Original article:

Occupation related differences in the thickness of metatarsal fat pads: an in vivo assessment in a young male adult population

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Abstract

Background: The foot combines mechanical complexities with structural strength to withstand pressure and the metatarsal fat pads play a major role in this. ***Methods Material:*** In this study, we determined the metatarsal fat pad thickness of 40 male students that constituted a control group and an age-matched 40 male auto mechanic artisans within Abakaliki metropolis, southeast Nigeria, which served as the quasi-experimental group. Evaluation was made using a brightness mode ultrasound system. Their weights, heights, foot length, foot breadth and mid foot circumference were measured. ***Results:*** Results show a significant (P<0.05) difference in the mid-foot circumference and metatarsal fat pad thickness between the control (9.99±0.55cm and 2.04±0.35mm respectively) and artisans (9.58±2.0.59cm and 2.50±2.0.38mm respectively). However, there was no significant (P>0.05) differences in the foot breadth and length between the control (9.86±0.84cm and 26.96±1.03cm) and artisans (10.03±0.54cm and 26.16±1.39cm). ***Conclusion:*** These findings indicate that occupation related physical activity that increases plantar pressure can induce an unprecedented thickening of the Metatarsal fat pads thereby reducing elasticity and shock absorbing ability of the fat pads. This could trigger the development of overuse injuries of the foot and plantar foot ulcers. The assessment could also serve as a guidepost in the biomechanical evaluation of the metatarsal fat pad thickness.

Keywords: Metatarsal fat pad; Ultrasound; Occupation; Nigeria

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Introduction

The human foot combines mechanical intricacies with structural integrity to enable it play its roles in dynamic support, balance and mobility and thus functions as a propulsion engine. The metatarsal fat padis one of thefoot structures required to display some shock absorbing ability.Generally, fat pads are masses of closely packed fat cells surrounded by fibrous tissue septa that may be extensively supplied with capillaries and nerve endings[1].

Metatarsal fat pads under the metatarsal heads provide the primary source of cushioning to protect the skin from damage during walking running, jumping or landing[2]. These fat pads are invested in the flexor tendons of the toes and originate from the plantar ligaments, which are firmly attached to the proximal phalanges[3, 4]. They also help transfer and distribute body weight to necks and shafts of the metatarsals[5].

Hyperextension of the metatarsal-phalangeal joint exposes the metatarsal fat to elevated levels of mechanical pressure during gait[6,7]. Elevated plantar pressure is a major risk factor for plantar ulceration[8,9]. Increased metatarsal fat pad thickness has been implicated as a contributing factor in overuse injuries of the foot as a result of loss of metatarsal fat pad elasticity[10]. Studies have shown that this thickness is significantly greater in diabetics[11]. Some studies have examined its importance in the kinetic and kinematics of gait pattern and have repeatedly stated that deficits in its function may likely induce a high degree of biomechanical stress on other soft tissue of the foot like the plantar fascia[12]. The fat pads normally atrophy with age but the risk of fat pad loss

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increases if the individual is overweight, diabetic, has often worn thin-sole or high-heel shoes, or worn cleats in athletic activities to any degree.

Therefore, there could be a significant impact of the occupation of individuals on the structural integrity of the metatarsal fat pads. In Nigeria and various developing countries, the number of artisans are increasing in order to adjust to the rising pressure on the economy. These artisans, especially in the motor mechanic sites/workshops are significantly exposed to various forms of lifting associated with undue stress and strain of the plantar surface of the foot. These individuals also do not believe in the appropriate podiatric packaging that could be protective of the plantar surface of the foot. Hence, the structural integrity of the load-cushioning metatarsal fat pad may always be put to test.

In view of the above and even with the known numerous roles of the metatarsal fat pad on the foot, very little attention has been given to it; it is absolutely necessary to evaluate and compare its structural inclination among a group of individuals who are not exposed to plantar stress and strain and individuals who are continuously exposed to the likelihood of overuse. By this evaluation in two occupational categories, one can conclusively establish the effect of occupation on the structural integrity of the metatarsal fat pads with a view of making appropriate recommendations to safety agencies and government/ private occupational health parastatals. The effect of known anthropometric variables on the Metatarsal fat pads were also investigated to understand which anthropometric parameter best evaluates the fat pads.

