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ULTRASONOGRAPHIC EVALUATION OF THE ACHILLES TENDON IN PATIENTS WITH TYPE 2 DIABETES: A DUAL CENTER STUDY IN PORT HARCOURT

DO Umelo, *EW Ugboma, NC Nwankwo, CN Wekhe

Department of Radiology, Department Of Radiology, University Of Port-Harcourt Teaching Hospital, Port-Harcourt

***Corresponding Author:** Enighe Wananyo Ugboma; **Email:** enighe.ugboma@uniport.edu.ng

ABSTRACT

Background: *Thickening of the Achilles tendon in the diabetic patient has been implicated in the development of diabetic foot ulcers which increases morbidity and mortality. Ultrasonography is a non-invasive, non-ionizing, reproducible and affordable procedure that can be used to evaluate the Achilles tendon in the management of the disease.*

Aim: *To evaluate the Achilles tendon thickness (ATT) in type 2 diabetic patients comparing the findings to their age and sex-matched non-diabetic counterparts. It also tried to establish a relationship, if any, of ATT with peripheral neuropathy, Body Mass Index (BMI) and duration of disease in the study population.*

Method: *This was an analytical cross-sectional study involving 108 adult diabetic participants and 108 non-diabetic control participants. The ATT in both groups were evaluated by ultrasonography. The ATT of the study group was correlated with their peripheral neuropathy score, BMI and duration of disease. Data was analysed using Statistical Package for Social Sciences (SPSS) version 20.0 software*

Results: *The mean ATT was higher in diabetic subjects compared to the control subjects. The increased thickness of the AT was significantly more in the presence of PN (p=0.0001). The optimal cut-off point of ATT for identifying the risk of PN in the feet of diabetics was determined to be > 5.75mm with an accuracy of 83.3%*

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Conclusion: *Patients with type 2 diabetes mellitus have significantly thicker AT than their age and sex-matched control subjects and the presence of peripheral neuropathy further worsens the ATT. An ATT of > 5.75mm is the optimal cut-off for identifying the risk of PN in the feet of diabetics.*
Key Words: *Diabetes mellitus, Achilles tendon thickness, Peripheral neuropathy*

INTRODUCTION

Diabetes mellitus (DM) is a challenging health problem and a leading cause of death and disability worldwide.[1, 2] The number of diabetic patients is estimated to increase from 366 million in 2011 to 522 million by 2030 worldwide.[3] The estimated prevalence of DM in Africa is 1% in rural areas and ranges from 5% -7% in urban sub-Saharan Africa.[4] In Nigeria, the prevalence of diabetes mellitus has increased from 2.2% as documented by Akinkugbe[5] from a national survey in 1997 to 5.0% by 2013.[6]

Diabetes mellitus is a metabolic disorder characterized by high blood sugar and disturbances of carbohydrate, fat and protein metabolism due to a relative lack of or insensitivity to insulin or both. Type 2 DM is the commonest type of DM affecting more than 95% of the diabetic population in Nigeria.[7] A study done in Port Harcourt[8] showed a prevalence of 6.8% for type 2 DM.

In the functioning of the foot, the Achilles tendon(AT), plantar fascia, and metatarsophalangeal joints represent a complex biomechanical unit[9] and contribute actively to the plantar pressure on the forefoot[10], a key mechanism in the development of diabetic foot ulcers. Metabolic disorders such as DM alter the mechanical properties of tendons.[11] In the context of type 2 DM, the AT and plantar fascia are sites of major interest because of their potential role in diabetic foot biomechanics.[12] These structures contribute to the increased forefoot pressure in patients with T2DM, thus increasing the risk of diabetic ulcerations.[13] There is increasing evidence that static stiffness and thickening of the Achilles tendon may be, in part, responsible for the increased forefoot loading that might initiate the pathologic process.[14,15] This static stiffness may be initiated by glycation of the tissues or peripheral neuropathy-induced motor imbalance (one of the main etiologic factors for diabetic tendinopathy).[16-18] For this reason, AT lengthening has been successfully proposed for the management of recurrent diabetic ulcers.[19]

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The global prevalence of diabetic foot ulcer is 6.3% (95%CI: 5.4–7.3%).[20] This varies from 0.9 to 8.3% in Nigeria.[21]

Ultrasonography (US) is a non-invasive, relatively low cost, non-ionizing and readily available technique of imaging the Achilles tendon, it also allows its study in real-time dynamic mode.[22-24] Other imaging modalities that can be used for the evaluation of the Achilles tendon include conventional radiography and magnetic resonance imaging (MRI). Conventional radiography has poor soft tissue resolution while MRI has excellent soft tissue resolution. However, some authors defend that high resolution US presents a better spatial resolution than MRI, when studies obtained with more modern devices are compared.[24] This is due to the fact that tissues with few mobile protons like tendons emit little or no signal. Therefore, tendon internal architecture is not well demonstrated by MRI.[25]

This present study evaluated the Achilles tendon thickness in patients with type 2 diabetes in Port Harcourt using ultrasonography. There are very few documented reports on the ultrasonographic evaluation of the Achilles tendon in patients with type 2 DM in other parts of Nigeria more so, there is limited data in our environment which necessitated the need for this study.

The broad objective of this study was to determine the thickness of the Achilles tendon on ultrasonography in adult patients with type 2 diabetes at the University of Port Harcourt Teaching Hospital and Rivers State University Teaching Hospital, Port Harcourt.

The specific objectives included:

1. To compare the Achilles tendon thickness (ATT) in adult patients with type 2 diabetes with that of their age- and sex-matched non-diabetic counterparts in Port-Harcourt.
2. To assess for peripheral neuropathy in type 2 diabetics using the Semmes Weinstein Monofilament neuropathy test score.
3. To determine the optimal cut-off point of ATT for identifying peripheral neuropathy risk based on clinical assessment using the Semmes Weinstein Monofilament neuropathy test score.
4. To examine the correlation between ATT and clinical characteristics such as body mass index and peripheral neuropathy score.

