

Prevalence of peripheral arterial disease using plethysmographic ankle brachial index and correlation with carotid intima-media thickness among adult diabetics in University of Benin Teaching Hospital

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Abstract

Background: Diabetes mellitus is an important risk factor for the development of atherosclerosis which leads to macrovascular and cardiovascular complications such as peripheral arterial disease (PAD). PAD has been associated with an increased risk of lower limb amputation, morbidity, and mortality from major cardiovascular events such as stroke and myocardial infarction.

Materials and Methods: This was a prospective cross-sectional descriptive study which involved the use of an automated ankle-brachial index (ABI) assessment known as plethysmography to determine the prevalence of PAD and to analyze the pulse volume waveform (PVW) among 100 people living with diabetes. The ABI values were correlated with the subject's common carotid artery intima-media thickness (CCA-IMT). Collated data were analyzed using the Statistical Package for the Social Sciences version 20.0. Statistical tests were considered significant at $P < 0.05$ and 95% confidence interval.

Results: Twenty-three (23%) had ABI of ≤ 0.9 indicating PAD, while 75 (75%) had normal ABI indicating those without the disease. The presence of PAD correlated significantly with abnormal PVW pattern ($P = 0.0001$). The mean CCA-IMT from this study was 1.01 ± 0.28 mm. A statistically significant correlation was found between the PAD, mean CCA-IMT and right CCA-IMT ($P = 0.017$, $r = 0.238$ and $P = 0.003$, $r = 0.290$).

Conclusion: The prevalence of PAD in type 2 diabetics was found to be 23% in this study; in addition, a significant correlation of PAD with CCA-IMT and other risk factors for diabetes was also found. Hence, screening for PAD should be done in all diabetic patients to detect this complication early.

Keywords: Ankle-brachial index, common carotid artery intima-media thickness, diabetes mellitus, peripheral arterial disease, plethysmography

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INTRODUCTION

Diabetic mellitus (DM) is a metabolic disorder of chronic hyperglycemia characterized by disturbance in carbohydrate, protein, and fat metabolism resulting from absolute or relative insulin deficiency.^[1] There are two principal forms of the disease: type 1 and type 2. Type 2 diabetes is more common and accounts for around 90% of all diabetes cases worldwide.^[2] The latest prevalence of DM by the International Diabetes Federation is put at 425 million persons worldwide, with nearly 50% of these undiagnosed.^[3] In Nigeria, the current estimated prevalence of DM is 5%.^[4] Peripheral arterial disease (PAD) is one of the macrovascular and cardiovascular complications of DM, and it is related to the atherosclerotic and thromboembolic processes affecting the aorta, visceral branches, and the arteries of the lower limbs.^[5] Functional changes such as arterial wall stiffness and flow-mediated dilatation occur first in the arteries, leading to the loss of elasticity.^[6] This is followed by structural changes such as fatty degeneration and foam cell formation with resultant intima-media thickening, plaque formation, and finally clogging of the artery.^[6] The plaques eventually can rupture and lead to thrombus formation.^[6] This atherosclerotic process leads to narrowing of the major arteries of the lower limb.^[7] Significant narrowing can lead to ischemia of the tissue supplied by the affected artery, with the attendant signs and symptoms of the disease. The most common symptom of PAD is intermittent claudication.^[8] Other complications include rest pain, ulceration, and gangrene with increased risk of limb amputation and major cardiovascular events such as stroke and myocardial infarction.^[8] Other terms used for this condition are peripheral vascular disease, peripheral arterial occlusive disease, and lower extremity arterial disease.^[6] Among individuals aged 40 years and older, the prevalence of PAD is 4.3%, ranging from 3.1% to 5.5%; however, the prevalence in individuals with diabetes ranges from 20% to 30%.^[9] Other risk factors for the development of PAD include smoking, obesity, hypertension, and dyslipidemia. Smoking and diabetes are said to have the strongest association.^[9]

The ankle-brachial index (ABI) is a method of assessing the presence of PAD, and it is the ratio of the systolic blood pressure at the ankle to the systolic pressure at the upper arm.^[8] PAD has been typically classified according to clinical symptoms using the Fontaine and Rutherford System.^[10,11] Intima-media thickness in the common carotid arteries common carotid artery intima-media thickness (CCA-IMT) measured by ultrasound (US) is a common tool in risk stratification for cardiovascular events due to atherosclerosis.^[12] An increase in CCA-IMT

has been associated with risk of cardiovascular disease, such as myocardial infarction, stroke, and cardiac death.^[12] CCA-IMT has been found to predict the amount of plaques in the coronary arteries.^[13] CCA-IMT has also been found to correlate well with ABI in overall risk assessment for atherosclerosis.^[14] The normal range of ABI is 0.91–1.30,^[9] while, values between 0.7 and 0.9 indicate mild disease, 0.40–0.69; moderate disease, and <0.40; severe disease.^[9] However, values >1.30 are considered as resulting from poor vascular compressibility as could occur in cases of arterial wall calcification (Monckeberg's sclerosis) or intraluminal thrombus.^[9] The ABI is the easiest way to detect the presence or absence of atherosclerotic PAD.^[11,15,16]

An ABI of ≤ 0.90 is commonly used in both clinical practice and epidemiological research to diagnose PAD, both in symptomatic and asymptomatic patients.^[17] The normal CCA-IMT varies with age; at age 10, it is approximately 0.4–0.5 mm, while from the fifth decade of life onward, this progresses to 0.7–0.8 mm.^[18]

The other radiological diagnostic tests for PAD include peripheral angiography, magnetic resonance angiography, and computed tomographic angiography. Peripheral angiography – conventional or digital subtraction angiography is said to be the gold standard. However, it is limited by its invasive nature.^[11]

Screening for PAD by measuring ABI is preferred to clinical inspection of the lower limbs and palpation of the feet pulses.^[16] ABI measurement is a noninvasive procedure performed using a Doppler US device and has a sensitivity of 95% and specificity of 100% for diagnosing PAD compared to the gold standard angiography.^[16]

The ABI assessment can be done using a handheld Doppler US probe and sphygmomanometer. However, there are limitations related to lack of skill, subjectivity, and rest period of about 10 min before the procedure.^[19,20] These factors and the time-consuming nature of the procedures have been identified as significantly limiting their use in a busy healthcare setting.^[21] In recent years, several manufacturers have developed automated ABI devices which aim to obviate the need for a rest period and subjectivity of the measured parameters.^[22] The plethysmographic assessment of ABI is a type of automated ABI device that utilizes Duplex US to diagnose PAD by measuring the ABI and gives a further graphic pulse volume waveform (PVW) tracing which can be interpreted and used to classify the severity of PAD.^[23] The CCA-IMT is measured noninvasively by means of B-mode ultrasonography.^[13]

The aims of this study were to determine the prevalence of PAD and associated risk factors in adult ambulatory diabetic patients attending the Endocrinology clinic of the University of Benin Teaching Hospital (UBTH), by means of an automated ABI device and determine the severity using the PVW tracing. The ABI values were also correlated with the patients' CCA-IMT.

