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Sonographic Assessment of the Effects of Hyperglycemia on Plantar Aponeurosis in Type-2 Diabetic Patients.

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ABSTRACT

In adults, investigations on effects of diabetes on the skin of the upper and lower limbs have been carried out using ultrasound and punch biopsies but plantar aponeurosis thickness in isolation has not been examined in this locality.

The aim of this study was to assess sonographically the effects of hyperglycemia on the plantar aponeurosis in type 2 diabetic patients. A total of 400 subjects (200 healthy non diabetic and 200 diabetic adult Nigerians) were studied. The non diabetic subjects consisted of 105 men (age range = 18 71; mean age ± SD = 42.40 ± 6.72) and 95 women (age range = 23 69 years; mean age ± SD 37.71 ± 4.23). Diabetic subjects were made up of 111 men (age range = 33 74 years; mean age ± SD = 62.53 ± 9.21) and 89 women (age range = 35 69 years; mean age ± SD = 58.44 ± 6.12).

A high resolution dedicated small parts ultrasound machine (with a 10 MHz transducer) was used to assess the plantar aponeurosis. The fasting blood sugar levels (FBSL) of all patients and the Haemoglobin (HbAlc) were recorded against the plantar aponeurosis thickness. The data was analyzed using SPSS (version 14.0).

The results show that the plantar aponeurosis of the diabetics with hyperglycemia was significantly thicker than that of diabetics with normal blood sugar level and control group ($p < 0.001$). Plantar aponeurosis thickness (PAT) was directly related to fasting blood sugar level. Male gender and Body mass index (BMI) were also directly related to plantar aponeurosis thickness.

Hyperglycemia accelerates the accumulation of glycation-end products resulting in the thickening of the plantar aponeurosis in type 2 diabetic patients.

Key words: Ultrasound● Diabetics● Plantar Aponeurosis● Thickness● Hyperglycemia, Glycation.

INTRODUCTION

Diabetes Mellitus (DM) is a chronic disorder of carbohydrate, fat and protein metabolism, owing to either insufficient secretion of insulin or target tissue insulin resistance[1]. It occurs in two major forms, type 1 and type 2 both of which differ in etiology, pathology, age of onset and treatment. About 95% of persons with diabetes mellitus have type 2 and the rest have type 1[2]. The pathogenesis of type-2 DM is not well understood and remains enigmatic[3,4]. Insulin regulates carbohydrate metabolism by aiding the transport of glucose and amino acid from the blood stream into the storage organs such as liver and muscles. In diabetes mellitus, there is hindrance of glucose transport to such a degree that threatens or impairs health.

The Plantar Aponeurosis (PA) or Plantar Fascia is a ligamentous structure that extends from the calcaneum to the proximal phalanges. It is composed primarily of type 1 collagen[5] and is divided into three parts, the central (the thickest and strongest part) the lateral and medial parts. The central part divides into five bands, one for each toe and thus provides an intermediate structure between the skin and the osteo-ligamentous frame work of the foot. It plays a dual static and dynamic role in the longigudinal arch support in the foot[6,7] The stress placed on the plantar skin and plantar aponeurosis during daily activities makes these tissues extremely susceptible to trauma, particularly in subjects with diabetes[8]. Despite the fact that the PA is a structure of the foot which could be affected by the complications of various disease processes, it

has not been examined comprehensively in diabetics.

The incidence of type- 2 DM is growing rapidly worldwide[9,10,11]. In Nigeria, there is a progressive rise in the incidence of diabetic nephropathy from 19% in 1971 to 42% in 1988[12]. Epidemiological studies have provided the evidence of rising prevalence of diabetes all over Africa[13] The global estimate was put at approximately three million in 1994 and is due to go through a 2 to 3 fold increase by the year 2010[14].Investigations on effects of diabetes on the skin of the upper and lower limbs of adults have been carried out using ultrasound and punch biopsies[15,16,17,18], but plantar aponeurosis thickness in isolation has not been examined in this locality.

In view of the rising incidence of diabetes mellitus worldwide and its effects on some vital organs of the body, assessment of the plantar aponeurosis of diabetic patients becomes very necessary.

This study is designed to assess the effects of hyperglycemia on PA of type 2 diabetic patients and to determine any association between plantar apponeurosis thickness with blood sugar level, body mass index and sex.