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5. To determine the association between duration of DM from the time of clinical diagnosis and increase in ATT.

METHODOLOGY

Study Design

This was a hospital-based analytical cross-sectional study.

Study Population

Adult participants between the ages of 35years and 80years with type 2 diabetes mellitus (case group) and age and sex-matched non-type 2 diabetes mellitus adult volunteers (control group).

Eligibility Criteria

Inclusion criteria for the case group are that the subject should be a known Type 2 diabetic mellitus patient with an aged between 35 years and 80 years. While that for the control group were that the subjects must be adults without a diagnosis of type 2 diabetes mellitus with an aged between 35years and 80 year.

Subjects who had the following were excluded from the study:
For the case group any history of previous and current foot ulcer, smoking, Congenital ankle deformities, chronic use of steroids, charcot neuroarthropathy and hallux rigidus as a result of previous trauma, chronic heel pain, amputation involving the lower limbs, history of peripheral vascular disease, neurological disorders (other than those of diabetic aetiology), musculoskeletal or rheumatoid disease, athletes and bodybuilders, dyslipidaemia, pregnancy, and renal failure.

For the control group any history of diabetes mellitus renal failure, history of previous foot ulcer, smoking, congenital ankle deformities, chronic use of steroids, charcot neuroarthropathy and hallux rigidus as a result of previous trauma, chronic heel pain, amputation involving the lower limbs, history of peripheral vascular disease, musculoskeletal or rheumatoid disease, athletes and bodybuilders, dyslipidaemia a pregnancy.

Study Site

This study was carried out in the Radiology department and Medical out-patient department of the University of Port-Harcourt Teaching Hospital (UPTH) and Rivers State University Teaching

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Hospital (RSUTH) both in Port Harcourt, the capital of Rivers State. UPTH is a 510-bed multi-specialist teaching hospital in the south-south geopolitical region of Nigeria. RSUTH is a 375-bed Specialist Health Institution, which is one of the largest hospitals in the Niger Delta. The catchment areas of the hospitals extend beyond Rivers State, to include much of the Niger delta regions with a population of about ten million people.

Sample Size Calculation

Sample size was calculated using the formula[26] for statistically significant result,

$$n = \frac{Z^2pq}{d^2}$$ which gave 97.39 participants.

To allow for attrition, 108 diabetic subjects were used for this study.

A group of 108 apparently healthy non-diabetic subjects matched for age and sex were also used as control for this study, giving a total of 216 subjects.

Sampling Technique

Simple random sampling via computer generated table of random numbers was employed in the selection of subjects in the study. Using a sampling frame drawn from the register of diabetic patients in the Endocrinology clinic of Medical Out-Patient Department, University of Port Harcourt Teaching Hospital and Rivers State University Teaching Hospital, nine patients were sampled per clinic day in order to obtain the calculated sample size over the three month data collection period.

The control subjects were selected based on the age (± 5years) and sex matching criteria from the General out-Patient Department, University of Port Harcourt Teaching Hospital and Rivers State University Teaching Hospital over a period of 3 months.

Data Collection

Data was collected from subjects (patients with type 2 DM), who presented to the consultant Endocrinology clinic of Medical Out-Patient Department of the University of the Port-Harcourt Teaching Hospital and Rivers State University Teaching Hospital, Port Harcourt. The control

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group was drawn from patients in General Out-Patient Department who satisfied the inclusion criteria. Data was collected using a structured pro forma.

Study Procedure

The study protocol was explained to the patients that met the inclusion criteria. The contents of the consent form were read out and explained (where necessary) and duly signed by participants and their witnesses, in addition to providing their contact details. Medical records, a short clinical history and physical examination were performed on participants to know the duration of diagnosis of diabetes, inquire of any foot ulcers and to exclude other exclusion criteria.

Questionnaires were then administered where the research participants' bio data and demographic data such as age, sex, height and body weight were recorded. Blood sample (needle prick) was taken from the control group using aseptic method for the measurement of fasting blood sugar or random blood sugar with ACCU-CHEK active glucometer. Control subjects with fasting blood sugar >7.0mmol/L or random blood sugar >11mmol/L were excluded from the study. Fasting blood sugar value for the case group were obtained from the patients' folder.

The body mass index (BMI) was calculated with the formula:

BMI (Kg/m^2) = weight (kg) / Height $(m)^2$

Subjects were categorized using the baseline BMI of less than $18.5kg/m^2$ as underweight, $18.5kg/m^2$ to $24.9kg/m^2$ as normal weight, $25kg/m^2$ to $29.9kg/m^2$ as overweight and $30kg/m^2$ or more as obesity. Physical examination was done for diabetic subjects and PN assessed using 10g Semmes Weinstein monofilament. This was achieved by applying mild pressure on the pressure points of the feet using the monofilament till it buckles into a c-shape. 1 point was assigned for normal response, 0.5 point for incomplete response and 0 for complete lack of perception.

Techniques of musculoskeletal ultrasound scan

The ultrasound measurement of the Achilles tendon thickness was measured for both the diabetic participants and non-diabetic controls. The patients were scanned using real-time ultrasound (MINDRAY, model: DC-8, SN – QE3B001806, Year: 2013 and GE LOGIQ 9 Model: 5177000-2, SN-90834US7, Year 2012) with 7-10MHz linear array transducer.