MATERIALS AND METHODS

This was a prospective cross-sectional descriptive study among 100 adult subjects with confirmed diabetes mellitus attending the Endocrinology clinic of UBTH, Benin City in Edo State, Nigeria. The study was carried out between November 25, 2019, and April 25, 2020. The study size was calculated for a cross-sectional study using Cochran's formula below,^[24] with current Nigerian diabetes mellitus prevalence rate of 5%.^[4] Ethical clearance was obtained and adhered to as per the institutional criterion. Subjects were only examined after written informed consent had been granted following thorough explanation of the study objectives and method of examination.

We included subjects ≥ 18 years and subjects diagnosed with diabetes using WHO1999 criteria.^[25] Exclusion criteria included nondiabetic patients, diabetic patients with bilateral lower limb amputation, active ulceration on both halluxes, end-stage renal disease, pregnancy, and those with ABI > 1.30 (to exclude arterial medial calcification – Monckeberg's sclerosis).

The study was in two steps; the first step involved using an automated device (Dopplex® Ability, CF 245 HN; Huntleigh Healthcare, Cardiff, UK 2016 model) which utilized volume plethysmography to measure and calculate the ABI and provided a paper printout of the PVW. The second step involved gray-scale longitudinal scan of the common carotid arteries using a high-frequency (7.5–10 MHz) linear array transducer of a SONOACE X6 (Medison Inc, Korea 2010) US machine.

A written informed consent was obtained from each participant, and a brief questionnaire was administered afterwards. Recent laboratory test results were obtained from patients' case notes. These included fasting blood sugar (FBS), random blood sugar, glycated hemoglobin (HbA1C), and lipid profile. A brief medical history was obtained from the patients, and their medication use was determined either by direct questioning or obtained from patient case notes. Anthropometric parameters were obtained, and the body mass index (BMI) was calculated: $BMI = \text{Weight (kg)} / \text{Height}^2 (\text{m}^2)$.^[26]

Plethysmographic ankle-brachial index measurement and plethysmographic pulse volume recordings

The pulse volume recording is also known as pulse plethysmography. The machine records the arterial volume changes with each cardiac cycle.^[27] Normally, each cardiac cycle produces significant vascular volume changes within the limb segment.^[27] By using a pressure cuff applied on the limb, it is possible to compress away venous input and record only arterial input.^[27] When properly applied, the system automatically records the air pressure at the brachial and ankle levels. The pulse volume recording was used to generate waveforms, as shown in Figure 1. The various components of the waveform include brisk systolic upslope, sharp systolic peak, gradual downslope, and a dicrotic notch (reflected wave) during diastole. The PVW interpretation constitutes a further noninvasive diagnostic procedure that can be utilized to evaluate blood flow in the extremities. Its use is recommended by both the European Society of Cardiology and the American College of Cardiology/American Heart Association as a second-level assessment tool for patients with suspected PAD.^[27] A four-level PVW grading system is used to grade the severity of PAD into Grades A to D,^[28] as shown in Figure 2; Grade A: consists of a normal PVW, Grade B: sharp peak, absent dicrotic notch, bowing of the downslope away from the baseline (mild PAD), Grade C: absent dicrotic notch, flattened systolic peak, amplitude reduction, and pulse-elongation (moderate PAD), and Grade D: severe amplitude reduction, pulse elongation, and pulse flat-line (severe PAD).

Technique for ankle-brachial index using plethysmography

Before the testing, the patient was informed to put on light clothing that is not constricting because pressure cuff would be applied to the limbs. The patient was then asked to lie

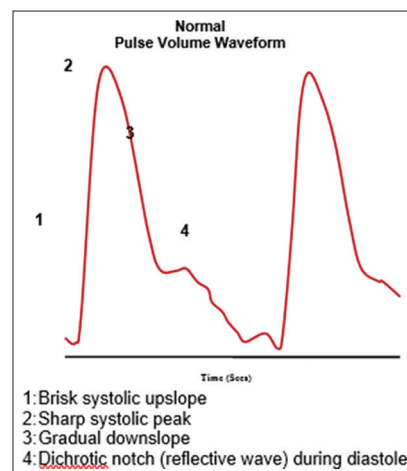


Figure 1: Normal pulse volume waveform^[28]

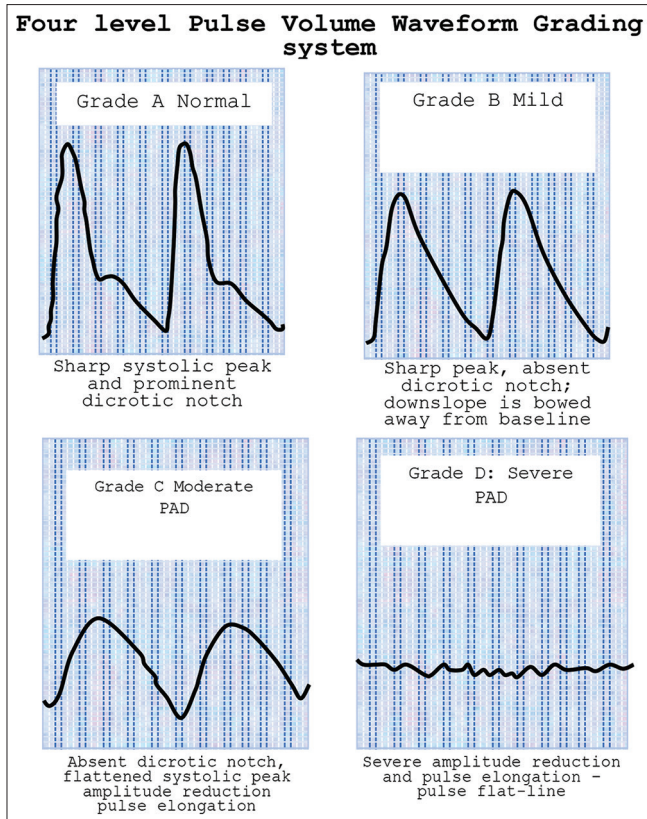


Figure 2: Pulse volume waveform interpretation (according to four-level grading system).^[28] PAD – Peripheral arterial disease

