J Expt. & Clin. Anat. 10 (1)21-26

JECA

Estimating Plantar Aponeurosis Thickness (PAT) Using Known Anthropometric Variables: An Ultrasound Based Study

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ABSTRACT

The study was carried out to evaluate the possible use of some anthropometric variables to estimate the thickness of plantar aponeurosis (PAT) in an Igbo population in southeast Nigeria. Ultrasound was used to assess PAT and standard anthropometric tools were used to measure height and weight. BMI and BSA were calculated. Results show that Height, weight and BSA were strongly related to PAT ($P<0.01$). Simple regression equations were derived for each parameter and PAT (dependent variable). Males also had a significantly higher PAT than females. These relationships could serve as a guide in the study of plantar fascia thickening and plantar fasciitis and in the biomechanics of the foot.

Key words: Plantar Aponeurosis, estimation, ultrasound, Nigeria

The plantar aponeurosis (PA), or plantar fascia, has received considerable attention in the scientific literature and has been shown to be the most important structure for dynamic longitudinal arch support in the foot (Thordarson et al, 1995). The PA comprises histologically both collagen and elastic fibers arranged in a particular network of bundles and are a tough tendinous (rather than a fascial) layer of the plantar aspect of the foot. This sophisticated combination of fibers, having different biomechanical properties during stress application to the plantar aponeurosis, affords an increased modulus of elasticity during weight bearing (Straub, 1950).

The plantar aponeurosis originates from the medial tubercle of the calcaneus and inserts into the phalanges through a complex network of fibrous tissue (Erdemir et al, 2004). It is composed of densely compacted collagen fibres oriented mainly longitudinally, but also transversely (Sinatamby, 2000); and it is divided into three (3) parts- Central, Medial and Lateral parts.

The plantar fascia has long been considered to have a significant purpose in the weightbearing foot, both in static stance and in dynamic function. Various functional and structural roles have been indicated by virtue of its anatomical attachments (Aquino and Payne, 1999). Hicks (1954) described the function of the plantar aponeurosis as being analogous to the windlass mechanism in which the arch of the foot elevates by winding of the plantar aponeurosis around the heads of the metatarsals during toe extension. Various cadaveric studies have revealed that release of plantar aponeurosis decreases arch height, confirming the arch supporting function of the plantar aponeurosis (Kitaoka et al, 1997; Thordarson et al, 1995; Sharkey et al, 1998).

Ker et al (1987) identified the plantar aponeurosis as a mechanism of energy storage in the foot in an in vitro experiment. Kim and Voloshin (1995) in their study of the role of plantar aponeurosis on the load bearing capacity of the foot using computer models also opined that it is the energy storage mechanism of the foot. Another function of the aponeurosis was to provide better cushioning against the high ground reactions forces occurring in the late stance phase by tightening of the soft tissue framework beneath the metatarsal heads (Bojsen-Moller and Lamoreux, 1979).

Plantar aponeurosis thickness (PAT) has been used to access the mechanical properties of the plantar fascia. Berkowitz et al (1991) using magnetic resonance imaging stated that PAT for normal adults to be 3.00mm. Bolton et al (2005) using computed tomography discovered that PAT was 3.6mm. Udoh (2006) in a Nigerian population stated that the range of PAT was 2.88- 3.75mm for males and 2.00-3.25mm for females with mean thickness of 3.25mm for males and 2.36 for females. Recently, Huang et al (2010) in their ultrasonographic study stated that PAT was 5.5mm; a value higher than others. These thickness values for plantar fascia may affect the relative occurrence of individual foot prints considering its imposing effect on the foot arch morphology where Hicks (1954) described a windlass mechanism to initiate a mechanical pull between the Calcaneus and the proximal phalanges. As a result, the PA is highly involved in the kinetics and kinematics of gait and human locomotion. In addition, it contributes to the formation of the outline of the feet, which is important in the forensic identification of an individual. Being a principal component of the foot which has been used to estimate stature in numerous cases (Krishan, 2008), it is necessary to ascertain its relationship with some known anthropometric variables to enhance further understanding of its structural disposition. And since no study in our sub-saharan African environment has assessed the PAT in relation with these anthropometric variables, and where as its functional significance is near absolute and its role in the occurrence of plantar heel pain and plantar fasciitis is certain, it is even more necessary to evaluate its structural inclination in this population with a view to establish correlations with known anthropometric parameters like height, weight, body mass index (BMI) and body surface area (BSA). This may guide physicians in the diagnosis of plantar pain, which its incidence has not been reported in our environment even though it has been estimated to affect 10% of runners and is present in the general population at the same rate in the US (Demaio et al, 1993). The study will describe anthropometric parameters that could be used to assesses the PAT and by application, guide physicians in examination of cases of Plantar fasciitis. It will also be a pointer to future biomechanical studies of the PA in our environment.