MATERIALS AND METHODS

A total of 400 subjects (200 healthy, non-diabetic and 200 diabetic adult Nigerians) were studied. The non diabetic subjects consisted of 105 men (age range = 25 71; mean age ± SD = 42.40 ± 6.72) and 95 women (age range = 26 69 years. Mean age± SD = 37.71 ± 4.23). Diabetic subjects were made up of 111 men (age range = 33 74 years; mean age ± SD = 62.53 ± 9.21) and 89 women (age range = 35 69 years; mean age ± SD = 58.44 ± 6.12). Pregnant women, acromegalic subjects, those with foot ulcers, joint diseases or acutely painful conditions which could affect gait, were excluded from the study. The procedures and aims were clearly explained to the subjects and all gave informed consent. The Human Rights and Ethics Committees of Ebonyi State University Teaching Hospital and Nnamdi Azikiwe University, approved the study. The ultrasound machine used in measuring the PA is Siemens SL-1 model. Patient lay prone on the examination couch, with the knee flexed. Ultrasound gel was applied on the plantar aspect of the foot and scanning was done longitudinally, with emphasis on the central portion of the aponeurosis. To obtain measurement, the transducer was placed at least 3 cm from the calcaneal insertion of the aponeurosis. Measurement of the aponeurosis was made from its anterior to the posterior wall. The PA of the diabetics were first measured before they were placed on anti diabetic drugs regimen. The PA was measured again after 3 weeks of treatment. The fasting blood sugar levels(FBSL) of the subjects were measured using a digital glucose meter-Accu check with serial number GGo3111364 (Roche group, Uk). The capillary blood was obtained by pricking the finger with a small lancet, after the area had been appropriately cleaned with methylated spirit and cotton wool. A drop of capillary blood was placed on the reagent strips and glucose levels were determined electronically. HbAlc was determined using Bio-Rad Diamat analyzer (Bio-Rad, Hercules, CA) in both control and diabetic subjects. The weight and height of the subjects were measured using electronic weighing scale and meter rule.

PAT was categorized according to FBSL, sex and age, SPSS software was used to analyze the data. The significant level was determined at $P<0.05$. T- test was used to compare the PAT of male with that of female as well as that of non diabetic with those of diabetic patients. PAT of diabetics with normal blood sugar level were also compared with those of diabetic patients. PAT of diabetics with normal blood sugar level were also compared with those with hyperglycemia. The relationship of PAT with FBSL, BML and duration of DM were assessed using regression analysis.

RESULT

A total of 400 subjects were included in the study. This comprised of 200 healthy, non diabetic subjects (control group) and 200 diabetic patients. The control group consisted of 105 males (age range = 18 71 years, means age ± SD = 42.40 ± 6.72 years), and 95 females (age range 23 69 years, means age ± SD = 37.71 ± 4.23 years). The diabetic patient were made up of 111 males (age range = 33 74 years mean age ± SD = 62.53 ± 9.21 years) and 89 females (age range = 35 69 years), mean age ± SD = 58.44 years.

Males had significantly thicker PAT, 3.25 ± 0.11 mm than females, 3.00 ± 0.26 mm (P < 0.05). Diabetic subjects with hyperglycemia had significantly thicker PAT, 4.56 ± 1.94 mm than the diabetics with normal blood sugar levels 3.12 ± 0.18 mm (P = 0.000). there was a strong positive correlation between PAT and FBSL (r = 0.69), (P < 0.05). BMI also had a strong positive correlation with PAT (r = 0.484). There was no significant correlation between age and PAT.

Fig.1

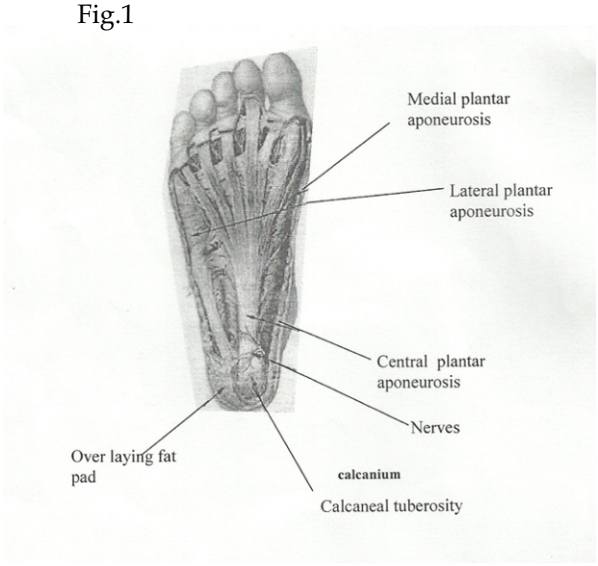

Table:1 Comparing some variables between diabetics with normal FBSL and diabetics with hyperglycemia. *=P<0.05.

Variables	**Diabetes With Normal Fbsl**	**Diabetics With Hyperglycemia**
BMI	22.63 ± 1.3	26.74 ± 3.5
Age	39.46 ± 3.51	60.71 ± 6.60
Sex M ; F	105:95	111.89
FBSL (mg/dl)	112.61 ± 4.13	198.56 ± 9.69*
PAT (mm)	1.13 ± 0.15	4.20 ± 1.31*
HbAlc (%)	6.5	8.9*

Table 2: Variation of PAT between non-diabetic subjects with increased FBSL of same age group.

