Original Article

Activity related differences in the thickness of achilles tendon among four different occupational groups in nigeria: an ultrasound based study

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Abstract:

Background:The degree of physical activity may induce strain and stress on the Achilles tendon because of its role in the elastic mechanics of gait. Material &Methods: The study was carried out to determine the effect of occupation-related physical activity on the thickness of the Achilles tendon. The effect of occupation-related physical activity on the thickness of the Achilles tendon in three phases (ATT at Normal phase, ATT at Dorsiflexed phase and ATT at Plantarflexed phase) was assessed, by ultrasound, among four classes of occupations- Labourers/farmers, Dancers, Athletes and a less active class (control group). ***Results:*** Results show that the less active (control group) had the least value for ATT (normal) (3.31±0.50mm) being almost at par with those of the dancers. The athletes and labourers/farmers had significantly higher values than the control (P=0.000 and 0.007 respectively). ***Conclusion:*** Our findings have conclusively established that occupation-related prolonged physical activity induces thickening of the Achilles tendon.

Keywords: Achilles tendon, Occupation, physical activity, Nigeria.

Introduction

The Achilles tendon can always be described as the strongest and thickest tendon in the body whose substance consists of collagen (about 95% is type 1 collagen) and elastin embedded in a matrix consisting of Proteoglycan and water[1]. Collagen type-1 accounts for approximately 70% and elastin accounting for 1%- 2% of the dry mass of the tendon [2]. The proteins and carbohydrates are produced by tenoblasts and tenocytes, which are elongated fibroblasts and fibrocytes that lie in rows between the collagen fibres[3].

At rest, the Achilles tendon fibres have a wavy configuration [4] and the elastin it contains grants a certain degree of elasticity on the tendon [5]. The elasticity of the tendon provides an important mechanism: namely, storage and release of elastic strain energy, which improves the economy and performance of motion [6].

Gross inspection reveals that Achilles tendon constitutes the distal insertion of the gastrocnemus-soleus musculotendinous unit (Triceps Surae Muscle). The gastrocnemus muscle with two bellies, originates from the posterior surface of the femoral condyles and the soleus originates from the proximal end of the tibia and fibula and the intervening tendinous arch. The aponeuroses of the three muscles join to form the Achilles tendon, which transmits loads generated by the gastrocnemus and soleus muscles to the calcaneus[3]; a reason for having direct impact on the biomechanics of the foot. And it may be based on that that Griffiths[7] stated that it also acts as a mechanical buffer for the muscles.

Achilles tendon thickness (ATT) has been used to ascertain the structural disposition of the tendon especially in diagnosing some systemic diseases like Familial Hypercholesterolemia (FH) and systemic heart disease (SHD) [8,9,10] and the ATT of the affected individuals are always higher than normal subjects. In a study by Koivunen-Niemela and Parkkola [11], a relatively comprehensive report of ATT of normal subject was made. They stated that children under 10 years had an ATT of 4.6±0.8mm; between 10 -17 years of age had an ATT of 6.1±0.8mm; between 18-30 years had an ATT of 6.3±0.5mm while over 30 years had an ATT of 6.9±1.0mm. This showed that ATT increased with age. They also established that ATT was significantly correlated to the individual's

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height and that women had slightly thinner tendons than men although the difference was statistically significant in the elderly. Mabuchi et al [8] posited 6.3±0.2mm as ATT for normal subjects and an abnormally high value of 12.5±0.4mm for patients with Familial Hypercholesterolemia. In another study, Mathieson et al 12 recorded ATT of 6.2mm for normal subjects.

Considering that the tendon plays an important role in reducing the energy cost of locomotion by storing energy elastically and releasing it at a subsequent point in the gait cycle [13,] it possible that the impact of plantar pressure within the foot on the gait as a result of prolonged physical activities may affect the structural disposition of the tendon. And since Mathieson et al [12] recorded different range of ATT for individuals involved in range of athletic activities and may be a pointer to the effect of physical activity on the mechanics of the great tendon, this study X-rays the possible structural disposition of the Achilles tendon in individuals involved in a range of physical activities and exert a certain degree of pressure on the tendon based on their occupations.

In most developing countries human locomotion forms the basic tool in economic growth. The foot is also a veritable tool among athletes who are constantly involved in running, cycling, jumping and other sports that require a sustained use of the feet. Among dancers, it is fundamental in the artistic communication of the beauty of dancing especially in traditional groups where most cultural exhibition of skills are directly associated with finesse articulation of feet movements; a persistent manifestation of dexterity associated with twisting and turning that imposes relatively high degrees of stress and strain within the foot components.

