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ROLE OF SHEAR WAVE ELASTOGRAPHY IN ASSESSING ACHILLES TENDON IN NORMAL INDIVIDUALS, DIABETIC PATIENTS WITH AND WITHOUT FOOT COMPLICATIONS

Radio-Diagnosis

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ABSTRACT

Introduction: Diabetes mellitus (DM) is an endocrine disorder which is characterized by several metabolic abnormalities as well as long-term complications. Among the dreaded consequences of diabetes mellitus (DM) is diabetic foot. According to a number of studies, diabetic patients may experience foot issues as a result of alterations in the Achilles tendon (AT). In diabetic patients, early detection of these changes may prevent impending foot complications.

Aim:

- To perform ultrasound and document the thickness of the Achilles tendon in normal individuals, diabetic patients with and without foot complications.
- To assess the role of shear wave elastography in assessing Achilles tendon stiffness and deriving cut-off values in normal individuals, diabetic patients with and without foot complications.

Methods: Shear wave elastography (SWE) was used to assess the elasticity of AT in 55 healthy volunteers (Group 1), 55 diabetic patients without foot complications (Group 2) and 55 diabetic patients with foot complications. The thickest part of the middle portion of the Achilles tendon, which is nearly 2-6 cm proximal to the calcaneus insertion, was chosen for shear wave elastographic examination. Elasticity was expressed in kilopascal (kPa). **Results:** The study found a male predominance with 121 (73.3%) males and 44 (26.7% females) patients. The mean age was 55.14±10.11, with no significant differences in age or disease conditions. Diabetic patients had significantly higher fasting blood sugar (FBS) levels and post-prandial blood sugar (PPBS) levels compared to healthy individuals. The elasticity of AT was significantly lower in diabetic patients with foot complications as compared to the other two groups, which implies that the elasticity of AT in patients with foot complications was significantly lower as compared to those diabetic patients without foot complications. **Conclusion:** Modifications in the structure of AT occurs before the onset of foot complications in diabetic patients. Reduced elasticity of AT is a reliable marker of impending foot complications in diabetic patients.

KEYWORDS

Diabetes mellitus, Diabetic foot ulcer, Achilles tendon, Shear wave elastography, Diabetic foot complications

INTRODUCTION

Diabetes mellitus (DM) is derived from the Latin term mellitus, which means sweet, and the Greek word diabetes, which means syphon, to pass through. A historical analysis reveals that Apollonius of Memphis first used the term "diabetes" about 250–300 BC. The term "diabetes mellitus" originated when ancient Greek, Indian, and Egyptian civilizations realised that the urine produced in this condition was pleasant. In 1889, Mering and Minkowski made the discovery that the pancreas plays a part in the pathophysiology of diabetes. Diabetes remains one of the most prevalent chronic illnesses both domestically and globally. It continues to rank as the seventh most common cause of death in the United States.[1]

One of the most frequent side effects in individuals with poorly managed DM is diabetic foot ulcers. It is occurs due to inadequate foot care, peripheral vascular disease, underlying neuropathy, or poor glycemic management. It is also a prevalent cause of lower-limb amputations and osteomyelitis of the foot. Most common organism causing infection is Staphylococcus. These ulcers typically appear in the parts of the foot that are subjected to pressure points and recurrent trauma.

The biggest tendon in the body, the Achilles tendon (AT), is crucial for mobility in humans. When sprinting, leaping, and hopping, AT bears most stress of the body, extending up to ten times the weight of the body.[1] Structural alterations and reduced stiffness of AT in individuals with diabetes may raise the foot stress and hasten the development of diabetic foot. In clinical practise, it is simple to assess the thickness and stiffness of the AT in patients with diabetes because of its superficial nature.[2,3]

The mechanical and material characteristics of the tendon may be quantitatively investigated due to new technologies like elastography.[4] Shear Wave Elastography (SWE) has been proposed as a viable technique to measure tissue stiffness in a number of recent research.[5] A single shear wave can be produced throughout the tissue by the Ultrasound (US) probe in SWE. When compared to quasistatic elastography, the SWE gathers velocity data while traversing soft tissue, allowing for the calculation of the elastic modulus.[6]

Limited studies have been carried out thus far to determine the usefulness of the SWE of AT. Hence our study is aimed to assess the utility of SWE in assessing AT stiffness and determining its role as a marker of impending foot complications.

MATERIALS AND METHODS

Study Design, Sample Size And Source Of Data

This prospective comparative study included a total of 165 subjects. 55 non-diabetic controls (Group 1), 55 diabetic patients without foot complications (Group 2) and 55 diabetic patients with foot complications (Group 3) referred for ultrasound examination to the department of Radio-Diagnosis at the R.L. Jalappa Hospital and Research Centre attached to Sri Devaraj Urs Medical College, Tamaka, Kolar over a period of 18 months from September 2022 to February 2024 were included in the study.