It is important to know that the choice of ultrasonogragphy in the assessment of these 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 tissues pathologies in different body locations[13] and has long been a reliable tool in assessing human fat pad thickness[11].

Materials and methods

Study Design

This study was a Quasi-experimental design involving convenient purposive method of sampling. A total of eighty (80) apparently healthy male Nigerian volunteer with age ranging from 18-32 (40 control and 40 artisans) were recruited for this study. They were informed to avoid any physical activity or exercises (e.g., running, cycling, etc) weeks before the study as this have found to cause increase in fat pad thickness[14]. None of the subjects had any clinical evidence of musculoskeletal injury, were diabetic or had any history of Familial hypercholesterolemia. The forty[4] artisans were selected because they had been involved in the occupation for at least 12 calendar months. The data collection lasted between January and June, 2014.

The study procedures were clearly explained to the volunteer and they all signed a written informed consent form. Ethical approval was obtained from the ethic/research committee of the Faculty of Basic Medical Sciences, Ebonyi State University, Abakaliki, south-east, Nigeria.

This study was conducted at Life-scan Ultrasound Centre, Felix Memorial Hospital, 7 Hilltop Road, Abakaliki, Ebonyi State, South-eastern Nigeria, which serves as the approved imaging laboratory for the Department of Anatomy, Ebonyi State University, Abakaliki. Brightness mode (B-mode) ultrasound scan system (Siemens Sonoline SL-1) was used to measure the thickness of metatarsal fat pad with 7.5MHZ linear transducer.

The subjects were made to lie in a prone position on a

Figure 1: Measurement of the thickness of metatarsal fat pad

Figure 2: Showing the Sonogram of the Metatarsal fat pad.

couch with legs extended and the pad was measured from its tarsal boarder to the end of the fat pad[15]. The ultrasound gel was applied on the surface of the fat pad and the transducer. One investigator measured each subject three times and the average taken. This is to avoid inter-observer variability[16]. The weight and height of the subject were determined using an electronic weighing scale and a calibrated wall.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 [17]. BSA= (Weight $^{0.425}$X Height(cm)$^{0.725}$)0.007184. All data collected for each subject were analyzed using the Statistical Package for Social Sciences (SPSS) version 20. The results were arranged as mean±standard deviation, and correlation were calculated using a bivariant Pearson's method for correlation at both significant 0.05 and 0.01 (or 2-tailed).

Result

Foot width (FW), Foot length (FL), mid-foot circumference (MFC) and metatarsal fat pad (MFP) in the control

For the entire study population, the foot width range was 8.9 – 11.9 cm, with mean 9.86 cm and standard deviation of 0.84cm while the foot length range was 24.9 – 29.0 cm, with mean 26.96 cm and standard deviation of 1.03 cm. The mid foot circumference range was 9.1 – 11.1 cm, with mean 9.99cm and standard deviation of 0.55cm and the metatarsal fat pad range was 1.5 – 2.7 mm, with mean 2.0 mm and standard deviation of 0.35 mm (Table 1).

Table 1: Descriptive statistics of Foot width (FW), Foot length (FL), mid-foot circumference (MFC) and metatarsal fat pad (MFP) in the control.

Parameters	Min	Max	Mean	SD	95% Confidence Interval	
					Lower value	Upper value
FW (cm)	8.9	11.9	9.86	0.84	9.72	10.16
FL (cm)	24.9	29.0	26.96	1.03	26.15	26.97
MFC (mm)	9.1	11.1	9.99	0.55	9.73	10.25
MFP (mm)	1.5	2.7	2.0	0.35	1.88	2.20

Relationship between anthropometric parameters and foot width, foot length, mid-foot circumference (cm) and metatarsal fat pad (mm) in the control