These factors like the consistent use of the bipedalic system of motion by farmers and their associates in the harvest and transportation of farm produce; by labourers in numerous construction sites in Africa and Asia where mechanization has not been totally employed and who transport heavy work tools and building materials on foot; by professional athletes who are constantly using their feet to earn a living by strenuous acts of running, jumping, cycling; by traditional dancers in Ebonyi State, southeast Nigeria and the rest of Africa who entertain people by exhibiting extra-dexterity in feet movement, may impart on the structural and functional inclinations of the different foot components and because of the vital role of the Achilles tendon in the elastic mechanism of gait, a comprehensive assessment of the tendon should be carried out in all categories of individuals described without avoiding those involved in underutilization of the foot.

Subjects and Methods

DESIGN: This is a quasi experimental research which was carried out within Abakaliki metropolis, Ebonyi State, southeast, Nigeria.

Study Centre

The study centre was done in an ultrasound scanning centre - Veramax imaging centre, Abakaliki, Ebonyi State. This ultrasound and Imaging centre receives patients from within Abakaliki metropolis and beyond. 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 beyond and those not accommodated in the Federal Medical Centre, Abakaliki and Ebonyi State University Teaching Hospital, Abakaliki, Ebonyi State.

Study Population

Abakaliki Metropolis is made up of the capital territory of Ebonyi State, Nigeria. It has a land mass of about 2000 sq. km and bordered in the north by Benue State, in the west by Enugu State, in the east by Cross River State and in the south by Ezza North Local Government area. It has a population of over 400,000 people. Agriculture is the main stay of its economy and the people are essentially farmers. It has a rich cultural heritage and also known for the popular Quarry Industries where some of its people are exposed to a myriad of hazards, especially the women folk. These women are continuously involved in lifting of crushed stones and probably imposing stress and strain on the natural weight bearing/cushioning parts of the foot. Also due to the large production of stones, a lot of construction sites abound. These women and some few men are always continuously lifting building materials, at times without appropriate podiatric wears. These individuals, earning a living in this case, are most likely to induce plantar pressure on their feet 14.

As a result of its rich cultural heritage, the State Government established a State Council for Arts and Culture and the metropolis plays home to a lot of cultural/traditional dance groups that are always training to earn a living through it and to entertain vigorously, the entire populace. With these categories of people, the Metropolis has all the classes of individuals required for this extensive study and that was why we considered it an ideal choice.

Thus, the study populations comprise

a) A convenient study population of 30 Igbos whose occupation is not very physically involving. For instance Bankers, Lecturers, Students who are resident in Abakaliki metropolis.
b) A convenient sample population of 30 Igbos whose occupations are labourious - they undergo a high degree of strenuous work. Examples are those in the Quarry industry, Abakaliki and labourers in building and construction sites resident in Abakaliki metropolis.
c) A convenient Sample population of 30 highly active individuals who are athletes or involved in active sports like football, Lawn tennis, Long Jump etc.
d) A convenient Sample population of 30 Traditional music dancers in Abakaliki Metropolis, Ebonyi State who are also highly active.

Inclusion Criteria:

a) The subjects must be apparently healthy; must have no history of any systemic disease like diabetes, familial hypercholesterolemia etc and foot deformity or have undergone any form of foot surgery. This is to avoid any possible effect of these ailments.
b) The group (a) study population must not have any other type of job that increases physical activity and must have worked for a minimum of two (2) calendar years.
c) The group (b) study population must not have any other job impeding his /her degree of physical activity except his normal rest periods.
d) The group (c) study population must be professional athletes/sportsman registered in any private or state owned sports outfit within Abakaliki and Enugu Metropolis.
e) The group (d) study population must be professional traditional music dancers Abakaliki Metropolis registered with the Ebonyi State Council for Arts and Culture.

Exclusion Criteria

a) Subjects that had any history of foot deformity or foot surgery.
b) Subjects who were pregnant. This is to avoid the effect of pregnancy on fat distribution and gait mechanics.
c) Subjects with a history of any systemic disease like diabetes, familial hypercholesterolemia etc. This is to avoid any possible effect of these ailments.