Control group				**Diabetic subjects**			
Age (Years)	FBSL Mean ± SD mg/dl	PAT Mean ± SD (mm)	N	FBSL Mean ± SD (mg/dl)	PAT Mean ± SD (mm)	N	P Value (PAT)
25 - 34	73.00± 5.00	3.14 ± 0.44	41	174.00 ± 30.32	3.70 ± 1.60	20	0.000
35 - 44	83.00±7.45	3.12±0.44	74	188.60 ±71.11	4.34 ± 1.07	55	0.000
45 - 54	80.00±9.76	3.13±0.47	45	213.62 ± 41.20	4.69 ± 2.01	55	0.000
55 – 64	92.00 ±7.50	3.14 ± 0.09	34	210.55 ± 45.90	4.37 ± 1.03	26	0.000
65 – 74	90.00 ±0.38	3.10 ± 0.38	6	206.09 ±67.00	4.28 ± 2.18	44	0.000

Table 2 shows that PAT of diabetes with increased FBSL are significantly thicker than of their non diabetic counterpart in all age group.

Table 3: Comparing PAT in diabetics with normal blood sugar levels and those with hyperglycemia.

Age	With normal Blood Sugar level PAT, mean ± SD (mm)	With hyperglycemia PAT, mean ± SD (mm)
23 – 34	3.21 ± 0.51	4.53 ± 1.68*
35 – 44	3.35 ± 0.75	4.61 ± 2.13*
45 – 54	3.30 ± 0.38	4.42 ± 2.33*
55 – 64	3.32 ± 0.66	4.77 ± 1.91*
65 – 74	3.25 ± 0.55	4.25 ± 1.74*

= $P < 0.001$.

Table 3 shows that PAT of diabetics with hyperglycemia were significantly thicker than PAT of diabetics with normal blood sugar levels.

DISCUSSION:

The range of PAT for apparently normal subjects in our study is 2.88 mm to 3.45 mm for the males and 2.75 mm to 3.33 mm for the females. The mean thickness is 3.25 ± 0.11 mm for the males and 3.00 ± 0.26 mm for the females. The findings are similar to earlier studies[19] that used Magnetic Resonance Imaging (MRI) to assess plantar aponeurosis. Bolton et al[20] in their study using computed tomography ,noted PAT of normal adults to be 3.6 mm. males, in our study, had significantly thicker PAT than females ($P < 0.05$). This conforms to the anatomical variation between males and females. Differences in hormonal constitution between male and female is the most possible reason for the differences noticed. PAT in the diabetic ranged from 3.31 mm to 7.60 mm with a mean of 4.36 ± 0.94 mm. This is significantly thicker than that of normal subjects ($P < 0.005$). The PA of diabetics remained significantly thicker than that of the control group even when adjustment was made for other variables (BMI, male gender, HbA1c). Thickened plantar aponeurosis has also been observed in patients with plantar fasciitis[19,21]. The pathogenesis of the thickening of PA in diabetic patients is thought to be non enzymatic glycation[8]. Non enzymatic glycation is the process by which glucose is chemically attached to amino group of proteins without the aids of enzymes[3]. The PA is composed primarily of densely compacted collagen fiber[5] which is highly susceptible to non enzymatic glycation[8]. The collagenous component of the PA, in the presence of excess glucose, undergoes non enzymatic glycation resulting to thickening of this tissue in diabetics with hyperglycemia.

FBSL had a strong positive correlation with PAT ($r = 0.696$). This means that the higher the blood sugar level, the thicker the PAT. This is explained by the fact that the degree of non-enzymatic glycation is directly related to the level of blood glucose,[3]. Non-enzymatic glycation is a reversible process, and so if the factors that encourage its progress such as presence of excess glucose in the blood stream are withdrawn or controlled, the reverse process may occur; leading to a reduction in the size of the tissue to a normal level. In our study, 35% of the diabetics had good control of their blood sugar levels (mean level, 113.20 ± 10.13 mg/dl). Their mean PAT was 3.37 ± 0.25 mm. This means that in diabetic subjects whose blood sugar levels are brought under good control, their PAT could reduce to normal size. Regression analysis shows that a unit rise in FBSL results in 0.03127 mm rise in PAT ($P = 0.001$).

Conclusion:

PAT of diabetic patients with hyperglycemia re mained significantly thicker than normal even when corrections were made for other variables. PAT is therefore related to the blood sugar level and could be useful in the assessment of blood glucose level and management of diabetes mellitus.

It would be interesting to know how long it would take the thickened PA of diabetic patients with high blood sugar levels to return to normal size with good control of the blood sugar levels. This study is already in progress.

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