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The participants were requested to lie down in a prone position on an examination couch with their feet extending beyond the distal edge of the couch exposed by rolling up the clothing to the level of the knee. The ankle was placed in a neutral position at an angle of 90°and the feet pointing downward. The coupling agent (gel) was then applied over the area of the AT to ensure appropriate contact between the patient's skin and transducer. Then the ultrasound probe was applied at 90° to the tendon to prevent anisotropy. Depth and gain settings were adjusted as necessary. Scanning of the AT was done in longitudinal and transversal planes (B-mode) from the myotendinous junction to its calcaneal insertion. The ATT (antero-posterior dimension) was then measured on transverse plane at the level of the inferior margin of the medial malleolus. Both the left and right AT were evaluated, their thicknesses measured three consecutive times to minimize intra-observer variability and the mean value for each side recorded in millimeters. Other parameters assessed for included other structural changes in the AT like architectural distortion, tendon calcification and hypoechogenicity. Towels were used to clean off the gel at the end of the study.

Data Analysis

Data was imputed into Excel spreadsheet and exported to IBM Statistical Package for Social Sciences (SPSS) version 20.0 for statistical analysis. Data presentation included charts, tables. Continuous variables such as age, BMI, thickness of Achilles tendon were summarized using means and standard deviation while frequencies and proportions were used for categorical variables.

The differences in means across diabetic patients and control group were compared using independent t-test. Chi-square statistics was used to determine significant differences in proportions. The accuracy of Achilles tendon thickness as a marker for identifying peripheral neuropathy in relation to clinical assessment of Semmes Weinstein Monofilament test score was determined using Receiver Operator Characteristics (ROC) curve and Area under the Curve (AUC) statistics. The optimal cut-off value for Achilles tendon thickness as a marker for peripheral neuropathy was determined using Youden's index. Pearson's correlation was then performed to assess the relationship between numerical variables. Estimates are presented with their 95% confidence intervals and a p-value less than 0.05, were considered statistically significant.

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RESULTS

Socio-Demographic Characteristics of the Study Population

In total, there were 216 people who participated in this study. The mean age of study population was 55.11±11.05 years, while the mean age for males and females in the study were 55.01±10.28 years and 55.17±11.59 years respectively. The mean age for the cases and controls study groups were 55.37±11.10 years and 54.84 ± 11.05 years respectively. The difference was not statistically significant (p = 0.727). Females and males were 59.3% and 40.7% for both diabetic and control groups Compared to the males, the females had higher frequencies in the study population, but these differences in proportion were not statistically significant (p=0.890). [Table 1].

Table 1: Socio-demographic characteristics among groups in the study

Variables	Study group: Cases n (%)	Study group: Controls n (%)	Total n (%)	
Age category				
35 – 44 years	22 (20.4)	24 (22.2)	46 (21.3)	*Chi Square=0.718*
45 – 54 years	26 (24.1)	30 (27.8)	56 (25.9)	
55 – 64 years	34 (31.5)	30 (27.8)	64 (29.6)	*p-value= 0.949*
65 – 74 years	22 (20.4)	20 (18.5)	42 (19.4)	
≥75 years	4 (3.7)	4 (3.7)	8 (3.7)	
Sex				
Male	44 (40.7)	44 (40.7)	88 (40.7)	*Chi Square*=0.019
Female	64 (59.3)	64 (59.3)	128 (59.3)	*p-value= 0.890*
Marital status				
Single	3 (2.8)	2 (1.9)	5 (2.3)	
Married	100 (92.6)	91 (84.3)	191 (88.4)	*Fisher's exact test*
Widowed	4 (3.7)	9 (8.3)	13 (6.0)	= 6.547
Divorced	1 (0.9)	3 (2.8)	4 (1.9)	*p-value = 0.162*
Separated	0 (0.0)	3 (2.8)	3 (1.4)	

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Clinical Characteristics of the Diabetic Cases

The mean duration of diabetes in the study population was 9.37 ± 7.28 years. Patients who had diabetes for 6-10 years had the highest frequency (25.9%) in the case group, while those who have had diabetes for ≤ 1year had the least frequency (12.0%) [Figure 1].

The BMI was categorized into three groups: Normal (18.5 – 24.9 kg/m^2), over-weight (25.0 – 29.9 kg/m^2) and obese (≥30.0 kg/m^2). The mean BMI for the cases and controls were 26.66 ± 4.23 and 27.40 ± 4.38 respectively, this was not statistically significant (p = 0.206). In the case group, 43.5% had normal weight, 35.2% were overweight, and 21.3% were obese. While in the control group, 29.6%, 43.5%, and 26.9% were normal weight, overweight and obese respectively,

