients, detailed clinical history, physical examination, anthropometric measurements, and relevant biochemical investigations were recorded.

Exclusion Criteria

Patients meeting any of the following criteria were excluded from the study:

1. History of cerebrovascular disease.
2. History of peripheral vascular disease.

3. History of muscular dystrophy, limb deformities, or previous lower limb surgeries that could affect anthropometric measurements.
4. Patients diagnosed with type 1 diabetes mellitus.

Data Collection

Data were collected using a structured questionnaire designed for the study, incorporating variables reported in previous related research. The questionnaire included information on demographic characteristics, clinical history, and relevant risk factors. Anthropometric and clinical measurements were obtained using standardized procedures.

Anthropometric Measurements

Anthropometric parameters including height, weight, waist circumference, and calf circumference were measured for all participants.

Waist circumference was measured at the midpoint between the lower margin of the last palpable rib and the iliac crest at the end of normal expiration using a non-stretchable measuring tape.

Calf circumference was measured at the maximum circumference of the calf while the participant stood upright with body weight evenly distributed on both feet. Measurements were taken for both legs, and the average of the two readings was used for analysis.

The waist-to-calf ratio (WCR) was calculated as the ratio of waist circumference (WC) to calf circumference (CC).

Interpretation of Waist-to-Calf Ratio

Although universal cut-offs are still evolving, several studies provide approximate interpretation ranges:

Waist - Calf Ratio	Interpretation
< 2.2	Lower cardiometabolic risk
2.2 - 2.6	Moderate metabolic risk
> 2.6	Higher risk of insulin resistance and vascular disease

Higher ratios indicate disproportionate central adiposity relative to peripheral muscle mass, which is linked with metabolic dysfunction.

Carotid Ultrasound Assessment

Carotid atherosclerosis was evaluated using high-resolution B-mode ultrasonography. Bilateral common carotid arteries (CCA) were examined using a 10 MHz linear transducer.

Ultrasound scanning was performed at the mid and distal segments of the common carotid artery using a lateral longitudinal projection. Carotid intima-media thickness (CIMT) was measured at three points on the far wall of the mid and distal common carotid artery and 1 cm proximal to the carotid bulb dilation.

The mean value of six measurements (three from the right CCA and three from the left CCA) was calculated and used for analysis.

CIMT was defined as the distance between the lumen–intima interface and the media–adventitia interface.

A carotid plaque was defined as a focal area of hyperechogenicity or protrusion into the arterial lumen with a thickness at least 50% greater than that of the surrounding arterial wall.

Carotid atherosclerosis was defined as the presence of either focal carotid plaque or diffuse thickening of the carotid arterial wall with CIMT ≥1.1 mm.

Statistical Analysis

The collected data were entered into Microsoft Excel 2016 and analyzed using SPSS software version 20. Categorical variables were expressed as frequencies and percentages, whereas continuous variables were presented as mean ± standard deviation (SD) and median values where appropriate. For comparison of quantitative variables between groups, the unpaired Student's t-test was used. Associations between categorical variables were assessed using the Chi-square test or Fisher's exact test where appropriate. A p-value <0.05 was considered statistically significant.

Ethical Considerations

The study was conducted after obtaining approval from the Institutional Ethics Committee of NRI General Hospital. Written informed consent was obtained from all participants prior to enrollment. Confidentiality and privacy of patient information were strictly maintained throughout the study.

RESULTS

Table 1. Age and Gender Distribution of Study Participants (n = 100)

Variable	Category	Number (n)	Percentage (%)
Age Group (years)	< 40	10	10.0
	41 – 50	33	33.0
	51 – 60	24	24.0
	61 – 70	22	22.0
	> 70	11	11.0
	Total	**100**	**100.0**
Gender	Male	70	70.0
	Female	30	30.0
	Total	**100**	**100.0**

Among the 100 study participants with type 2 diabetes mellitus, the majority belonged to the 41–50 years age group (33%), followed by 51–60 years (24%) and 61–70 years (22%). Only 10% of the patients were below 40 years of age, while 11% were above 70 years. Regarding gender distribution, males constituted the majority of the study population (70%), whereas females accounted for 30%, indicating a male predominance in the study sample.