supine on the examination couch and rest for about 5 min in a comfortable position for the examination. The appropriately labeled ankle and arm cuffs were applied on both ankles and just above the cubital fossa. Consistent cuff placement and tightness were maintained to avoid cuff loosening during recording. An appropriately matched color-coded cord was connected to the arterial/occlusion cuff port in front of the machine while the other end of the cord was connected to the cuff on the arm and ankle, as shown in Figure 3. After all appropriate and required machine data had been entered, the perform/test button was clicked to inflate the cuffs. The patient was expected to remain still until the process was completed. The system then automatically displayed the waveform tracing and recorded the air pressure in the arm and also displayed the ABI for both lower limbs on the screen, which was printed out for analysis. A copy of the ABI recordings and PVW tracings is shown in Figure 4. The procedure took about 5 min per patient.

Technique for carotid artery ultrasonography

The patient was asked to lie in supine position with the head turned slightly (about 45°) away from the side to be examined. After proper exposure of the neck down to the level of the clavicle and necklaces removed, the neck was hyperextended slightly by placing a pillow under the



Figure 3: Subject in a supine position connected to the plethysmographic machine with appropriate cuff placement

patient's shoulders. Scanning was done in the overhead position, in which the researcher sat beyond the patient's head, beside the end of the examination table, with the patient's feet away from the examiner. Coupling gel was applied along the track of the carotid artery and scanning was done in both longitudinal and transverse planes. High-frequency (7.5–10 MHz) linear array transducer was used for the examination. The carotid bifurcation was identified usually 1–2 cm below the angle of the jaw while scanning in the transverse plane. The common carotid IMT was measured on the far arterial wall about 10 mm from the carotid bulb, as the distance between the echogenic lumen-intima interface and the echogenic media-adventitia interface, as shown in Figure 5.

Analysis of data

Data obtained from the questionnaire, including plethysmographic evaluation of the subjects, as well as the laboratory and anthropometric data were entered into the computer spreadsheet, Microsoft Excel (Microsoft Corporation USA), and analysis was done using the Statistical Package for the Social Sciences version 20.0 (SPSS Inc. Chicago, IL, USA). The results were expressed in mean $\pm$ standard deviation (SD) and presented in the form of tables and figures as appropriate. Data comparison (statistical test of significance) was done using Spearman correlation analysis, Chi-square test for categorical data, Student's *t*-test, and analysis of variants where applicable. At 95% confidence interval (CI), two-tailed $P \leq 0.05$ was considered statistically significant.

RESULTS

One hundred subjects who fulfilled the inclusion criteria were recruited into this study. The age ranged from 18 to 90 years

with a mean and SD of 60.6 ± 11.0 years. The sex distribution showed female dominance with 73 (73.0%) females and 27 (27.0%) males giving a male-to-female ratio of 1:2.7 [Table 1].

Clinical characteristics of the study population

The mean age at diagnosis of diabetes mellitus was 48.1 ± 10.3 years, with a male and female distribution of 47.2 ± 12.0 years and 48.4 ± 9.7 years, respectively, as illustrated in Table 1. The majority of the subjects were diagnosed at age 51–60 years (35.0%); this was followed closely by those diagnosed at 41–50 years (33.0%) and 31–40 years (20.0%). Only seven (7.0%) of the subjects were diagnosed at ≥ 61 years and 3 (3.0%) at ≤ 30 years of age. Sixty-one (61.0%) of the subjects had a positive family history of diabetes mellitus, whereas 39 (39.0%) had no positive family history of diabetes mellitus or were not sure.

Table 1: Clinical characteristics of the study population

Variables	Frequency (%)			P
	All	Male	Female	
Age range of years at diagnosis				
≤ 30	3 (5.0)	3 (11.1)	2 (2.7)	0.470
31–40	20 (20.0)	4 (14.8)	16 (21.9)	
41–50	33 (33.0)	9 (33.3)	24 (32.9)	
51–60	35 (35.0)	10 (37.0)	25 (34.2)	
≥ 61	7 (7.0)	1 (3.7)	6 (8.2)	
Mean age of years at diagnosis $\pm$ SD [*]	48.1 ± 10.3	47.2 ± 12.0	48.4 ± 9.7	0.605
Family history of DM				
Yes	61 (61.0)	20 (74.1)	41 (56.2)	0.103
No	39 (39.0)	7 (25.9)	32 (43.8)	
Chronic complications [*]				
Retinopathy	42 (42.0)	15 (55.6)	27 (37.0)	0.095
Neuropathy	71 (71.0)	18 (66.7)	53 (72.6)	0.561
Nephropathy	8 (8.0)	0	8 (11.0)	0.073
None	20 (20.0)	5 (18.5)	15 (20.5)	0.822
Previous foot ulcers	17 (17.0)	6 (22.2)	11 (15.1)	0.398
Present foot ulcers	1 (1.0)	0	1 (1.4)	1.000
Tobacco/smoking	5 (5.0)	1 (3.7)	4 (5.5)	1.000
Intermittent claudication	26 (26.0)	4 (14.8)	22 (30.1)	0.121
Ischemic rest pain	19 (19.0)	2 (7.4)	17 (23.3)	0.072
History of hypertension	73 (73.0)	17 (63.0)	56 (76.7)	0.169