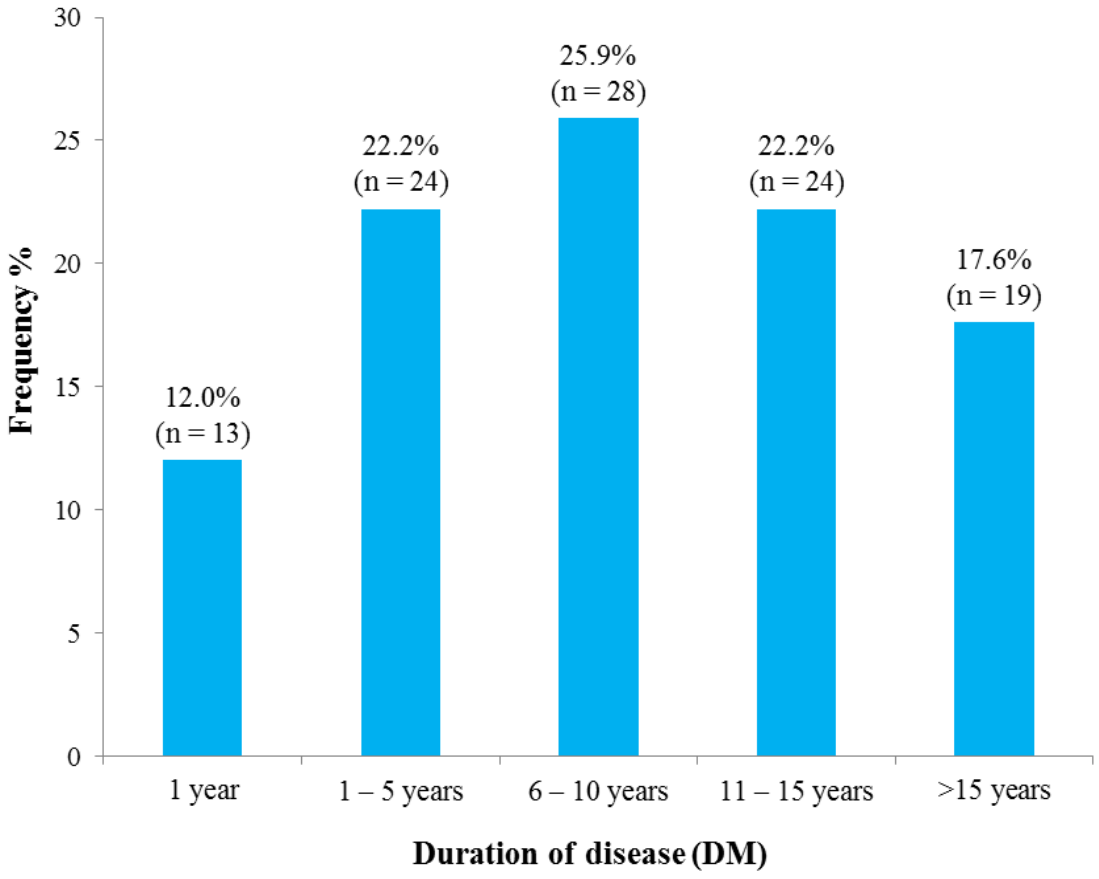

Figure 1: Duration of Diabetes Mellitus among cases

Ultrasound Findings of the Achillies Tendon

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The different images observed were thickening of the AT (Figures 2, 3 and 4) with degenerative changes such as architectural distortion (Figure 2) and linear hypoechoic changes were noted in some patients with thickened AT (Figure 4).

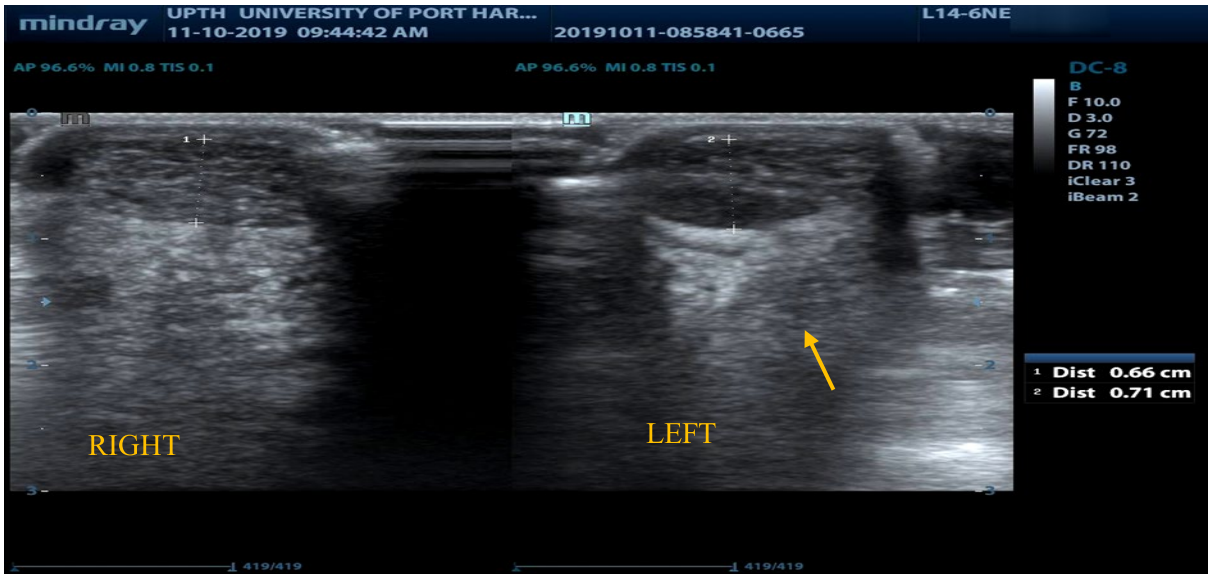

Figure 2: Gross thickening of the Achilles tendons in a known diabetic with peripheral neuropathy. There is associated architectural distortion and hypoechoic changes (arrow).

