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KNEE OSTEOARTHRITIS AND ITS ASSOCIATION WITH FOOT ARCH INDEX AND QUADRICEPS ANGLE: FINDINGS FROM NATIONAL ORTHOPAEDICS HOSPITAL ENUGU

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Abstract: *Osteoarthritis (OA) is a chronic degenerative joint disease characterized by the breakdown of cartilage in joints, potentially altering joint biomechanics such as the quadriceps (Q) angle. The biomechanics of the patellofemoral joint is influenced by the direction and magnitude of force exerted by the quadriceps muscle, which may also impact foot biomechanics. This study aimed to determine the relationship between foot arch index (FAI) and Q-angle among patients with knee osteoarthritis (KOA). An exploratory cross-sectional study was conducted with 58 adults with KOA from the National Orthopaedic Hospital, Enugu. Q-angle, pain intensity (PI), and FAI were assessed using a goniometer, numerical pain rating scale, and the Staheli's equation, respectively. Data were analyzed using descriptive statistics and Pearson's correlation coefficient at an alpha level of 0.05. The results indicated no significant relationship between right (r=0.066, p=0.624) and left (r=0.171, p=0.199) FAI and their ipsilateral Q-angle. Additionally, no significant relationship was found between right (r=0.19, p=0.15) and left (r=0.05, p=0.76) knee pain PI and their ipsilateral Q-angle. However, a significant relationship was observed between right foot PI and right Q-angle (r=0.41, p=0.001), while no significant relationship was found between left foot pain intensity and left Q-angle (r=0.41, p=0.76). The findings suggest that foot deformity may lead to patella lateral rotation, increasing the Q-angle and potentially predisposing the knee to osteoarthritis. Evaluating the Q-angle and arch index could provide additional insights for treating patients with knee osteoarthritis. Therefore, physiotherapeutic assessment should include an evaluation of the Q-angle.*

Keywords: *Osteoarthritis, Q-angle, Foot arch index, Patellofemoral biomechanics, Pain intensity*

INTRODUCTION

Osteoarthritis (OA) is a long-term chronic disease characterized by breakdown of cartilages in joints (Haq et al, 2003). The first changes of OA that occur in particular cartilages include decrease in the superficial proteoglycan content, deterioration of superficial collagen fibrils and decrease in water content. The loss of proteoglycan and collagen result in diminished collagen stiffness (Dritzker, 2003). Subsequently, the chondrocyte increases the synthesis of cartilage matrix proteins and the destruction of components in the extracellular matrix accelerates. The thickness of collagen may also increase. At the same time, calcified cartilage and subchrondal bone becomes thicker as a response to the increase formation and re-absorption

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of the subchrondal bone (Radin, Paul, and Rose, 1972). As the cartilages detoriate, there is increased friction between the articular surfaces resulting to stiffness, pain, and subsequently loss of function. Osteoarthritis commonly affects joints in the knees, hips, hands, feet, and spine.

Knee OA is a common form of arthritis that often affects the bones, cartilages, and the synovium of the knee joint (Odole et al, 2019). This condition occurs as the cartilage in the knee wear away eventually causing bone on bone contact between the joint surfaces. Knee OA can be divided into two types, primary and secondary. Primary OA is articular degeneration without any apparent underlying reason while secondary OA is the consequence of either an abnormal concentration of forces across the joints, which may be as a result of trauma or abnormal articular cartilage. The intensity of clinical symptom and the rate of progression may vary for individuals; common clinical symptoms include knee pain that is gradual in onset and worsen with activity, knee stiffness, swelling, pain after prolonged sitting and resting, and pain which may worsen over time. Knee OA has been an age long disease and the single most common cause of disabilities in older adults; it's mostly affecting the population aged 45 and greater (Laupattarka, Laropaiboon & Laupattarkasem, 2008).

Quadriceps angle (Q-angle) is an important determinant of knee health (Morris, 1993); it is the measurement of alignment at the patella-femoral joint (Horton and Hall 1998). According to Alfred (2009), Qangle is an angle formed by a line drawn from the anterior-superior iliac spine to the central patella and a second line drawn from central patella to tibial tubercle. Q-angle is formed by the vector of combined pull of the quadriceps femoris muscle and patella tendon. Patello-femoral joint biomechanics is influenced by the direction and magnitude of force exerted by quadriceps muscle (Jack, 2015).

In a normal knee, the line of force exerted by the quadriceps is lateral to the joint line probably due to large force of Vastus lateralis. Any alteration in alignment that increases the Q- angle is thought to increase the compression of the lateral patella on the lateral lip of femoral sulcus (Levangie & Norkin, 2005). In the presence of enough lateral force, the patella may actually sublux or dislocate over the femoral sulcus when the quadriceps muscle is activated on the extended knee. Therefore, increase in Q-angle is associated with increased risk of lateral subluxation of the patella (Nejati et al., 2011). In a normal knee, the line of force exerted by the quadriceps is lateral to the joint line probably due to large force of Vastus lateralis. Any alteration in alignment that increases the Q- angle is thought to increase the compression of the lateral patella on the lateral lip of femoral sulcus (Levangie & Norkin, 2005). Excessive loading of the knee can result from factors that increase compressive and/or shear stress on the tibio-femoral or patelo-femoral component. In such instances, the load is subsequently transferred to the foot which absorbs the mechanical stress of ground contact, which alters the postural alignment and joint motion at the knee and throughout the lower limb (Williams, Rudolph and Zech et al., 2001). Repeated excessive loading of the foot may stretch ligament beyond their elastic limits, damaging soft tissues and increasing the risk of foot pathologies (Doweling et al., 2001).