*Multiple response. SD – Standard deviation, DM – Diabetes mellitus

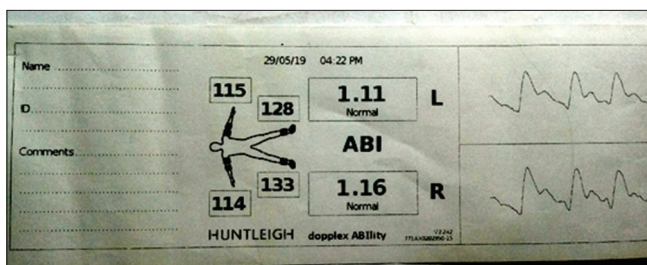


Figure 4: Print out from automated device (plethysmograph), showing the ankle-brachial index in both limbs and the pulse volume waveform tracings

The predominant chronic complication was neuropathy. The distribution of other chronic complications includes 42 (42.0%) for retinopathy and 8 (8.0%) for nephropathy. Twenty (20.0%) had no record of chronic complications. Most of the subjects were nonsmokers; this accounted for 95 (95.0%) with only five (5.0%) subjects having a history of smoking. Intermittent claudication was present in only 26 (26.0%) of the subjects and absent in most of the subjects, i.e., 74 (74.0%). Ischemic rest pain was present in 19 (19.0%) of the subjects, whereas 81 (81.0%) of the subjects did not have rest pain. The majority of the subjects – 73 (73.0%) also had concurrent hypertension which was absent in 27 (27.0%) of the subjects.

Clinical and biochemical parameters of the study population

The BMI for the study population was 27.7 ± 5.0 and 29.1 ± 4.5 for the male and female subjects, respectively, with an overall mean of 28.7 ± 4.7 . This was not statistically significant ($P = 0.191$). The mean fasting blood glucose for the study population was 134.1 ± 4.7 mg/dl, with a slightly higher value in the female subjects, as shown in Table 2. Again, there was no statistically significant difference among both groups ($P = 0.764$). The mean HbA1c, mean total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), and triglycerides are shown in Table 2. Among these parameters, the difference in mean HDL between both sexes was found to be statistically significant ($P = 0.025$), while the other parameters were not statistically significant.

Plethysmographic variables of the study population

The mean arm pressures for the male and female subjects were 147.2 ± 20.2 and 143.3 ± 22.0 , respectively, whereas the mean lower limb pressures were 149.8 ± 23.6 and 147.2 ± 20.5 for males and females, respectively. These

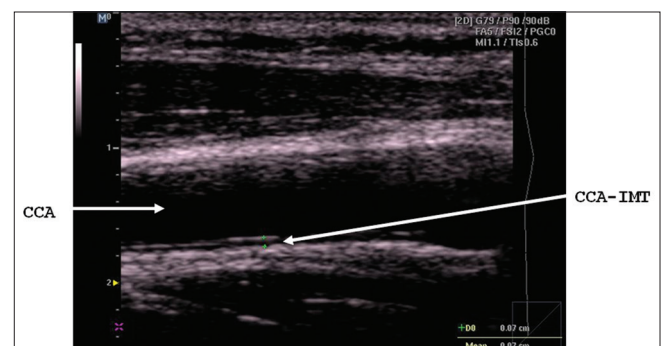


Figure 5: Carotid sonogram showing longitudinal scan of the common carotid artery and a normal intima-media measurement of 0.07-cm (see arrow) common carotid artery (CCA) that indicates common carotid artery, and CCA-intima-media thickness signifies the common carotid intima-media thickness. CCA-IMT – Common carotid artery-intima-media thickness

differences in the arm and lower limb pressures were not statistically significant ($P = 0.484$ and 0.587 , respectively). However, slightly higher pressure was noted in the male population, and higher pressures were also noted on the right arms and right lower limbs for both male and female populations.

The mean ABI for the study population was 1.02 ± 0.12 with a slightly higher value in the females (1.03 ± 0.11) than the male subjects (0.99 ± 0.12). The difference was not statistically significant ($P = 0.082$). Higher ABI values were noted in the right lower limb than in the left lower limb for both sexes. These differences were also not statistically significant ($P = 0.138$ and 0.209 , respectively), as shown in Table 3.

Ultrasonographic parameters of the study population

The mean CCA-IMT for the study population was 0.90 ± 0.02 mm. The comparison of the mean CCA-IMT between the male (0.89 ± 0.34) and female (0.90 ± 0.19) showed slightly higher measurement in females, which however was not statistically significant ($P = 0.76$). The mean CCA-IMT for the right CCA was 0.88 ± 0.26 mm and 0.99 ± 0.21 mm for the males and females, respectively, while the mean CIMT for the left CCA was 0.90 ± 0.32 mm and 0.91 ± 0.21 mm for the males and females, respectively. The differences in the right and left CIMT were not statistically significant ($P = 0.67$), as shown in Table 4.

Prevalence of peripheral arterial disease based on ankle-brachial index

The percentage of patients that had normal ABI, low ABI, and high ABI on at least one side of the limb were 75 (75.0%), 23 (23.0%), and 2 (2.0%), respectively, indicating the absence of PAD, presence of PAD, and arterial wall calcification. The side-specific percentages and severity are shown in Table 5. Therefore, using the ABI to diagnose PAD, the overall prevalence of PAD from this study was 23.0%.

Figure 6 illustrates the prevalence of PAD by gender and age group. Subjects with $ABI \leq 0.9$ were more in age groups 71–80 (17.4%) than in age groups, 51–60 and 61–70 (8.7% and 4.3%, respectively) among the males. While the female subjects with $ABI \leq 0.9$ were more in age groups 51–60 and 61–70 (26.1% and 17.4%, respectively) than in age groups 41–50, 71–80, and ≥ 81 (all have 8.7% distributions).

Female subjects with $ABI \leq 0.9$ were more than the male subjects with $ABI \leq 0.9$. The prevalence of PAD among males was 30.4%, whereas the prevalence of PAD among females was 69.6%.