Method Of Data Collection

The study obtained approval from the Institutional Ethical Committee of Sri Devaraj Urs Academy of Higher Education and Research with the approval number SDUMC/KLR/IEC/268/2022-23. Informed consent was obtained from all participants in the study. A written consent form was obtained from all patients fulfilling the inclusion criteria after explaining the objective, procedure, and expected outcome in detail before the start of the study.

Comprehensive clinical data was collected from the patients, which included their age, gender and anthropometric measurements like height, weight and body mass index. Relevant medical history was taken which included symptoms such as sensory loss, numbness and tingling sensation in the feet indicative of peripheral neuropathy (PN). Foot ulcer if present was examined and documented. Fasting blood sugar (FBS) and post-prandial blood sugar (PPBS) were recorded for all patients.

All patients underwent SWE examination on Phillips EPIQ 5 machine. US examination was done with the patient in prone position with foot relaxed and hanging over the examination bed. The thickest part of the middle portion of the Achilles tendon, which is nearly 2-6 cm proximal to the calcaneus insertion, was chosen as the region of interest (ROI) for shear wave elastographic examination. Elasticity was expressed as Young's modulus in kilopascal (kPa) unit.

Inclusion & Exclusion Criteria

All diabetic patients with and without foot complications were included in this study. Healthy age and gender matched non-diabetic individuals were selected as controls. Patients with past history of foot surgery, trauma, varicose veins, acromegaly and Achilles tendinitis were excluded from the study.

Statistical Analysis

The data collected was analysed using IBM SPSS version 20.0. Normality of the data was assessed by Kolmogorov Smirnov test. Socio-demographic variables were analysed in terms of mean, standard deviation (SD), frequency (n) and percentage (%). Chisquare test was used for categorical variables. ANOVA test was performed to compare continuous variables of three groups. p-value of <0.05 was taken as statistically significant. Data results were represented in the form of tables and figures.

RESULTS

Table 1 shows that out of 165 individuals, 26.7% (44) are female and 73.3% (121) are male. This indicates a higher proportion of males compared to females in the sample.

Table.1 Gender Wise Distribution (n=165)

Gender	Frequency	Percent
F	44	26.7%
M	121	73.3%
Total	165	100.0

Table 2 summarizes the age distribution of a sample population. Of the 165 individuals, 46.1% (76) were under 55 years and 53.9% (89) are over 55 years old. The mean age is approximately 55.14 years with a standard deviation of 10.11 years, indicating some variability around the mean. The median age is 55 years, with an interquartile range (IQR) of 47 to 61 years, suggesting that the middle 50% of the sample falls within this age range. The ages span from a minimum of 38 years to a maximum of 86 years, showing a broad age distribution.

Table.2 Age Wise Distribution (n=165)

Age	N	%
<55 years	76	46.1%
>55 years	89	53.9%
Mean SD	55 .14± 10.11	
Median(IQR)	55(47-61)	
Min-Max	38-86	

The table 3 compares the median thickness across three groups: Normal, DM without foot complications, and DM with foot complications. The median thickness for the Normal group is 6.70 (IQR 6.10-7.10), for DM without foot complications group is 8.70(IQR 8.50-8.90), and for the DM with foot complications group is 9.50(IQR 9.20-10.0).The comparison shows that the median thickness was significantly lower in the Normal group compared to both the diabetic groups. The P-value of <0.001 indicates that these differences are statistically significant

Table. 3 Comparison Of Thickness (in Mm) Among The Control And Disease Group

Variable	Group	N	Mean ± SD	95% CI	Median (IQR)	P-value
THICK-NESS (in mm)	Normal	55	6.71 ± 0.69	(6.53,6.9)	6.70 (6.10-7.10)	P<0.001
	DM without foot complications	55	8.73 ± 0.36	(8.63,8.83)	8.70 (8.50-8.90)	
	Dm with foot complications	55	9.49 ± 0.5	(9.36,9.63)	9.50 (9.20-10.0)	

The table 4 compares the mean Young Modulus across three groups. The comparison shows that the mean Young modulus was significantly lower in the DM with foot complications group as compared to other two groups. There was no significant difference in the mean Young's modulus between Normal individuals and diabetic patients without foot complications (P value – 0.919). There was a significant difference in the Young's modulus of the other 2 groups.