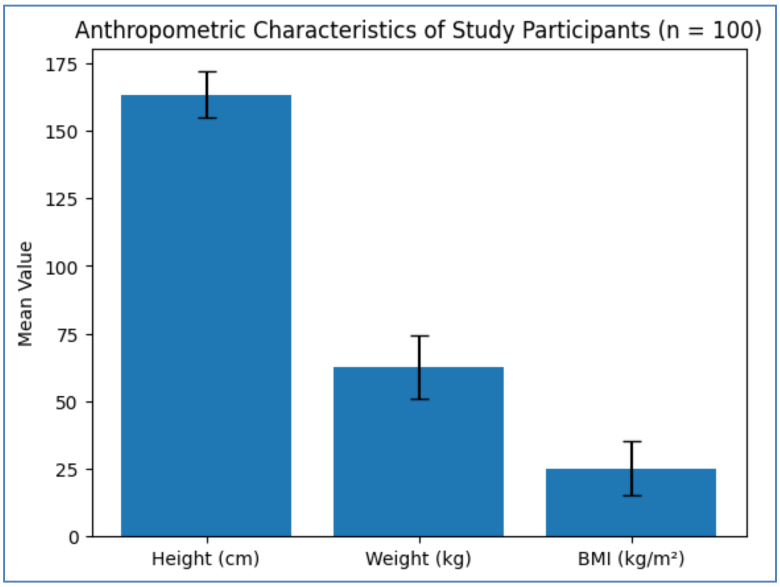

Figure 1. Anthropometric Characteristics of Study Participants (n = 100)

The mean height of the study participants was 163.25 ± 8.52 cm, while the mean body weight was 62.73 ± 11.68 kg. The average body mass index (BMI) of the participants was 25.2 ± 9.94 kg/m², indicating that the overall study population was in the overweight range according to standard BMI classification, which is commonly observed among patients with type 2 diabetes mellitus (Figure 1).

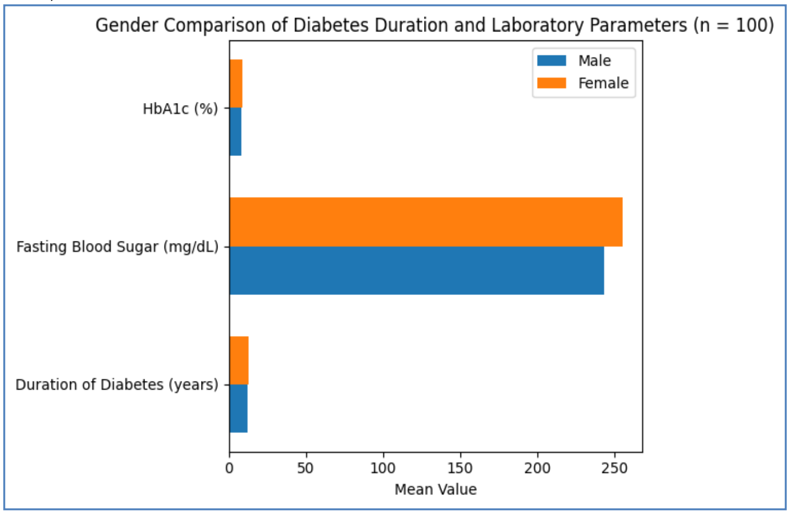

Figure 2. Comparison of Duration of Diabetes and Laboratory Parameters According to Gender (n = 100)

The mean duration of diabetes among male patients was 12.45 ± 5.32 years, while among females it was 13.09 ± 5.36 years, with no statistically significant difference between the groups (p = 0.583). Similarly, the mean fasting blood sugar (FBS) levels were 243.46 ± 27.64 mg/dL in males and 255.36 ± 36.00 mg/dL in females, which also did not show a statistically significant difference (p = 0.075). The mean HbA1c levels were 8.41 ± 2.40% in males and 8.59 ± 3.60% in females, again demonstrating no significant gender-based variation (p = 0.769). These findings indicate that glycemic control and duration of diabetes were comparable between male and female participants in the study (Figure 2).

Table 2. Association of Clinical Factors with Carotid Intima–Media Thickness (CIMT) (n = 100)

Variable	Category	Abnormal CIMT n (%)	Normal CIMT n (%)	Total n (%)	χ^2	p-value
Gender	Male	12 (17.1)	58 (82.9)	70 (100.0)	0.320	0.073
	Female	10 (33.3)	20 (66.7)	30 (100.0)		
Duration of Diabetes (Years)	1–10	3 (5.7)	50 (94.3)	53 (100.0)	20.5	0.001*
	11–20	12 (34.3)	23 (65.7)	35 (100.0)		
	>20	7 (58.3)	5 (41.7)	12 (100.0)		
ECG Findings	Normal	5 (8.2)	56 (91.8)	61 (100.0)	17.3	0.001*
	Abnormal	17 (43.6)	22 (56.4)	39 (100.0)		

Table 2 shows the relationship between selected clinical factors and carotid intima–media thickness (CIMT) among the study participants (n = 100). With respect to gender distribution, abnormal CIMT was observed in 12 (17.1%) males and 10 (33.3%) females, while 58 (82.9%) males and 20 (66.7%) females had normal CIMT. Although a relatively higher proportion of females showed abnormal CIMT compared to males, the association between gender and CIMT was not statistically significant (χ^2 = 0.320, p = 0.073).