Pulse volume waveform grading in the study population

Sixty-nine subjects (69.0%) had normal PVW (no PAD), 25 (25.0%) had mildly abnormal PVW (mild PAD), and 6 (6.0%) had moderately abnormal PVW (moderate PAD). A comparison of PVW pattern of the study population

Table 2: Clinical characteristics and Biochemical indices of the study population

Variables	All (n=100), mean±SD	Male (n=27), mean±SD	Female (n=73), mean±SD	t	df	P
Height (m ²)	1.7±0.1	1.73±0.07	1.65±0.08	5.049	98	0.000*
Weight (kg)	80.0±15.2	83.0±16.3	78.8±14.7	1.224	98	0.224
BMI (kg/m ²)	28.7±4.7	27.7±5.0	29.1±4.5	-1.318	98	0.191
FBG (mg/dL)	134.1±47.7	131.7±38.4	135.0±50.9	-0.301	98	0.764
HbA1c (%)	9.7±3.4	9.7±3.1	9.7±3.5	0.031	98	0.976
Total cholesterol (mg/dL)	205.3±41.8	200.0±46.3	207.2±40.1	-0.768	98	0.445
LDL cholesterol (mg/dL)	117.1±41.4	116.0±39.0	117.6±42.5	-0.165	98	0.869
HDL cholesterol (mg/dL)	50.9±19.5	43.7±15.4	53.5±20.3	-2.275	98	0.025*
Triglycerides (mg/dL)	142.0±53.2	145.3±51.2	140.7±54.2	0.385	98	0.701

*Statistically significant. FBG – Fasting blood glucose, HbA1c – Hemoglobin A1c, LDL – Low-density lipoprotein, HDL – High-density lipoprotein, t – Student's t-test, df – Degree of freedom, BMI – Body mass index, SD – Standard deviation

Table 3: Plethysmographic variables of the study population

Variables	All (n=100), mean±SD	Male (n=27), mean±SD	Female (n=73), mean±SD	t	P
Arm pressure					
Right arm	145.4±22.1	148.0±19.9	144.5±23.0	0.702	0.484
Left arm	144.0±21.5	146.4±21.5	143.1±21.5	0.683	0.496
Mean arm	144.7±21.5	147.2±20.2	143.8±22.0	0.703	0.484
Lower limb pressure					
Right lower limb	148.1±24.3	150.8±27.2	147.1±23.3	0.677	0.500
Left lower limb	147.1±21.8	148.7±23.3	146.5±21.6	0.456	0.650
Mean lower limb	147.9±21.3	149.8±23.6	147.2±20.5	0.545	0.587
Lower limb ABI					
Right lower limb	1.03±0.14	0.99±0.11	1.05±0.15	-1.496	0.138
Left lower limb	1.00±0.14	0.98±0.15	1.02±0.14	-1.266	0.209
Mean lower limb	1.02±0.12	0.99±0.12	1.03±0.11	-1.755	0.082

t – Student's t-test, P – Probability, ABI – Ankle-brachial index, SD – Standard deviation

with ABI is illustrated in Table 6. Among the subjects with PAD (ABI ≤ 0.9), 15 (65.2%) had mildly abnormal PVW, 6 (26.1%) had moderately abnormal PVW, and 2 (8.7%) had normal PVW. The relationship between the presence of PAD (ABI ≤ 0.9) and PVW grading was highly statistically significant ($P = 0.0001$).

Comparison of anthropometric and biochemical indices with peripheral arterial disease status in the study population

Ten (25.0%) of the subjects with low ABI were obese, 6 (15.0%) were overweight, and 7 (35.0%) had normal

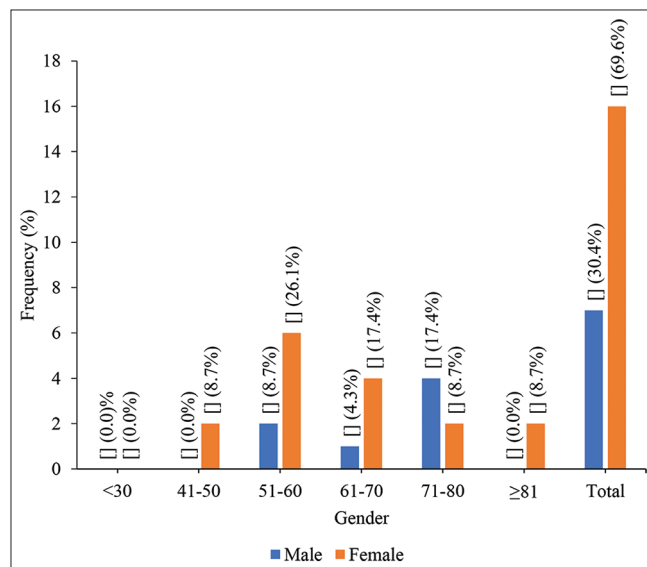


Figure 6: Bar chart showing the prevalence of peripheral arterial disease by gender and age group in the study population. Fisher's exact test = 4.647, $P = 0.334$

Table 4: Comparison of carotid intima-media thickness in the study population

Variables	All	Gender		<i>t</i>	df	<i>P</i>
		Male, mean±SD	Female, mean±SD			
Right CIMT	0.89±0.22	0.88±0.26	0.90±0.21	-0.294	98	0.769
Left CIMT	0.91±0.24	0.90±0.32	0.91±0.21	-0.242	98	0.809
<i>P</i>	0.669	0.850	0.691			
Mean CIMT	0.90±0.20	0.89±0.24	0.90±0.19	-0.307	98	0.760

CIMT – Carotid intima-media thickness, *t* – Student's *t*-test, *P* – Probability, df – Degree of freedom, SD – Standard deviation

Table 5: Pattern of ankle-brachial index and the prevalence of peripheral arterial disease

ABI values	Interpretation	Right side, frequency (%)	Left side, frequency (%)	Interpretation	On at least one side, frequency (%)
>1.3	Arterial calcification	2 (2.0)	0	Arterial calcification	2 (2.0)
0.91–1.30	Normal ABI	84 (84.0)	80 (80.0)	Normal ABI	75 (72.0)
0.70–0.90	Mild PAD	13 (13.0)	11 (11.0)	PAD (mild and moderate)	23 (23.0)
0.40–0.69	Moderate PAD	1 (1.0)	6 (6.0)		
<0.40	Severe PAD	-	-		
	Indeterminate		3 (3.0)		
Total		100 (100.0)	100 (100.0)		