The choice of ultrasonography in the assessment of the soft tissues was guided by the recommendations of previous studies, which stated that high resolution ultrasound should be employed as it is versatile in diagnosing soft tissue pathologies in different body locations (Ophir et al, 2000) of which the PA should is not left out.

SUBJECTS AND METHODS

Design: This is a research that was carried out within Abakaliki metropolis, Ebonyi State, Southeast Nigeria.

Study Centre: The study was done in an ultrasound scanning centre Veramax imaging centre, Abakaliki, Ebonyi State, Nigeria. This ultrasound and Imaging centre receives patients from within Abakaliki metropolis and beyond (Ogoja and Afikpo Metropolis). Their patients are mostly obstetric patients and individuals with soft tissue pathology including all forms of intra-abdominal pathologies. It is well staffed with a total of twelve (12) resident Medical Imaging Scientists. The centre receives patients from all private hospitals in Abakaliki Metropolis and neighbouring Metropolis like Afikpo and Ogoja Metropolis; and those not accommodated in the Federal Medical Centre, Abakaliki and Ebonyi State University Teaching Hospital, Abakaliki, Ebonyi State, Nigeria.

Study Population: The study population comprises a convenient study population of 120 (83 males and 37 females) Igbos living and working in Abakaliki Metropolis. These subject were recruited after their consent were duly sought and approval given. Those included in the study were subjects who were apparently healthy; had no history of any systemic disease like diabetes, familial hypercholesterolemia etc and foot deformity or had undergone any form of foot surgery. This was to avoid any possible effect of these ailments on the structural disposition of the PA. The exclusion criteria included subjects who had any history of systemic diseases like diabetes, familial hypercholesterolemia, undergone any form of foot surgery or was pregnant. These subjects were recruited over a period extending from June, 2010 to May, 2011

Instrument For Data Collection:
A 7.5 linear-array transducer (Siemens sonoline 940- 2000 model) with a diameter of 39mm was used for the assessment of the thickness of plantar fascia. Other instruments for anthropometric measurement include: Caliberated wall to measure height of subjects and Automatic weighing balance. Body Mass Index (BMI) was calculated using the formula BMI= WEIGHT/(HEIGHT)^2. The Body Surface Area (BSA) was calculated using the formula by Du Bois and Du Bois (1916). BSA= (Weight $^{0.425}$ X Height (cm) $^{0.725}$) 0.007184.

Experimental Protocols: For this study, direct measurement techniques were employed. On the arrival of the subjects, their heights were measured using the calibrated wall and their weights taken with the automatic weighing balance. After which the scanning protocol was observed.

Scanning Protocol:
During measurement of Plantar Aponeurosis thickness (PAT), each subject lay in a prone position on the couch with knees flexed with the ultrasound gel applied generously on the plantar aspect of the foot. Scanning was then carried out when the probe was placed longitudinally over the centre of the foot at about 3cm from the calcaneal insertion of the aponeurosis. The PAT was measured from its anterior wall to the posterior wall (Udoh, 2006).

All measurements were taken by one Medical Imaging Scientist to avoid interobserver variability and each measurement was taken three times for the two feet and the average obtained and recorded in a sheet. The data obtained from the measurements were analyzed using SPSS version 16.0.

Ethical Approval
Ethical approval for this work was obtained from the Research/Ethics committee of the Faculty of Basic Medical Sciences, Abia State University, Uturu, Southeast Nigeria.

RESULTS

Table I Descriptive Statistics for PAT for the general population

	PAT (RT) mm	PAT (LT) mm	Height (m)	Weight(Kg)	Age(yrs)	BMI (Kg/m^2)	BSA	N0 of Subjects
Mean±SD	3.41±0.74	3.40±0.75	1.66 ±.09	66.50±9.25	28.78±5.81	24.10 ± 2. 61	1.25 ± 0.04	120
Range	2.0-5.8	1.9-5.9	1.45-1.84	50-104	18-43	19-95 32.10	1.17-1.41	

The table above describes the mean values of PAT (RT and LT) for the general population to be 3.41±0.74 and 3.40±0.75 mm respectively. Other values are the descriptives of the anthropometric variables assessed- height, weight, age, BMI and BSA. The mean height for the study population was 1.66 ±.09m; weight was 66.50 ±9.25; BMI was 24.10 ± 2.61; BSA was 1.25±0.04 and age was 28.78±5.81.

Table II. Correlations between the PAT and some anthropometric parameters.