There was no correlation between the age and foot width (r = –0.040, P>0.05), foot length (r = –0.193, P>0.05), mid-foot circumference (r = -0.269, P>0.05), and age and metatarsal fat pad thickness (r = -0.001, P>0.05). However, there was a significant positive correlation between height and foot width (r = 0.463, P<0.05), and foot length (r = 0.584, P<0.05), but no correlation between height and mid-foot circumference (r = 0.379, P>0.05), and metatarsal fat pad thickness (r =-0.401, r = 0.080). Also, there was a significant positive correlation between the weight and foot width (r = 0.755, P<0.05), foot length (r = 0.462, P<0.05) and mid-foot circumference (r = 0.040, P<0.05), but no correlation between weight and metatarsal fat pad thickness (r = -0.355, P>0.05). Meanwhile, there was a significant positive correlation between BMI and foot width (r = 0.575, P<0.05) and mid-foot circumference (r = 0.588, P<0.05), but no correlation between BMI and foot length (r = 0.225, P>0.05) and metatarsal fat pad thickness (r = -0.169, P>0.05). There exist a significant positive correlation between BSA and foot width (r = 0.765, P<0.05), foot length (r = 0.589, P<0.05), and mid-foot circumference (r = 0.709, P<0.05), but no correlation between BSA and metatarsal fat pad (r = -0.420, P>0.05).

Table 2: Relationship between anthropometric parameters and foot width, foot length, mid-foot circumference (cm) and metatarsal fat pad (mm) in the control.

Parameters	Foot width (cm)		Foot length (cm)		MFC(cm)		MFP (mm)	
	R	P-value	r	P-value	r	P-value	R	P-value
Age (years)	-0.040	0.865	-0.193	0.415	-0.269	0.252	-0.001	0.996
Height (m)	0.463*	0.040	0.584*	0.007	0.379	0.100	-0.401	0.080
Weight (kg)	0.755*	0.000	0.462*	0.040	0.714*	0.000	-0.355	0.125
BMI (kg/m^2)	0.575*	0.008	0.225	0.339	0.588*	0.006	-0.169	0.475
BSA	0.765*	0.000	0.589*	0.006	0.709*	0.000	-0.420	0.065

* P<0.05 the correlation is significant

Comparison of the parameters in Student Control group and the Quasi-experimental Artisan group

As shown in table 3, there was no significant difference (P>0.05) between the mean age, height and standard deviation of the control (25.15±2.52 years and 1.74±0.07m) and Artisan group (23.25±4.72 years and 1.73±0.05 m) respectively. There was no significant difference (P>0.05) between the mean BSA ± standard deviation of the control (1.83±0.142) and peasant (1.75±0.12) respectively (Table 3). There was no significant difference (P>0.05) between the mean foot width and standard deviation of the control (9.86±0.84 cm) and peasant (10.03±0.54 cm) respectively (Table 3).

However, there was a significant difference (P<0.05) between the mean weight, mean BMI, mean foot length, mean mid-foot circumference, metatarsal fat pad and standard deviation of the control (69.50±10.47 kg, 22.98±3.08 (kg/m^2), 26.96±1.03cm, 9.99±0.55cm and 2.04±0.35mm) and peasant group (63.05±7.76 kg and 21.13±2.06s (kg/m^2) 26.16±1.39cm, 9.58±2.0.59cm and 2.50±2.0.38mm) respectively (Table 3).

Table 3: Comparison of the parameters between the Control group and Artisan group

Parameters	Control Mean±SD	Peasant Mean±SD	t-test	Df	P-value
Age (yrs)	25.15±2.52	23.25±4.72	1.588	38	0.121
Height (m)	1.74±0.07	1.73±0.05	0.682	38	0.499
Weight (kg)	69.50±10.47	63.05±7.76	2.214*	38	0.033
BMI (kg/m^2)	22.98±3.08	21.13±2.06	2.233*	38	0.031
BSA	1.83±0.142	1.75±0.12	1.989	38	0.054
FW (cm)	9.86±0.84	10.03±0.54	-0.762	38	0.451
FL(cm)	26.96±1.03	26.16±1.39	2.067*	38	0.046
MFC (cm)	9.99±0.55	9.58±0.59	2.298	38	0.027
MFP (mm)	2.04±0.35	2.50±0.38	-3.968*	38	0.000

* P<0.05 difference is significant

Discussion

The foot's complex architecture provides a unique foundation for stable support, mechanical leverage, shock dissipation, balance, and sensibility. Stresses within the foot structure are dependent on the three–dimensional geometry of its components, including anatomical areas through which muscular and skeletal forces are transferred[18].