A significant association was observed between duration of diabetes and CIMT (χ^2 = 20.5, p = 0.001). Among patients with diabetes duration of 1–10 years, only 3 (5.7%) had abnormal CIMT, whereas the proportion increased markedly to 12 (34.3%) in those with 11–20 years of diabetes and 7 (58.3%) in patients with diabetes duration greater than 20 years. This finding indicates that longer duration of diabetes is strongly associated with increased CIMT, suggesting progressive subclinical atherosclerosis with chronic disease duration.
Similarly, ECG findings showed a statistically significant association with CIMT (χ^2 = 17.3, p = 0.001). Among participants with normal ECG, only 5 (8.2%) had abnormal CIMT, while 17 (43.6%) of those with abnormal ECG findings demonstrated abnormal CIMT. This suggests that patients with abnormal ECG changes are more likely to have increased CIMT, indicating a possible relationship between subclinical carotid atherosclerosis and cardiovascular abnormalities.

Table 3. Association of Anthropometric Parameters with Carotid Intima–Media Thickness (CIMT) (n = 100)

Variable	Category	Abnormal CIMT n (%)	Normal CIMT n (%)	Total n (%)	χ^2	p-value
Waist Circumference (cm)	≤80	0 (0.0)	4 (5.1)	4 (4.0)	8.11	0.04*
	81–100	10 (45.5)	53 (67.9)	63 (63.0)		
	100–140	12 (54.5)	19 (24.4)	31 (31.0)		
	>140	0 (0.0)	2 (2.6)	2 (2.0)		
Calf Circumference (cm)	20–25	1 (4.5)	1 (1.3)	2 (2.0)	8.35	0.03*
	26–30	17 (77.3)	37 (47.4)	54 (54.0)		
	31–40	4 (18.2)	34 (43.6)	38 (38.0)		
	>40	0 (0.0)	6 (7.7)	6 (6.0)		
Waist–Calf Ratio	<3	0 (0.0)	24 (30.8)	24 (24.0)	46.73	0.001*
	3–3.5	7 (31.8)	50 (64.1)	57 (57.0)		
	3.6–4	12 (54.5)	4 (5.1)	16 (16.0)		
	4–4.5	2 (9.1)	0 (0.0)	2 (2.0)		
	>4.5	1 (4.5)	0 (0.0)	1 (1.0)		

The association between anthropometric measurements and carotid intima–media thickness (CIMT) is presented in the table. Waist circumference showed a statistically significant association with CIMT (χ^2 = 8.11, p = 0.04). Among

individuals with abnormal CIMT, 12 (54.5%) had a waist circumference of 100–140 cm, while 10 (45.5%) were in the 81–100 cm category. None of the participants with waist circumference ≤80 cm or >140 cm showed abnormal CIMT. In contrast, most participants with normal CIMT were in the 81–100 cm category (53; 67.9%). This indicates that increasing waist circumference, particularly in the 100–140 cm range, is associated with a higher prevalence of abnormal CIMT.
A statistically significant association was also observed between calf circumference and CIMT ($\chi^2 = 8.35$, $p = 0.03$). The majority of participants with abnormal CIMT had calf circumference between 26–30 cm (17; 77.3%), followed by 31–40 cm (4; 18.2%), while only 1 (4.5%) participant belonged to the 20–25 cm category. Participants with normal CIMT were more frequently seen in the 26–30 cm (37; 47.4%) and 31–40 cm (34; 43.6%) categories. These findings suggest that variations in calf circumference may be associated with differences in vascular changes.