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 Achilles tendon.
SCANNING PROTOCOLS: During the measurement of the Achilles tendon thickness (ATT), subjects were examined in the prone position with the foot hanging over an edge of the couch. Each subject was examined at rest, then during dorsiflexion and plantarflexion of the foot. Tendon thickness was routinely measured at a point 1cm above the superior calcaneal surface12, 15. All measurements were taken by one (1) sonographer to avoid interobserver variability.

Statistical Analysis

All measurements obtained were expressed as means± standard deviation. The data obtained were analyzed using Statistical package for social sciences (S.P.S.S) in Microsoft windows.

Ethical Approval

In line with Belmonth declaration of 1979 , ethical approval was obtained from the Ethics/Research Committee of the College of Health Sciences, Abia State University, Uturu.

Results:

Tables I. Descriptive Statistics for ATT for Control group

	ATT-RT (NORM)	ATT-RT (DF)	ATT-RT (PF)	ATT-LT (NORM)	ATT-LT (DF)	ATT-LT (PF)	N0 of Subjects
Mean±SD	3..31±**0.50**	2.73±**0.38**	4.01±**0.66**	3.33±**0.47**	2.72±**0.38**	4.04±**0.65**	30
Range	2.6-4.2	2.2-3.3	3.1-5.3	2.6-4.1	2.0-3.3	3.1-5.1	

Table I shows the mean values of ATT at rest, Dorsiflexion and Plantarflexion (DF and PF) phases for the RT and LT sides. The values are 3.31±0.50 and 3.33±0.47 for ATT at rest phase for RT and LT sides respectively. 2.73±0.38 and 2.72±0.38 for Dorsiflexion phases of the RT and LT sides respectively; and 4.01±0.66 and 4.04±0.65 mm for plantarflexion phases of the RT and LT sides respectively.

Table II Showing descriptive Statistics for ATT for Labourers group

	ATT-RT (NORM)	ATT-RT (DF)	ATT-RT (PF)	ATT-LT (NORM)	ATT-LT (DF)	ATT-LT (PF)	N0 of Subjects
Mean±SD	3.71±0.72	3.00±**0.76**	4.19±**0.78**	3.69±**0.69**	2.99±**0.72**	4.12±**0.79**	30
Range	2.5-4.9	1.9-4.5	2.6-5.55	2.6-5.5	1.9-4.5	2.6-5.5	

*Table II shows the descriptive values for ATT at rest, Dorsiflexion phases and (DF) Plantarflexion (PF) for the RT and LT sides. The values are 3.71±0.72 and 3.69±**0.69** for rest phase of ATT of the RT and LT side respectively; 3.00±**0.76 and** 2.99±**0.72** for the ATT phase of dorsiflexion on the RT and LT respectively; 4.19±**0.78** and 4.12±**0.79** phase of plantarflexion on the RT and LT sides respectively.*

Table III. Showing descriptive statistics of ATT of the Traditional dance group

	ATT-RT (NORM)	ATT-RT (DF)	ATT-RT (PF)	ATT-LT (NORM)	ATT-LT (DF)	ATT-LT (PF)	N0 of Subjects
Mean±SD	3.22±0.58	2.73±0.60	3.78±0.59	3.18±0.60	2.73±0.59	3.75±0.59	30
Range	2.5-4.0	2.0-4.1	2.9-4.5	2.4-4.0	2.0-3.9	3.0-4.4	

*Table III describes the mean values of ATT at the three phases assessed- normal phase, dorsiflexion and plantarflexion. It shows that the mean values are **3.22±0.58** and **3.18±0.60** mm for normal phase of ATT for the RT and LT sides; **2.73±0.60** and **2.73±0.59** mm for dorsiflexion phase of ATT on the RT and LT sides respectively; **3.78±0.59** and **3.75±0.59** mm for the plantarflexion phase of ATT for the RT and LT sides respectively.*

Table IV. Showing descriptive statistics of ATT of Athletes.