ABI – Ankle-brachial index, PAD – Peripheral arterial disease

weight. The difference between the low ABI and high ABI with BMI was not statistically significant ($P = 0.206$), as shown in Table 7. The comparison between the groups showed CCA-IMT was higher among ABI ≤ 0.9 in both right CCA-IMT, left CCA-IMT, and mean CCA-IMT. The difference between the two groups was not statistically significant on the left CCA-IMT ($P = 0.258$); however, it was statistically significant in the right and mean CCA-IMT ($P = 0.002$ and 0.020 , respectively). The CCA-IMT was found to be higher on the left in both subjects with PAD (ABI ≤ 0.9) and subjects without PAD (ABI > 0.9). Subjects with PAD (ABI < 0.9) had higher FBS, HbA1c, total cholesterol, LDL, and triglycerides, but lower in HDL. Conversely, those without PAD (ABI > 0.9) had higher HDL. The difference between HbA1c, total cholesterol, and LDL values in both groups was statistically significant ($P = 0.001$, 0.049 , and 0.046 , respectively).

Logistic regression between ABI, CCA-IMT, and other significant diabetic risk factors is illustrated in Table 8. The odds ratios (ORs) for each measured parameter were displayed, and all the variables were directly associated with the presence of PAD (ABI ≤ 0.90). HbA1c (OR 1.334, 95% CI 1.093–1.629) was significantly associated with the presence of PAD (ABI ≤ 0.90). However, variables such as CCA-IMT, total cholesterol as well as LDL were not statistically significant ($P > 0.05$).

DISCUSSION

Diabetes is a global public health problem with attendant complications such as PAD, and atherosclerosis is the principal pathophysiologic mechanism.^[5] The ankle-brachial index is a well-recognized, easily assessed, and noninvasive method of determining the presence of PAD. Intima-medial thickness in the carotid arteries is also a common tool in risk stratification for cardiovascular events, such as stroke and CAD.^[12] This study set out to determine the prevalence of PAD among adult diabetes. In this study, 100 diabetics were recruited with age 18–90 years and a mean age of 60.60 ± 11.0 years. The prevalence of PAD from this study was 23%. This is similar to the percentage

prevalence reported by Soyoye *et al.*^[29] in the study on the prevalence and correlates of PAD among 300 subjects consisting of 150 diabetics and 150 controls in Obafemi Awolowo University, Ile-Ife, where a prevalence of 22% was reported by means of ABI. The percentage from this study is also similar to that found by Rasheed *et al.*^[30] on the prevalence of PAD in type 2 diabetics and its associated risk factors in Pakistan, where 25% prevalence was reported. However, in earlier study by Umuerrri and Obasohan^[31] in Benin, higher prevalence of 35.6% was reported. The difference in the prevalence may be due to a much higher sample size of 388 used in their study. The mean duration of diabetics in this study was 12.5 ± 8.3 years, and most

of the subjects were diagnosed between the ages of 51–60 years. The mean duration of DM was slightly higher than the findings by Arora *et al.*^[32] and Rasheed *et al.*^[30] where the mean duration of diabetics was found to be 9.13 ± 6.56 years and 10.6 ± 9.2 years, respectively. This higher duration may be due to the fact that in this study a larger proportion of the subjects were much older; this may have skewed the data toward older subjects with a much longer duration of diabetics.

The mean CCA-IMT was also found to be higher on the left CCA (0.91 ± 0.24 mm) than the right CCA (0.89 ± 0.22 mm) for the study population, and possible explanation may be due to the anatomical and/or hemodynamic of the left CCA being a direct branch of the thoracic aorta, resulting in different shear stress that may lead to faster development of atherosclerosis on the left side.^[12] Slightly higher values of mean CCA-IMT were reported by Kota *et al.*,^[33] where a mean CCA-IMT of 1.01 ± 0.28 mm was found among diabetics compared to healthy subjects with CIMT of 0.73 ± 0.08 . In their study, values >0.8 mm were found to be associated with the occurrence of stroke. This study showed a statistically

Table 6: Comparison of pulse volume waveform pattern of the study population with ankle-brachial index

ABI	PVW				P
	A, n (%)	B, n (%)	C, n (%)	D, n (%)	
≤ 0.9	2 (8.7)	15 (65.2)	6 (26.1)	-	0.0001*
> 0.9	67 (87.0)	10 (13.0)	0	-	

*Statistically significant. A – Normal PVW (no PAD), B – Mildly abnormal PVW (mild PAD), C – Moderately abnormal PVW (moderate PAD), D – Severely abnormal PVW (severe PAD), PVW – Pulse volume waveform, ABI – Ankle-brachial index, PAD – Peripheral arterial disease

Table 7: Comparison of anthropometric and biochemical indices with peripheral arterial disease status in the study population

Variables	All (n=98)	ABI status, mean $\pm$ SD		t	df	P
		≤ 0.9 , Frequency (n=23) (%)	> 0.9 , Frequency (n=77) (%)			
Mean BMI (kg/m ²)	28.7 $\pm$ 4.7	28.5 $\pm$ 4.9	28.8 $\pm$ 4.7	-0.279	98	0.781
BMI category, n (%)						
Normal	20 (100.0)	7 (35.0)	13 (65.0)	3.162#	2	0.206
Overweight	40 (100.0)	6 (15.0)	34 (85.0)			
Obese	40 (100.0)	10 (25.0)	30 (75.0)			
CCA IMT						
Right	0.89 $\pm$ 0.22	1.01 $\pm$ 0.28	0.86 $\pm$ 0.19	3.114	98	0.002*
Left	0.91 $\pm$ 0.24	0.96 $\pm$ 0.24	0.89 $\pm$ 0.24	1.139	98	0.258
Mean CCA-IMT	0.90 $\pm$ 0.20	0.99 $\pm$ 0.24	0.87 $\pm$ 0.18	2.372	98	0.020*
FBS	134.1 $\pm$ 47.7	145.4 $\pm$ 54.6	130.7 $\pm$ 45.3	1.302	98	0.196
HbA1c (%)	9.7 $\pm$ 3.4	11.7 $\pm$ 2.4	9.1 $\pm$ 3.4	3.452	98	0.001*
Total cholesterol (mg/dL)	198.0 $\pm$ 41.3	212.8 $\pm$ 49.6	193.6 $\pm$ 37.7	1.990	98	0.049*
LDL (mg/dL)	113.1 $\pm$ 41.9	128.4 $\pm$ 50.7	108.6 $\pm$ 38.2	2.024	98	0.046*
HDL (mg/dL)	47.0 $\pm$ 17.7	42.4 $\pm$ 11.6	48.4 $\pm$ 19.0	-1.441	98	0.153
Triglycerides (mg/dL)	142.0 $\pm$ 53.2	149.1 $\pm$ 42.4	139.8 $\pm$ 56.1	0.732	98	0.466