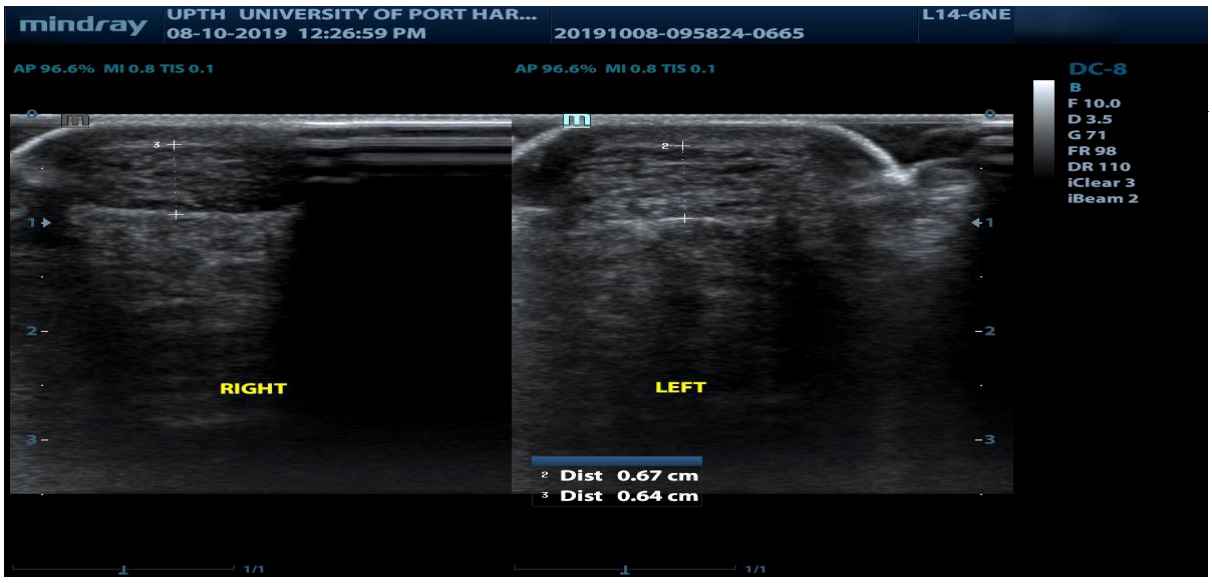

Figure 3. Thickened Achilles tendon with hypoechoic changes, more on the left (arrows), in a diabetic patient with peripheral neuropathy

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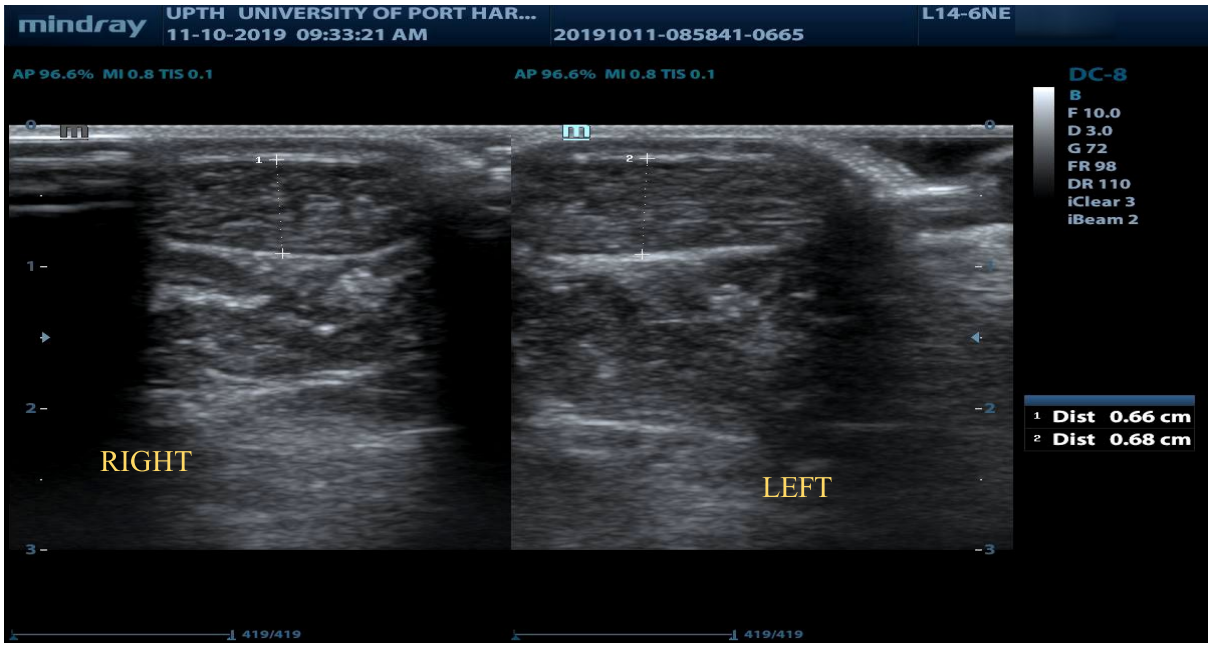

Figure 4: Bilateral thickening of the AT in a diabetic patient.

Achilles Tendon Thickness in the Study Population

The mean ATT was 5.56 ± 0.65mm and 5.59 ± 0.61mm for the right and left lower limb in the case group and 4.72 ± 0.44mm and 4.77 ± 0.40mm for the right and left in the control group. These values were statistically significant (p=0.0001). Furthermore, the AT were significantly thicker in males compared to females in the study populations in both the right and the left feet (p=0.0001). The mean ATT in the left foot in the male case and control subjects measured 5.73±0.58mm and 4.89±0.40mm respectively. The right AT was also found to be significantly thicker in male diabetics (5.68±0.67 mm) than in their sex-matched control group (4.82±0.43mm) with p=0.0001. Likewise, the female case subjects had significantly thicker left and right AT than their sex-matched control subjects (p = 0.0001).

Determining the Optimal Cut-Off Point of ATT for Identifying Peripheral Neuropathy Risk

The Area under the curve (AUC = 0.904) was statistically significant (p=0.0001) in the receiver operator characteristics (ROC) curve for ATT in identifying PN risk in diabetics, showing that the ATT measurement is a useful test for PN risk assessment in Diabetics.[Figure 5]

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Using the Youden Index, the optimal cut-off point of ATT for identifying the risk of PN in the feet of diabetics was determined to be ≥ 5.75mm [Figure 6]. Sixty-four feet of diabetic patients with ATT ≥ 5.75mm had moderate to severe PNS while only 10 has a normal score of 1 for the same ATT . On the other hand, for ATT <5.75mm, 116 feet of diabetics had a normal PNS while 26 had moderate PNS. With a cut-off of 5.75mm, the psychometric properties of this test were as follows: Accuracy= 83.3%, Sensitivity = 71.1% and Specificity = 92.1%