	ATT-RT (NORM)	ATT-RT (DF)	ATT-RT (PF)	ATT-LT (NORM)	ATT-LT (DF)	ATT-LT (PF)	N0 of Subjects
Mean±SD	4.52±**0.43**	3.86±**0.40**	5.46±**0.31**	4.507±**0.41**	3.84±**0.32**	5.507±**0.25**	30
Range	3.9-5.1	3.4-4.5	4.9-5.9	3.9-5.1	3.4-4.4	4.9-5.9	

*Table IV shows the mean values of ATT at the different phases examined; normal phase, dorsiflexion and plantarflexion. 4.52±**0.43** and 4.507±**0.41**mm are the mean values for normal ATT phase for the RT and Lt sides respectively; 3.86±**0.40** and 3.84±**0.32** mm are the mean values for the dorsiflexion phase of ATT for both RT and LT sides respectively; 5.46±**0.31** and 5.507±**0.25** mm for the plantarflexion phase of ATT for both RT and LT sides respectively.*

Fig I. Showing Bar chart of ATT (Normal) for all four (4) groups

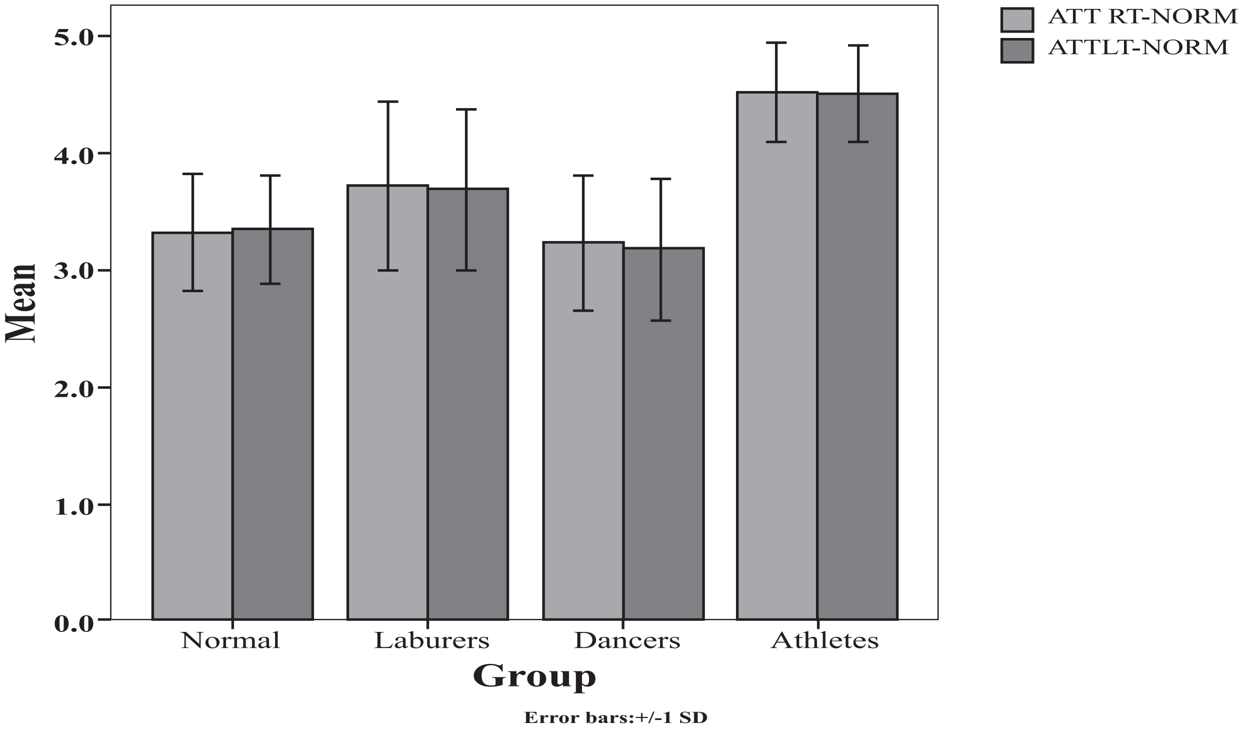

Figure I shows the bar chart indicating the thickness of Achilles tendon in the four groups. It shows that the ATT for athletes are higher than those of the other groups. The Athletes' group was followed by the Labourers' group.