*Statistically significant, #Chi-square. t – Student's t-test, df – Degree of freedom, FBS – Fasting blood sugar, HbA1c – Hemoglobin A1c, LDL – Low-density lipoprotein, HDL – High-density lipoprotein, BMI – Body mass index, CCA-IMT – Common carotid artery intima-media thickness, SD – Standard deviation, ABI – Ankle-brachial index

Table 8: Logistic regression of ankle-brachial index and common carotid artery intima-media thickness and other diabetic risk factors (for statistically significant variables only)

	ABI ≤ 0.90 , n (%)	ABI > 0.90 , n (%)	OR	95% CI	P
Age (years)	64.9 $\pm$ 11.8	59.3 $\pm$ 10.5	1.042	0.971–1.117	0.257
CCA-IMT					
Right	1.01 $\pm$ 0.28	0.86 $\pm$ 0.19	21.450	0.614–749.793	0.091
Mean CCA-IMT	0.99 $\pm$ 0.24	0.87 $\pm$ 0.18	10.681	0.501–227.515	0.129
HbA1c (%)	11.7 $\pm$ 2.4	9.1 $\pm$ 3.4	1.334	1.093–1.629	0.005*
Total cholesterol (mg/dL)	212.8 $\pm$ 49.6	193.6 $\pm$ 37.7	1.001	0.981–1.020	0.945
LDL (mg/dL)	128.4 $\pm$ 50.7	108.6 $\pm$ 38.2	1.009	0.989–1.030	0.367

*Statistically significant. OR – Odds ratio, CI – Confidence interval, ABI – Ankle-brachial index, HDL – High-density lipoprotein, CCA-IMT – Common carotid artery intima-media thickness, HbA1c – Hemoglobin A1c, LDL – Low-density lipoprotein

significant correlation of PAD with other risk factors such as duration of diabetes and HbA1c with $P = 0.0001$ and 0.001 , respectively. This is consistent with the findings by Umuerrri and Obasohan,^[31] Rasheed *et al.*,^[30] and Kumar *et al.*,^[34] where duration of diabetes and glycemic parameters like HbA1c were correlated with the development and severity of PAD, as these factors are known to contribute to the development of atherosclerosis. HbA1c enhances the covalent binding of lipoproteins to vascular wall proteins, promoting sequestration, free radical release, and induction of inflammation, all of which lead to the development of atherosclerosis and PAD.^[13] There was a statistically significant correlation between total cholesterol and LDL with the presence of PAD ($P = 0.049$ and 0.046 , respectively), but there was no significant correlation with HDL and triglyceride with $P = 0.153$ and 0.466 , respectively. This is similar to the findings by Ogbera *et al.*^[35] and Kota *et al.*,^[33]

This study has shown that the presence of PAD (ABI ≤ 0.9) correlated significantly with abnormal PVW pattern ($P = 0.0001$).

CONCLUSION

This study has reported a prevalence of 23% for PAD among type 2 diabetes in UBTH.

This study has shown that there is a significant correlation between increase in CCA-IMT and the presence of PAD. Abnormal PVW correlates with PAD, and visual assessment of the wave pattern is a useful grading tool. As with other previous studies, HbA1C, total cholesterol, and LDL correlated with PAD.

Recommendations

1. ABI measurement by means of plethysmography should be incorporated as a routine screening test for the evaluation of diabetic patients, and annual follow-up measurement should be encouraged in others to detect early PAD and allow for prompt institution of therapy
2. Those with moderate-to-severe PAD on routine screening should be sent for CCA-IMT measurement to assess for arterial wall thickness and the presence or absence of plaques. This will help detect imminent complications such as stroke and coronary heart disease
3. Further prospective study of the ABI by means of plethysmography in which the patients who are recruited in the study are assessed with long-term follow-up