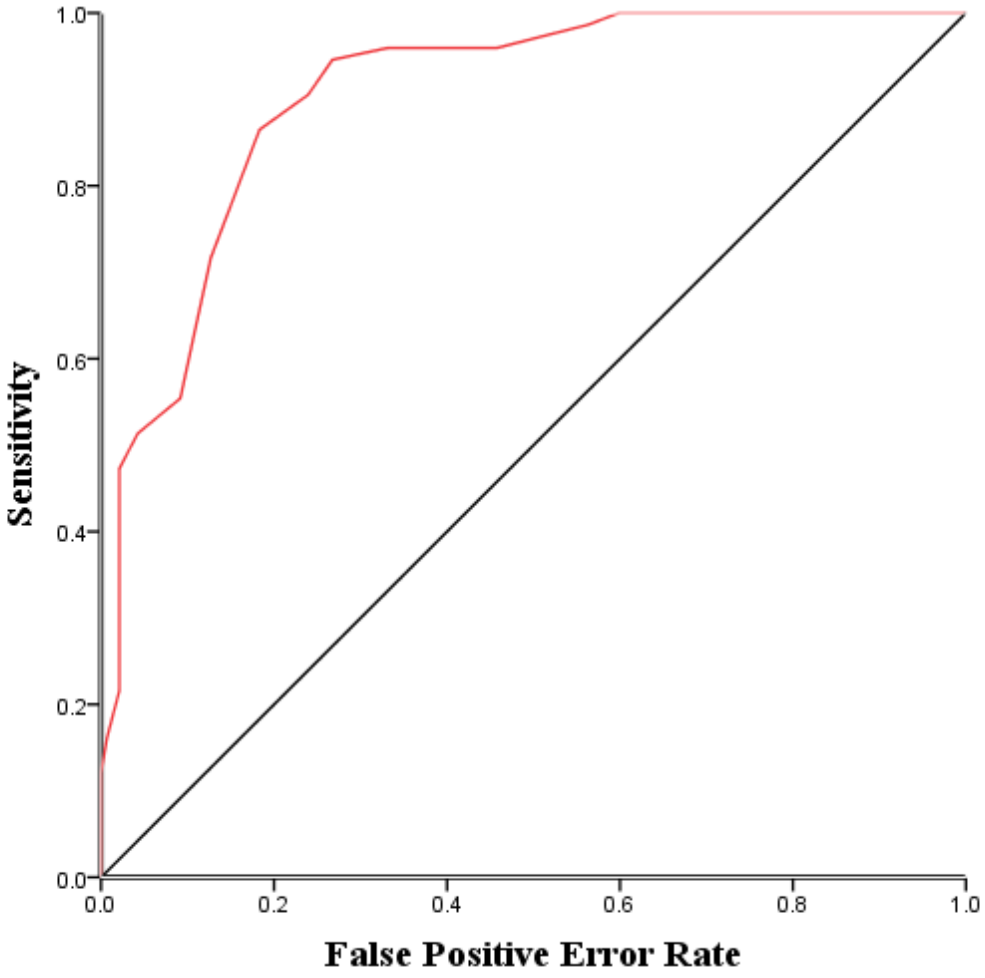

Figure 5: Receiver Operator Characteristics (ROC) Curve for Achilles tendon thickness in identifying peripheral neuropathy risk among diabetic patients (cases)

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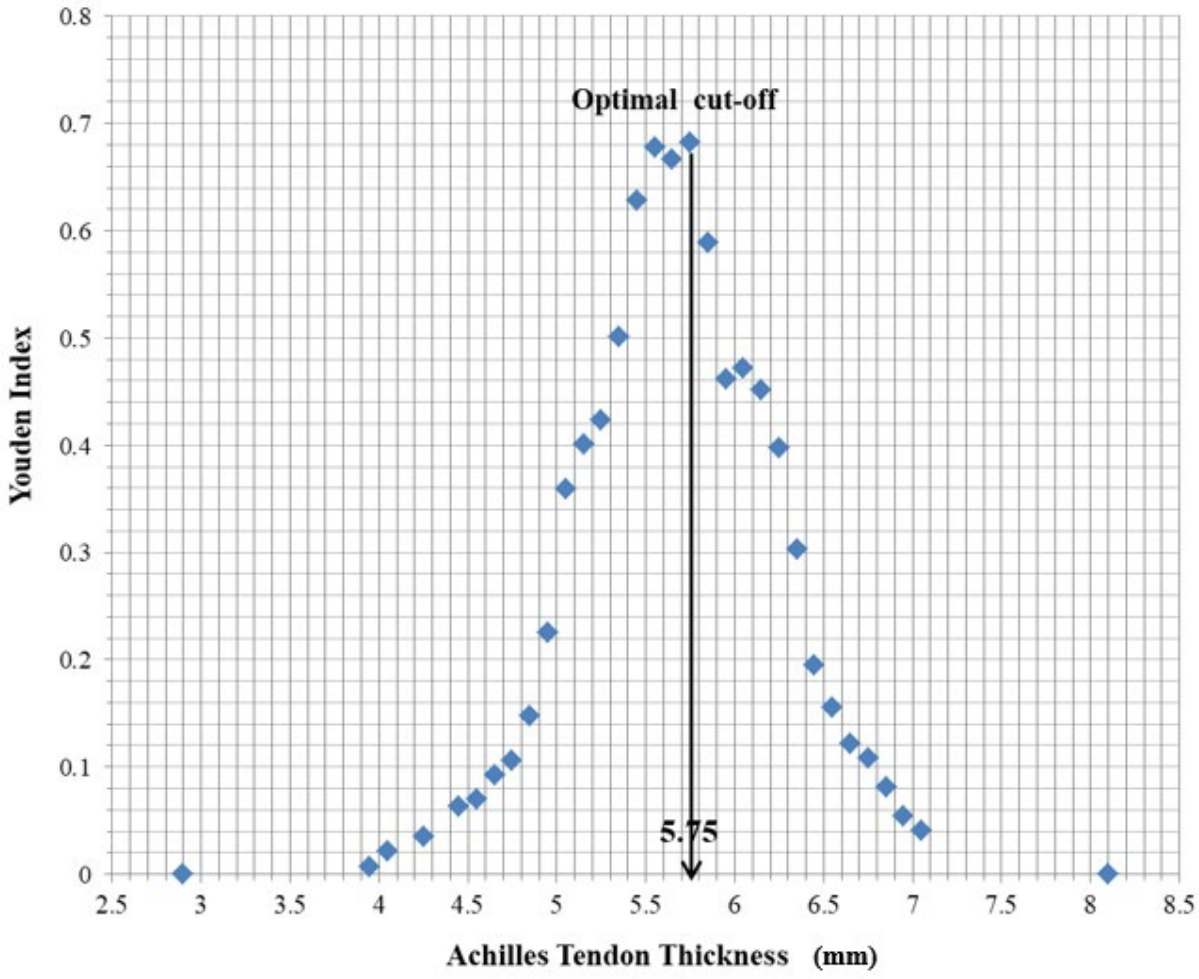