Fig II. Showing the ATT values at dorsiflexion for all the four (4) groups

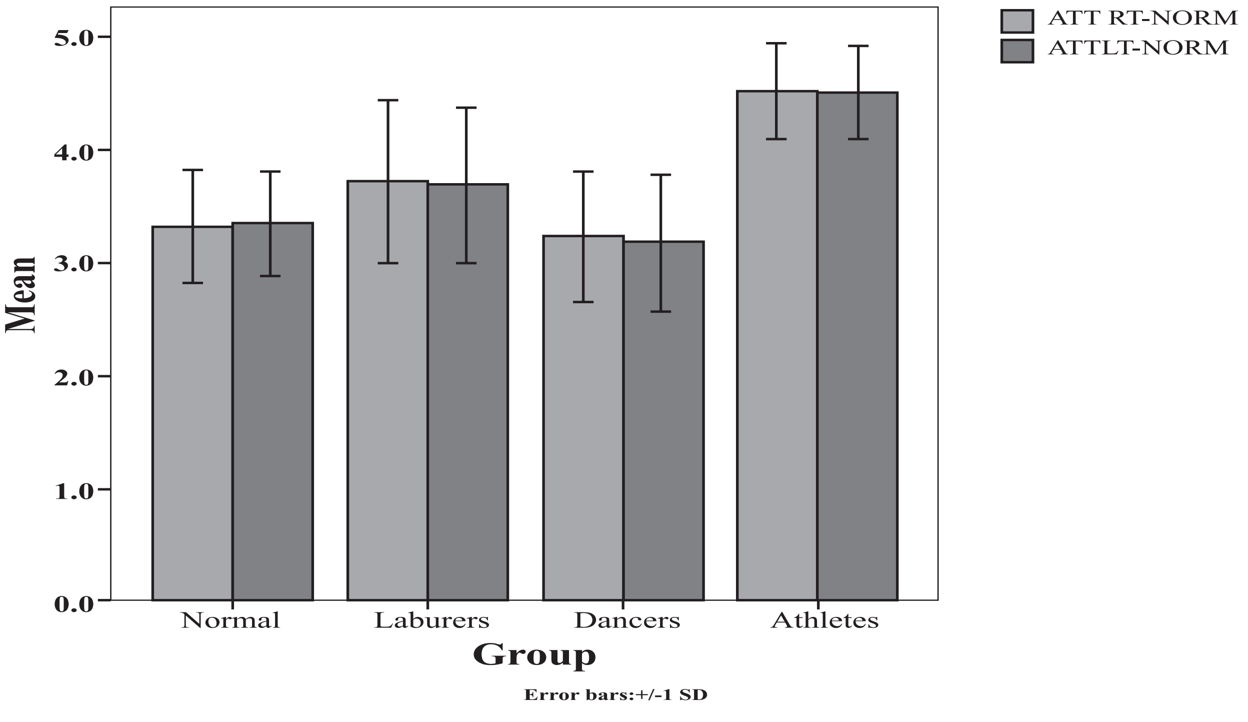

Figure II also shows that the athletes have a thicker Achilles tendon followed by the Labourers' group and then the rest of the groups.

Fig III. Showing the Bar chart for the ATT values at Plantarflexion for the four (4) groups