4. Further studies using large-scale, community-based cohorts of diabetics in different centers in Nigeria should also be done to validate the accuracy of the findings in this study.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. WHO. Definition, Diagnosis and Classification of Diabetes Mellitus and Its Complications, part 1, Geneva: WHO; 1999. Available from: https://whqlibdoc.who.int/hq/1999/WHO_NCD_NCS_99.2.pdf. [Last accessed on 2019 Aug 08].
2. WHO Fact Sheet; 2018. Available from: <https://www.who.int/News/Factsheets>. [Last accessed on 2019 Aug 08].
3. International Diabetes Federation. Diabetes Atlas. 8th ed. Brussels: International Diabetes Federation; 2017. Available from: <https://diabetesatlas.org/resources/2017-atlas.html>. [Last accessed on 2019 Aug 08].
4. IDF Diabetes Atlas. 6th ed. Belgium: International Diabetes Federation; 2013. Available from: <https://www.idf.org/diabetesatlas>. [Last accessed on 2018 Apr 17].
5. Dieter RS, Chu WW, Pacanowski JP Jr., McBride PE, Tanke TE. The significance of lower extremity peripheral arterial disease. *Clin Cardiol* 2002;25:3-10.
6. Federman DG, Trent JT, Froelich CW, Demirovic J, Kirsner RS. Epidemiology of peripheral vascular disease: A predictor of systemic vascular disease. *Ostomy Wound Manage* 1998;44:58-62, 64, 66 passim.
7. Hirsch AT, Criqui MH, Treat-Jacobson D, Regensteiner JG, Creager MA, Olin JW, *et al.* Peripheral arterial disease detection, awareness, and treatment in primary care. *JAMA* 2001;286:1317-24.
8. White CJ. Atherosclerotic peripheral arterial disease In: Goldman L, Goldman SA. Cecil Medicine. 25th ed., Vol. 1. Philadelphia: Elsevier Saunders; 2016. p. 497-503.
9. American Diabetes Association. Standards of medical care in diabetes. *Diabet Care* 2015;38:51-94.
10. Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S, *et al.* Recommended standards for reports dealing with lower extremity ischemia: Revised version. *J Vasc Surg* 1997;26:517-38.
11. Fontaine R, Kim M, Kieny R. Surgical treatment of peripheral circulation disorders. *Helv Chir Acta* 1954;21:499-533.
12. Lundberg C, Hansen T, Ahlström H, Lind L, Wikström J, Johansson L. The relationship between carotid intima-media thickness and global atherosclerosis. *Clin Physiol Funct Imaging* 2014;34:457-62.
13. Kablak-Ziembicka A, Tracz W, Przewlocki T, Pieniazek P, Sokolowski A, Konieczynska M. Association of increased carotid intima-media thickness with the extent of coronary artery disease. *Heart* 2004;90:1286-90.
14. Bots ML, Hofman A, Grobbee DE. Common carotid intima-media thickness and lower extremity arterial atherosclerosis. The Rotterdam study. *Arterioscler Thromb* 1994;14:1885-91.
15. Dasgupta A, Mazumdar A. Peripheral arterial disease in the lower extremities prevalence and epidemiology. *E J Cardiol Pract* 2018;15:4-14.
16. Tyagi V, Gupta A, Bansal N, Virmani SK. Prevalence of peripheral arterial disease in diabetes mellitus. *Int J Res Med Sci* 2017;5:4881-5.
17. Criqui MH, Aboyans V. Epidemiology of peripheral artery disease. *Circ Res* 2015;116:1509-26.
18. Iana S. Intima-media thickness: Appropriate evaluation and proper measurement, described. *E J ESC Coun Conc Cardiol Pract* 2015;13:1.

19. Nicolaï SP, Kruidenier LM, Rouwet EV, Bartelink ML, Prins MH, Teijink JA. Ankle brachial index measurement in primary care: Are we doing it right? *Br J Gen Pract* 2009;59:422-7.
20. Davies JH, Kenkre J, Williams EM. Current utility of the ankle-brachial index (ABI) in general practice: Implications for its use in cardiovascular disease screening. *BMC Fam Pract* 2014;15:69.
21. Mohler ER 3rd, Treat-Jacobson D, Reilly MP, Cunningham KE, Miani M, Criqui MH, *et al.* Utility and barriers to performance of the ankle-brachial index in primary care practice. *Vasc Med* 2004;9:253-60.
22. Verberk WJ, Kollias A, Stergiou GS. Automated oscillometric determination of the ankle-brachial index: A systematic review and meta-analysis. *Hypertens Res* 2012;35:883-91.
23. Anderson JL, Halperin JL, Albert NM, Bozkurt B, Brindis RG, Curtis LH, *et al.* Management of patients with peripheral artery disease (compilation of 2005 and 2011 ACCF/AHA guideline recommendations): A report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation* 2013;127:1425-43.
24. Araoye MO. Research Methodology with Statistics for Health and Social Sciences. 1st ed. Ilorin: Nathadex Publishers; 2004. p. 116-25.
25. Buse JB, Polonsky KS, Burant CF. Type 2 diabetes mellitus. In: Kronenberg HM, Polonsky KS, Larsen RP, editors. *Williams Textbook of Endocrinology*. 11th ed. Canada, Ottawa: Saunderson Elsevier; 2008. p. 1329-90.
26. WHO/Europe. Nutrition-Body Mass Index-BMI. Available from: <https://www.euro.who.int/en/health-topics/disease-prevention/body-mass-index-bmi.pdf>. Accessed Feb 9, 2023.
27. Arger PH, Iyob SD. Peripheral arterial system. In: *The Complete Guide to Vascular Ultrasound*. 1st ed. Philadelphia, USA: Lippincott and Williams; 2004. p. 26-44.
28. Lewis JE, Williams P, Davies JH. Non-invasive assessment of peripheral arterial disease: Automated ankle brachial index measurement and pulse volume analysis compared to duplex scan. *SAGE Open Med* 2016;4:2050312116659088. <https://doi.org/10.1177/2050312116659088>.
29. Soyoye DO, Ikem RT, Kolawole BA, Oluwadiya KS, Bolarinwa RA, Adebayo OJ. Prevalence and correlates of peripheral arterial disease in Nigerians with type 2 diabetes. *Adv Med* 2016;2016:3529419. <https://doi.org/10.1155/2016/3529419>.
30. Rasheed J, Naz J, Akram Z. Prevalence of peripheral arterial disease (PAD) in type II diabetics and its association with various risk factors. *PJMHS* 2018;12:368-70.
31. Umuerrri EM, Obasohan AO. Lower extremity peripheral artery disease: Prevalence and risk factors among adult Nigerians with diabetes mellitus. *West Afr J Med* 2013;32:200-5.
32. Arora E, Maiya AG, Devasia T, Bhat R, Kamath G. Prevalence of peripheral arterial disease among type 2 diabetes mellitus in coastal Karnataka. *Diabetes Metab Syndr* 2019;13:1251-3.
33. Kota SK, Mahapatra GB, Kota SK, Naveed S, Tripathy PR, Jammula S, *et al.* Carotid intima media thickness in type 2 diabetes mellitus with ischemic stroke. *Indian J Endocrinol Metab* 2013;17:716-22.
34. Kumar A, Kumar A, Kumar H, Jha HK, Nayaks, Roy C. Prevalence of peripheral arterial disease and associated risk factors among type 2 diabetes mellitus patients attending diabetic health camp. *Int J Med Res* 2018;3:90-2.
35. Ogbera AO, Adeleye O, Solagberu B, Azenabor A. Screening for peripheral neuropathy and peripheral arterial disease in persons with diabetes mellitus in a Nigerian University Teaching Hospital. *BMC Res Notes* 2015;8:533.