Table .4 Comparison Of Young`s Modulus (in Kpa) Among The Control And Disease Group

Variable	Group	N	Mean ± SD	95% CI	Median (IQR)	P-value
YOUNG'S MODULUS (in kPa)	Normal	55	166.91 ±17.52	(162.17, 171.65)	164(154-187)	0.919
	DM without foot complications	55	165.18 ±10.25	(162.41, 167.95)	167(157-171)	P<0.001*
	Dm with foot complications	55	116.87 ±14.1	(113.06, 120.69)	119(106-123)	P<0.001*

*Significance

DISCUSSION

Diabetes mellitus (DM) is an endocrine disorder associated with numerous long-term complications. Diabetic neuropathy has been extensively studied and has been considered the major cause of onset of foot ulcers. Other factors which might contribute to development of foot ulcers have not been sufficiently studied, as a result of which preventive measures for ulcers have been ineffective.[8] Some studies have proposed a relationship between tendinopathy and DM. Tendinopathy is characterized by thickening of peritendinous tissue, widespread proliferation of fibroblasts and connective tissue adhesions. These changes increase tendons' thickness, making the measurement of thickness an important indicator of tendinopathy.[9] Increased thickness of ligaments of the most distal parts of the body has long been observed in patients with DM. This study was programmed to assess the thickness and stiffness of Achilles tendons (AT) in diabetic patients with & without foot ulcers.

In our study we found significant thickening of the AT in patients with T2-DM with foot complications (9.49mm±0.5) and T2-DM without foot complications (8.73mm±0.36), compared to healthy patients (6.71mm±0.69). Similar results have been obtained in various studies assessing the effects of diabetes on the AT.

Giacomozzi et al. demonstrated that the AT was thicker in patients with diabetes than in controls. Thickening of the Achilles tendon became statistically significant for patients with neuropathy and with previous neuropathic ulcers compared to the control group. The results of our study were similar to this study. However, in contrast to the study by Giocomozzi et al., our patients had ongoing foot ulcers, while patients of their study had previous neuropathic ulcers. Patients with diabetes and previous history of ulceration occupy the highest category of risk for reulceration.[8] Because of the similarity between our study group with current ulcers and the group of patients with diabetes with previous neuropathic ulcers involved in Giocomozzi et al.'s study, the results may not be accidental.[8]

Cheing et al. showed that patients with diabetes with or without neuropathy had a thicker Achilles tendon than the healthy controls.[10] The results of the study done by them were similar to our study. The study by Papanas et al. also demonstrated increased thickness of the Achilles tendon.[11]

In a study conducted by D'Ambrogi et al. in 2005, they showed that thickening of Achilles tendon was more evident in the presence of neuropathy but already detectable in patients with diabetes without neuropathy.[12]

In our study, SWE was used for evaluation of the AT & was found to be softer in diabetic patients with foot complications as compared to diabetic patients without foot complications. Mean Young's modulus in diabetic patients with foot complications was found to be 116.87 ± 14.1 kPa & in those without foot complications was found to be 165.18 ± 10.25 kPa, which means to say that AT in patients with foot complications has reduced stiffness.

Evranos et al. in the year 2015 was the first to evaluate AT by elastography in patients with diabetes; they found that the stiffness in the middle and lower one-third of the AT was significantly lower in patients with foot ulcers compared with controls. This can be compared to our study which also showed similar results.[7] In their study, the Achilles tendon was softer in patients with longer duration of diabetes, or patients using insulin instead of oral anti-diabetic medications, having foot ulcers regardless of the site, or having neuropathy or Peripheral arterial disease. Our study yielded similar results where patients with diabetic foot complications had softer AT as compared to other groups.[7]

Our results were similar to the results of the study conducted by İyidir et al. in 2021. They assessed the thickness & elasticity of AT and

concluded that, 'Diabetic patients with neuropathy have thicker and softer Achilles tendon while the elasticity of Achilles tendon in diabetic patients without neuropathy is similar to the healthy controls. Softening of the Achilles tendon may be an early sign of diabetic foot and reveal the patients with a risk of diabetic foot. [13]

The results obtained in the present study support the hypothesis that DM induces changes in the AT. The altered morphology and softening of the AT may lead to altered foot mechanics and eventually may even have a role in the development of foot ulcers. A knowledge of the various diabetes-related changes evaluated using SWE helps in better prevention of foot complications in diabetic patients.

Small sample size was one of the limitation of the study. However, as the study was done in one center, it cannot be generalized to the entire population.

CONCLUSION

Diabetic patients with foot complications have a thicker Achilles tendon as compared to those without any foot complications. Non-diabetic controls had a relatively thinner Achilles tendon as compared to both the diabetic groups. The diabetic patients with foot complications had a relatively low Young's modulus compared to those without foot complications, which implies that the AT in patients with foot complications are less elastic as compared to those without foot complications. However, there was no significant difference in the stiffness of AT between non-diabetic controls & diabetic patients without foot complications. Hence, decrease in the elasticity of AT & its thickening in diabetic patients can be an important marker of impending foot complications.

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