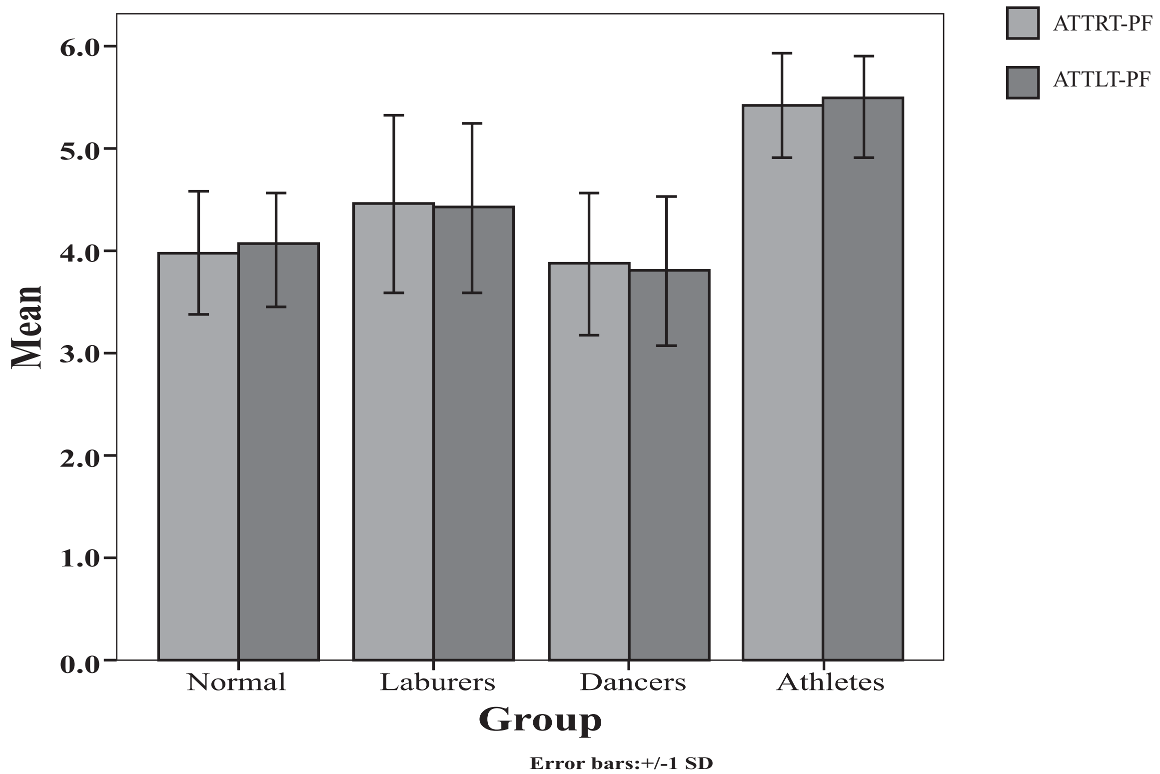

Figure III represents the values for the ATT of the four groups at plantarflexion. The chart shows that the athletes' group has a higher ATT than other groups. They are also followed by the labourers' group and then the Control group.

Table V. Showing Multiple comparisons between groups using Post Hoc test (P<0.05 as significant) for ATT-Normal

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
ATT –NORM	Control	Labourers	-.4033*	.1465	.007**
		Dancers	.0900	.1465	.540
		Athletes	-1.2033*	.1465	.000**
	Labourers	Control	.4033*	.1465	.007**
		Dancers	.4933*	.1465	.001**
		Athletes	-.8000*	.1465	.000**
	Dancers	Control	-.0900	.1465	.540
		Labourers	-.4933*	.1465	.001**
		Athletes	-1.2933*	.1465	.000**
	Athletes	Control	1.2033*	.1465	.000**
		Labourers	.8000*	.1465	.000**
		Dancers	1.2933*	.1465	.000**

Table V shows multiple comparisons using post-hoc test for the normal phase of ATT. Results indicate statistical difference between the Control group and the labourers and athletes (P=0.007 and 0.000 respectively). There was no statistically significant difference between the Control group and the dancers' group. There was a statistically significant difference between the Labourer's group and others (Control group, P=0.007; dancers, 0.001 and Athletes, 0.000). The value of ATT (normal) in dancers did not show any significant difference from those of the Control group. Athletes showed a significantly higher value than all the groups (P=0.000; 0.000; 0.000 for Control, dancers and labourers respectively).

Table VI. Showing Multiple comparisons between groups using Post Hoc test (P<0.05 as significant) for ATT-Dorsiflexion

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
ATT –DF	Control	Labourers	-.2567	.1433	.076
		Dancers	-.0033	.1433	.981
		Athletes	-1.1267*	.1433	.000
	Labourers	Control	.2567	.1433	.076
		Dancers	.2533	.1433	.080
		Athletes	-.8700*	.1433	.000
	Dancers	Control	.0033	.1433	.981
		Labourers	-.2533	.1433	.080
		Athletes	-1.1233*	.1433	.000
	Athletes	Control	1.1267*	.1433	.000
		Labourers	.8700*	.1433	.000
		Dancers	1.1233*	.1433	.000

The results from table VI shows that there was no significant difference between the values of ATT-DF in the Control group and those in the labourers and dancers groups (P=0.076; 0.981 respectively). However, the athlete group showed significantly higher values than the other groups (P=0.000; 0.000; 0.000 for the Control, Labourers and dancers respectively).

Table VII. Showing Multiple comparisons between groups using Post Hoc test (P<0.05 as significant) for ATT-Plantarflexion (ATT-PF)

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
ATT-PF	Control	Labourers	-.1800	.1576	.256
		Dancers	.2367	.1576	.136
		Athletes	-1.4433*	.1576	.000
	Labourers	Control	.1800	.1576	.256
		Dancers	.4167*	.1576	.009
		Athletes	-1.2633*	.1576	.000
	Dancers	Control	-.2367	.1576	.136
		Labourers	-.4167*	.1576	.009
		Athletes	-1.6800*	.1576	.000
	Athletes	Control	1.4433*	.1576	.000
		Labourers	1.2633*	.1576	.000
		Dancers	1.6800*	.1576	.000