The waist–calf ratio demonstrated a highly significant association with CIMT ($\chi^2 = 46.73$, $p = 0.001$). Most individuals with abnormal CIMT had a waist–calf ratio between 3.6–4 (12; 54.5%), followed by 3–3.5 (7; 31.8%), while smaller proportions were observed in 4–4.5 (2; 9.1%) and >4.5 (1; 4.5%) categories. In contrast, participants with normal CIMT were predominantly in the 3–3.5 ratio category (50; 64.1%) and <3 category (24; 30.8%). Notably, none of the individuals with a waist–calf ratio below 3 had abnormal CIMT.
Overall, these findings indicate that higher waist circumference and increased waist–calf ratio are significantly associated with abnormal CIMT, suggesting that central adiposity and body fat distribution play an important role in the development of subclinical atherosclerosis (Table 3).

DISCUSSION

The present study evaluated the association between waist-to-calf ratio (WCR) and carotid atherosclerosis in patients with type 2 diabetes mellitus using carotid intima–media thickness (CIMT) as a marker of subclinical atherosclerosis. Diabetes mellitus accelerates atherosclerosis through mechanisms such as chronic hyperglycemia, oxidative stress, and endothelial dysfunction. CIMT is a well-established non-invasive indicator of early vascular changes and has been widely used to identify individuals at increased cardiovascular risk (8).

In the present study, 22% of the patients had abnormal CIMT, indicating the presence of subclinical carotid atherosclerosis among diabetic individuals. Similar findings have been reported in previous studies where increased CIMT was commonly observed in patients with long-standing diabetes and was associated with increased risk of cardiovascular disease (8).
In the present study, abnormal CIMT was observed in 17.1% of males and 33.3% of females, but the difference was not statistically significant ($p = 0.073$). This suggests that gender alone may not significantly influence the development of carotid atherosclerosis in diabetic patients. Xuereb et al. also reported that gender differences were not independently associated with CIMT when metabolic risk factors were considered, indicating that vascular risk is more strongly related to metabolic abnormalities than gender itself (9).

A significant association was observed between duration of diabetes and CIMT ($p = 0.001$) in the present study. Patients with longer duration of diabetes (>20 years) had a markedly higher prevalence of abnormal CIMT compared to those with shorter duration. Similar observations were reported by Mykkänen et al., who demonstrated that long-standing diabetes is associated with increased CIMT and early vascular changes due to prolonged exposure to hyperglycemia and metabolic disturbances (10). These findings highlight the importance of early glycemic control in preventing vascular complications.
The present study also showed a significant association between ECG abnormalities and CIMT ($p = 0.001$). Patients with abnormal ECG findings had a higher prevalence of abnormal CIMT compared to those with normal ECG. ECG abnormalities may indicate underlying ischemic heart disease or structural cardiac changes, which are often associated with systemic atherosclerosis. Therefore, abnormal ECG findings in diabetic patients may serve as an indicator of increased cardiovascular risk.

A significant association was found between waist circumference and CIMT ($p = 0.04$). Patients with higher waist circumference showed a greater prevalence of abnormal CIMT, indicating the role of central obesity in the development of atherosclerosis. Central adiposity is associated with increased visceral fat, which contributes to insulin resistance and systemic inflammation, both of which are important mechanisms in atherosclerosis.

Calf circumference reflects peripheral muscle mass and subcutaneous fat distribution. In the present study, lower calf circumference was associated with increased CIMT ($p = 0.03$). Reduced skeletal muscle mass may worsen insulin resistance and metabolic dysfunction, thereby contributing to vascular damage. Previous studies have also suggested that greater peripheral muscle mass may have a protective role against cardiovascular disease.

The most significant finding of the present study was the strong association between waist-to-calf ratio and CIMT ($p = 0.001$). Higher WCR values were associated with a greater prevalence of abnormal CIMT. Kim et al. demonstrated that higher waist-to-calf ratio was significantly associated with carotid atherosclerosis in patients with type 2 diabetes, suggesting that WCR may be a useful marker of cardiovascular risk (11). Similar findings were reported by Rao et al., who showed that WCR correlates with increased CIMT and metabolic risk factors (12). Recent studies have also suggested that WCR may predict cardiometabolic risk more effectively than BMI or waist circumference alone (13).

CONCLUSION

The present study demonstrated that waist-to-calf ratio is significantly associated with carotid atherosclerosis in patients with type 2 diabetes mellitus. Increased waist circumference and higher WCR were associated with higher prevalence of abnormal CIMT, whereas larger calf circumference appeared to have a protective association. Duration of diabetes and abnormal ECG findings were also significantly associated with CIMT. These findings suggest that waist-to-calf ratio may serve as a simple and useful anthropometric marker for identifying diabetic patients at increased risk of subclinical atherosclerosis and cardiovascular disease.

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