The directions and magnitudes of these forces are basic factors that determine the stress state of foot[19]. These vectored forces are transferred through the soft tissues of the foot to the ground[20]. Focal tension of deep soft tissues occurs near the medial metatarsophalangeal joints during standing, and stresses that are up to eight times the normally expected tension values were predicted.

In this study, there was a significant increase in the thickness of metatarsal fat pad of the Artisans when compared to the Student control group. Poor rebound of the unloading process, i.e., prolonging time to recover the shapes in the plantar soft tissue[21], may have contributed to increased energy dissipation ratio in the metatarsals of the artisan group hence,

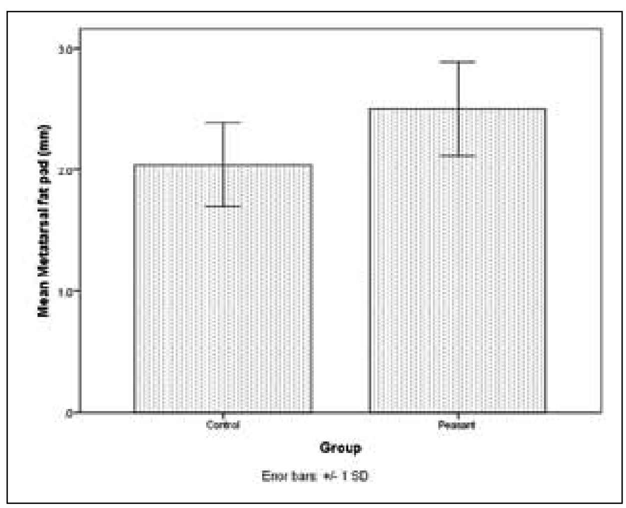

Figure 3: Bar Chart showing the difference in the two groups [Control and Artisans (peasants)]

the increased metatarsal fat pad thickness (P=0.000). An increased energy dissipation ratio damages the metatarsal and increases the susceptibility to foot ulceration in individual[21]. Reduction in toe function and resultant forward migration of some of the cushioning pad of the metatarsal heads is a possibility in the artisans[22, 23].

It is, therefore, probable that these tension and shear stress concentrations which could be expected to increase substantially and become repetitive during gait, cause micro-tears in the plantar pad. And considering the occupational requirements of the individuals (Artisans) involved, there could be a direct absolute relationship between the strains during unregulated load influenced repetitive gaits and the structural disposition of their Metatarsal fat pad.

The biomechanics of gait could be altered, leading to a higher risk for the development of overuse injuries of the foot and plantar foot ulcers[10]. Pearson's correlation did not establish any significant relationship between the studied fat pad and other anthropometric variable assessed. This is contrary to previous studies on the plantar heel pad, which demonstrated significant relationships with height, weight, BMI and BSA[24,25]. The contrast is possibly because the metatarsal fat pads are enclosed in smaller fibro fatty compartments that may not have allowed a wide range of impact by these known anthropometric variables.

The novelty of this study draws from the fact that this is the first report on the thickness of the metatarsal fat pad in any Sub-saharan African population. It has established a nomogram for the thickness of the fat pads in the population and has further established that activity related differences across occupational groups as seen in the Quasi-experimental group (Artisans) affects the structural disposition of the fat pads by increasing its thickness. This may be as a result of increased deposition of fatty tissue in the metatarsal fibrous compartments. The increased thickness reduces pad elasticity and could trigger plantar pain in the long run.

Conclusion

Occupation-induced plantar pressure can trigger an unprecedented thickening of the Metatarsal fat pads. This study has established a significantly higher difference in the thickness of Metatarsal fat pad in Artisans involved in occupational stress-induced increase in plantar pressure, when compared to students whose occupational disposition imparts mildly on their plantar pressure. Also the study has established that assessment of metatarsal fat pad using ultrasound could be beneficial in the early detection of fat pad atrophy from strains of overuse among various populations that are exposed to occupation induced increase in metatarsal fat pad pressure. The findings here-in will be important in occupational health and safety, physiotherapy and musculoskeletal imaging among the study population and beyond.

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