	Height	Weight	Age	BMI	BSA
PAT (Rt) Pearsons correlation	0.413**	0.358**	-0.085	0.039	0.406**
P- value	0.000	0.000	0.356	0.674	0.000
PAT (Lt) Pearsons					
Correlation	0.432**	0.393**	-0.099	0.067	0.438**
P-value	0.000	0.000	0.284	0.470	0.000

*Correlations is significant at P=0.05 (2-tailed)
**Correlations is significant at P=0.01 (2 tailed)

The tables shows very strong correlation between the PAT and height, weight and BSA (P= 0.000; 0.000 and 0.000). There was no significant correlation between the PAT and Age and BMI (P=0.284 and 0.470).
Following the strong correlation, simple regression equations were derived using the PAT as the dependent variable. They are:

1) PAT=-2.527+3.577 Height.
2) PAT=-0.179+2.067 BSA
3) PAT= 1.512+0.029 Weight.

Using independent sample t-test, the males had significantly higher PAT thickness than the females (P=0.002).

DISCUSSION

Plantar fascia is subjected to significant traction as body weight is transferred onto the forefoot during the later half of the contact phase of walking, and the intensity of the fascia's stresses and strains increases with the intensity of activity (Perry, 1983). These activities may affect the structural disposition of the plantar fascia.

Results from this study have shown that the PAT of the adult population was 3.41±0.74 mm and 3.40±0.75mm for the right and left foot respectively. The values ranged from 2.0-5.8mm for the right and 1.9-5.9mm for the left plantar aponeurosis thickness. These figures conform to the reports of a previous study in a Nigerian population where Udoh (2006) stated that the PAT values ranged from 2.88- 3.75mm for males and 2.00-3.25mm for females with mean thickness of 3.25mm for males and 2.36mm for females. Our results present a wider range (2.0-5.8mm) and a slightly higher mean value (3.41±0.74 mm and 3.40±0.75mm for the right and left sides respectively) for the entire population. This may be related to the degree of physical activity of the sample population, which may have altered slightly the structural inclination of the plantar aponeurosis. Results from Berkowitz et al (1991) using magnetic resonance imaging stated that PAT for normal adults to be 3.00mm. Bolton et al (2005) using computed tomography discovered that PAT was 3.6mm and Huang et al (2010) reported a higher 5.5mm. These variations from different populations may be attributed to environmental and activity related differences which affect the plantar fascia strain and stress that may in turn induce structural and biomechanical deviations. This may not necessarily indicate a clinical condition of any sought.

Independent sample t-test revealed that males had a significantly higher PAT value that their female counterparts. Pascual huerta and Alarcon Garcia (2007) reported the effect of gender on the thickness of the Plantar fascia and this occurs at the part proximal to the insertion of the fascia while Uzel et al (2006) also reported significantly higher values of PAT in males than in females when measured at 5mm from origin. In this study, 3cm distal to the origin has shown this significant gender difference and may also be related to hormonal and statural inclination of the sexes.

Pearsons correlation has revealed strong relationship between PAT and height; PAT and Weight and PAT and BSA (P=0.000; 0.000 and 0.000 respectively). These relationships imply that these individual anthropometric parameters should have mechanical and structural effects on the plantar fascia and may contribute to predisposing factors in the occurrence of plantar fasciitis. Pascual Huerta et al (2008) did not report any relationship between the PAT and the above named anthropometric parameters but stated that BMI was mildly related to Plantar Fascia thickness. In another study by Pascual Huerta and Alarcon Garcia (2007), it was also stated that Height and Age did not seem to influence as independent variables in plantar fascia thickness. In contrary, this study has shown a strong relationship between PAT and height. As a result, the regression equation derived could be used to assess the thickness of plantar fascia in the population of study. BSA and Weight could also be used to assess PAT in the population due to high level of structural relationship seen in this study. The lack of relationship between PAT and Age seen in this work was also described by Pascual Huerta and Alarcon Garcia (2007) and may be associated with the narrow age range associated with the subjects.

Estimation of the structural orientation of relatively deep and clinically relevant body structures using easily accessible anthropometric variables should extend the frontiers of experimental and clinical knowledge in the biomedical sciences and give a valuable insight in the occurrence of ailments associated with the body structure as it is related to the environment of study. Therefore, the regression equations derived should be validated by biomedical scientists and podiatric clinicians and used to establish a relationship with the variables and likely occurrence of plantar fasciitis in any environment. It should also be used to initiate biomechanical studies on the PA.

Further studies should ascertain the structural relationship between the PAT and the general outline of the foot and foot prints since it contributes greatly to the arch indices of the foot and physical activity related effects on PAT should be studied. Also cases of plantar fasciitis should be duly studied to possibly re-emphasize these relationships.

CONCLUSION

Plantar aponeurosis thickness can be estimated using height, weight and body surface area (BSA) and these derived equations for estimation should be validated for clinical and scientific use for detection of predisposing factors in the thickening of plantar fascia and associated fasciitis.

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