Figure 6: Determination of optimal cut off point for Achilles tendon thickness (for identifying peripheral neuropathy risk) from Youden Index of diabetic patients' feet (N = 216)

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Correlation between Achilles Tendon Thickness and Peripheral Neuropathy Among Cases and Controls.

The peripheral neuropathy score (PNS) was categorized into 3 groups using the Semmes Weinstein Monofilament neuropathy test score: Severe (score 0), moderate (Score 0.5) and normal (Score 1). This study showed that about a third of the case group had moderate score while 0.9% and 65.7% had severe and normal PNS respectively. There was a negative correlation between the ATT (right and left) and PNS in diabetics which was statistically significant (right: r=-0.664, p=0.0001 Left: r=-0.633, p=0.0001) Three groups comprising diabetics with peripheral neuropathy, diabetics without peripheral neuropathy and control subjects were compared based on the mean thickness of their AT in both feet. The mean thickness of the right AT was highest among T2DM subjects with PN, 6.16±0.47mm, compared to those with T2DM without PN which was 5.25±0.50mm. Meanwhile the mean right ATT of control subjects was the least with a value of 4.72 ± 0.40mm. These mean values were statistically significant (p = 0.0001). Similarly, the mean left ATT for the three groups were 6.12 ± 0.41mm, 5.32 ± 0.50mm and 4.77 ± 0.40mm respectively (p = 0.0001).

Using the Scheffe post-hoc test for multiple comparison of mean, it revealed that the ATT of the feet were significantly different between the 3 groups (p< 0.001).[Table 3]

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Table 3: Multiple comparison of means (Scheffe Post Hoc) Achilles tendon thickness between groups in the study

	Achilles tendon thickness (mm)	
Groups in the study	**Mean Difference**	**p-value**
RIGHT FOOT		
With peripheral neuropathy		
Without peripheral neuropathy	0.90876	0.0001*
Controls	1.44372	0.0001*
Without peripheral neuropathy		
With peripheral neuropathy	-0.90876	0.0001*
Controls	0.53496	0.0001*
Controls		
With peripheral neuropathy	-1.44372	0.0001*
Without peripheral neuropathy	-0.53496	0.0001*
LEFT FOOT		
With peripheral neuropathy		
Without peripheral neuropathy	0.81317	0.0001*
Controls	1.35125	0.0001*
Without peripheral neuropathy		
With peripheral neuropathy	-0.81317	0.0001*
Controls	0.53808	0.0001*
Controls		
With peripheral neuropathy	-1.35125	0.0001*
Without peripheral neuropathy	-0.53808	0.0001*

*Statistically significant ($p < 0.05$)

Correlation between Achilles Tendon Thickness and BMI among Cases and Controls

In the case group, the mean thickness of the right AT in those with normal BMI, overweight and obese BMI were 5.52 ± 0.57mm, 5.48 ± 0.61 and 5.77 ± 0.84mm respectively. These values were

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not statistically significant (p= 0.209) [Table 13]. Likewise, the ATT on the left did not significantly differ across the three BMI groups (p= 0.954). Among the control group, there was statistically significant increase in the ATT of both feet with increasing BMI (P<0.05).

The ATT of the limbs in control subjects had a significant correlation with BMI compared to that of the diabetic subjects.

Correlation Between Achilles Tendon Thickness and Duration of Disease (DM) among Cases

Diabetic patients with duration of diabetes >15years had the highest mean ATT of 5.78±0.71mm and 5.83±0.70mm for the right and left foot respectively. Conversely, those with duration of disease < 1year had the least mean ATT (right = 5.27±0.79mm and left = 5.31±0.69mm). However, these mean values were not statistically significant (right p = 0.071, left p = 0.068).

Distribution of Incidental Findings Among Patients With Peripheral Neuropathy, Without Peripheral Neuropathy and Controls

The presence of either disorganized fibers or hypoechoic foci in the AT was compared between T2DM + PN, T2DM without PN and control subjects. Although the frequency of occurrence was higher among diabetics than control subjects, the proportions were not statistically significant (p = 0.659).

DISCUSSION

Diabetes mellitus (DM) is a challenging health problem with associated life threatening chronic complications like diabetic foot disease. Thickening and increased stiffness of the Achilles tendon (AT) has been implicated in the development of diabetic foot ulcers.[13] This study revealed that there was significant thickening of the AT of both lower limbs of type 2 diabetic patients (T2DM), males and females, when compared to the control subjects who were matched for age and sex (p=0.0001). This is in agreement with what Afolabi et al[27] and other researchers[28,29] observed. However, Akturk *et al*[30] observed that the Achilles tendon thickness (ATT) was increased only in type 2 diabetic female population, no significant difference was found between type 2 diabetic male patients and the male control group. Similar findings were noted by Papanas et al[18] who studied the Achilles tendon volume in type 2 diabetic patients using MRI. These two studies

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suggest that there may be gender differences in AT pathology among subjects with diabetes. This difference may be due to small sample size in the aforementioned studies. Contrary to the finding of increased ATT in this study, Batista *et al*[31] in the study 'Achilles Tendinopathy in Diabetes Mellitus' in Brazil, examined the AT of 70 diabetics and 10 age-matched normoglycaemic controls. They noted that the AT in the control group was thicker than in the diabetic patients. The reason for this was not stated in the study. This may be due to the fewer number of control subjects compared to the diabetic subjects sampled.