Table VII reports the comparative analysis using post-hoc test between the groups. It shows that only the athlete group showed a significantly higher value of plantarflexion phase of ATT than all other groups (Control, P=0.000; Labourers, P=0.000 and dancers, P=0.000). The dancers' group also showed significantly lower values than the labourers' group (P=0.009)

The values of ATT have been presented in the three phases by which it was measured. These values showed that the ATT at the Plantarflexion phase was the highest of all the phases in all the groups which is expected. The ATT in all phases of the Athletes and Labourers were quite higher than those of the control group (less active group). However, only at the ATT (normal phase) are the values of the Labourers significantly higher than those of the control while the values for the athletes were significantly higher in all phases of ATT. On the other hand, the control group had slightly higher mean than the Dancers at all phases of ATT.

Discussion

The Achilles tendon maintains the posterior morphological trail of the foot. Statutorily, its elasticity varies in different phases of walking and possibly, undue twist and turning of the foot could affect the mechanostructural inclination of the big tendon.

Multiple comparisons between the control (less active) group and other physically active groups show that all the quasi experimental groups had values higher than the control group (except the Dancers' group) even though the values were not significant for the group of labourers. However, the values for the Athletes were significantly higher than those of the Control group (tables V-VII). These could be the outcome of activity related differences in the thickness of the Achilles tendon because Mathieson et al [12] recorded different ranges of ATT among individuals involved in a range of athletic activities. Also, Civeira et al [16] correlated anterioposterior thickness of Achilles tendon with physical activity. This structural difference may have manifested in a series of biomechanical relationships of the foot. Another reason that may have accounted for the significant difference in values between the athletes and the control group may be the fact that these subjects undergo a minimum of 5 hours/day of intense physical activities with an associated increase in vascular activity in the tendon leading to a corresponding increase in size. This increase may also be associated with the increased activity of the gastrocnemus and soleus muscular unit that may induce a corresponding increase in the size of the tendon resulting in the thicker Achilles tendon. Some studies have tried to establish a relationship between Achilles tendon and its muscle activity by reporting interactions between contractile (muscle) and elastic (tendon) components of physical activities [17]. Furthermore, Muraoka et al [18] noted that the difference in Achilles tendon's mechanical properties between men and women was correlated and linked to the difference in muscle strength. Therefore, it is possible that the increased thickness may have a direct connect with the increased muscle strength of the athletes due to increased physical training that may not impair the tendon's potential to store energy and release during gait cycle.

The other group (Labourers) that showed higher values than the control group could be attributed to the different degrees of physical activities associated with their occupation that have also contributed to increased muscular and accompanying tendinous activity. These individuals are always involved in a near lifetime occupation of shattering of stones, lifting of construction materials and during farming season, they cultivate mounds for planting and transport farm produce on foot to nearby communities. These factors obviously increase the biomechanical role of the tendon during the gait cycle and may have lead to the activity related thickening of the tendon.

The act of dancing involves a high degree of biomechanical dexterity and we expected higher values for the dancers than the control group but it wasn't the case. This could be attributed to the fact that degree of biomechanical dexterity involved in dancing over the prolonged period was not enough to alter the structural outline of the Achilles tendon. Therefore, dancing as an occupation cannot significantly induce thickening of the Achilles tendon.

Cheung et al [19] further established a positive correlation between Achilles tendon and plantar fascia tension. In their study, they stated that increasing tension on the Achilles tendon is coupled with an increasing strain of the plantar fascia. Overstretching of the Achilles tendon resulting from intense muscle contraction and passive stretching of tight Achilles tendon are plausible mechanical factors for overstretching of the plantar fascia. Consequently, the thickening of the Achilles tendon may have an extended effect on the functional role of the plantar fascia and if intervention programs involving the podiatric management of occupation induced strain among some of these occupational groups is not designed, a possible occurrence of Tendocalcanei/ plantar fascia related problems may be prevalent in the future, especially among the athletes.

Conclusion

This study has conclusively established that occupation-related physical activity initiates thickening of the Achilles tendon that may affect occupational efficiency and performance and may result to a podiatric problem among labourers/farmers and athletes. However, this thickening is more predominant among athletes.

Conflict of Interests

We the authors have declared no conflicts in anyway and do submit that the research was original and was not sponsored by any institution/organization/ agency/Government.

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