Studies reporting ATT cut-off for determining the risk of PN in diabetic subjects are scarce. Nevertheless, this study determined that the optimal cut-off point of ATT for identifying the risk of PN in the feet of diabetics was $\geq$ 5.75mm. This shows that ATT measurement in diabetics is a useful test for PN risk assessment in the feet of diabetic patients.

In this study, the increased ATT in diabetics was more evident among T2DM patients with PN compared to those without PN and the control group. A significant difference was seen between the three groups ($p = 0.0001$). Several other studies[27,28,32] corroborated these findings. Giacomozzi *et al*[28] observed that ATT was increased in type 2 diabetic subjects complicated by peripheral neuropathy (PN) compared to those without PN. This supports the fact that PN has effects on soft tissues of the feet. However, apart from diabetics with PN, those without PN also had significantly thicker AT compared to the controls in this study ($p < 0.05$). This may suggest that thickening of the AT, which through various biomechanical mechanisms predisposes to plantar ulcers, is even present prior to the onset of PN as proposed by Giacomozzi et al.[28] Akturk et al[30] also observed that the ATT values were higher in diabetic male patients with PN ($p = 0.019$) compared to the male DM patients without this complication. There was no significant result in the female study population. Contrary to the above studies, Papanas *et al*[18] noted that there was no significant difference in AT volume between patients with and without neuropathy ($p = 0.349$), they however noted that increased AT volume is associated with severity of PN in neuropathic patients.

Some studies suggest that the amount of fat distribution in the body may be a risk factor for Achilles tendon pathology.[33,34] Among the diabetics in this study, the correlation between BMI and ATT was observed to be insignificant. However, in the control group, there was statistically

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significant increase in the ATT of both feet with increasing BMI. This is in agreement with a study done in Nigeria by Afolabi *et al*[27] in which statistically significant results were also obtained among controls in the correlation of ATT with BMI. Similar to the findings in the diabetic population in this study, Abate *et al*[29] demonstrated that the effect of BMI on ATT in DM was weak (p = 0.004). They hypothesized that when the plantar fascia is abnormally thickened, the foot is locked in a rigid configuration and approaches the floor as a "functional flat foot." This may subject the AT to a lower stress and therefore to a lower overuse thickening[28]. Contrariwise, Evranos *et al*[32] noted that the ATT correlated with the BMI (p = 0.04) in diabetic patients when compared with control. This was corroborated by Akturk *et al*[30] who noted that The ATT correlated with the BMI and body weight, but was observed only in the diabetic female group. Mello *et al*[35] examined the AT in fifty healthy volunteers and found that there was no statistically significant difference in mean between ATT and BMI.

Soft tissue changes seen in diabetics may be expected to be worsened by increasing duration of disease. This study showed that diabetic patients with duration of diabetes >15years had the highest mean ATT of 5.78±0.71mm and 5.83±0.70mm for the right and left limb respectively. Conversely, those with duration of disease < 1 year had the least mean ATT (right=5.27±0.79mm and left=5.31±0.69mm). However, these mean values were not statistically significant (right p=0.071, left p=0.068). These findings may be because patients with long-standing DM were placed on statins prophylactically in the Endocrinology clinics at the study sites. Statins have been shown to cause thinning of the tendons in metabolic conditions[36] thereby opposing the long-term effects of hyperglycaemia on tendons.

This result was corroborated by Papanas *et al*[18] who demonstrated that there was no significant correlation between duration of diabetes and ATT or AT volume. Similarly, Batista *et al*[31] and Ursini *et al*[37] did not demonstrate any statistically significant relationship between ATT and length of DM diagnosis. However, Abate *et al*[38] had a contrasting view, they found a significant association between AT changes and duration of DM. Similarly, Afolabi *et al*[27] noted a significant but weak positive correlation between duration of diabetes and ATT.

Incidental sonographic findings in the evaluation of the AT in this study were focal areas of tendon hypoechogenicity and architectural distortion. Although the frequency of occurrence was higher

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among diabetic than control subjects, the proportions were not statistically significant (P=0.659). This could be due to reduced incidence of tendinopathy in patients on statins[39]. Other studies[27,29,40] had contrasting views. They noted that significant echotexture disorders were observed more frequently in subjects with diabetes. The study by Abate *et al*[29] showed that US abnormalities were found in a significant number of diabetic subjects compared to the control group.

CONCLUSION

The Achilles tendons are significantly thicker in diabetics than non-diabetics. The presence of peripheral neuropathy further worsens the thickness of Achilles tendon in diabetics.

ATT measurement is a useful test for peripheral neuropathy risk assessment in the feet of patients with diabetes mellitus and the optimal cut-off point of ATT for identifying the risk of PN is $\geq$ 5.75mm. There was no significant correlation between Achilles tendon thickness, BMI and duration of diagnosis of DM.

It is recommended that the Endocrinologists should ensure diabetics have a routine ultrasound scan of the Achilles tendon at least once a year to ensure appropriate management of diabetic foot disease and a longer follow-up duration for the case group may elucidate more changes in the AT in follow up studies.

LIMITATIONS

Limitations of the study are that the true duration of DM may predate the time of hospital diagnosis.

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