Furthermore, repeated excessive loading may also lead to collapse of the foot arches (Douglas, Gross &David, 2012). The foot has three arches, two longitudinal (medial and lateral arch) and one anterior transverse arch. They are formed by the tarsal and metatarsal bones and supported by ligaments and tendons in the foot, their shape allows them to act the same way as a spring, bearing the weight of the

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body and absorbing the shock produced during locomotion (Sam, 2018). The arch index (AI), represents the ratio of the area of the middle third of a foot print relative to the total area excluding the toes. The arch index is calculated by dividing the mid foot region by the entire footprint area, with a higher ratio indicating a flat foot and a low ratio indicating high arch. [AI score range include normal (0.21 to 0.28) high (<0.21) and lower arch (>0.28)] (Cavanagh and Rogers 1987).

According to Gross, et al., (2011), the condition of flat feet is associated with more frequent knee pain and medial cartilage damage in elderly. During walking the knee and foot are biomechanically aligned within a closed kinematics (Relly, Muir, Dohety, 2009). The chain of lower extremities during walking is well known by its obligation and sometimes compensatory movement through the kinematic chains. Alteration in alignment of the lower extremity can lead to unequal forces on the joints, mechanical insufficiency of the muscle; alter proprioception and feedback at the knee, hip and feet. This may further lead to abnormal neuromuscular function and control of the lower extremities (Nguen, et al.,2009). According to Solberg, (2008), lower limb mal-alignment may lead to musculoskeletal dysfunction of both proximal and distal joints which may possibly affect the Q-angle at the knee joint. Abnormal lower extremity alignment has been associated with musculoskeletal dysfunction which includes knee OA (Suri, et al., 2012). This possible relationship in assessment and management of OA have not been addressing the roles of proximal and distal joint dysfunctions but rather concentrates more on the joint structures and surrounding muscles only and thus the need to explore relationship between Q-angle and arch index so as to enable a holistic approach in the management of OA.

METHODS

Research Design

This exploratory cross-sectional study recruited samples using purposive sampling technique.

Participants

A total of Fifty-eight (58) adults with knee osteoarthritis from National Orthopaedic Hospital Enugu participated in this study. Only Adults within the age range of 18 to 80 years who had been diagnosed of knee osteoarthritis not more than 6 months prior to the commencement of this study were included. However, persons that met this inclusion criteria but with a history of unilateral lower limb amputation (this may increase weight-bearing on the unaffected limb, and thus, alter their foot arch indices), traumatic knee condition(s), history of knee replacement surgery, or any known knee deformity prior to the symptoms and diagnosis of osteoarthritis were excluded from this study.

Ethical approval

This was sought and obtained from the Research and Education Committee of National Orthopaedic Hospital Enugu. All the participants provided written informed consent prior to the study.

Materials

The following instruments and steps were followed in the study:

i. Plain white paper, Tracing sheet and Pencil: These were used to trace the foot print of the subject.

ii. Calibrated Meter Rule and Measuring Tape (Sanghia, Made in China) were used for measuring the length and width of the foot of the subject.

iii. Mechanical Weighing Scale / Stadiometer (Geepas, Made in China) were used to obtain the weight and height of the subject respectively.

iv. Numerical Pain Rating Scale: This was used to evaluate the intensity of both knee and foot pain. The minimum score is 0 (indicates no pain), a mid-sore of 5 (indicates moderate pain) and the maximum score is 10 (this indicates the worst possible pain experienced by the patient).

v. Talcum powder: was used to show the print of the foot for
easy tracing.

vi. Goniometer (E-Z read Jamer 360, Made in Italy) was used
to measure the Quadriceps angle of the participants

Procedure

The participants were recruited using purposive sampling technique; the purpose and relevance of the study were explained to each participant. Thereafter, their informed consent was sought and obtained. Demographic and anthropometric data were obtained as outlined below:

i. **Height measurement:** The participants were instructed to remove their shoes, heavy garments and hair ornaments. They were then asked to stand with their back to the height of the rule with their occiput, upper back, buttocks, calves and heels making good contact with the upright while their feet are together. It was ensured that the top of external auditory meatus were at the same level with the inferior margin of their cheek bone as the subjects were asked to look straight. The height was measured as the distance from the height scale platform to the vortex of the head. The height was then read off and recorded to the nearest 1.0cm (Ezeukwu, et al, 2015). ii. **Weight measurement:** The Participant was instructed to remove heavy garments/objects, and their shoes. The weighing scale was adjusted to the zero mark and each participant was instructed to stand straight in the centre of the weighing scale, weight distributed evenly to both feet. While looking straight ahead with hands by the side, the body weight was read off to the nearest 1.0kg (Hamzat et al, 2014).

iii. **Body Mass Index (kg/m2):** This was calculated using the formula below (Ekediegwu et al, 2017): Weight (kg) /
Height2 (m2) iv. **Assessment of Pain Intensity:** This was done using Numerical pain rating scale(Mathias et al., 2008), the patient was be asked to mark their pain ratings, corresponding to current, best and worst pain experienced at the foot and knee over the past 24 hours. The respondent was asked to indicate the numeric value on the segmented scale that best describes their pain intensity (Hawker, 2011). The number that the respondent indicates on the scale to rate their pain intensity was recorded. Scores range from 0–10. Higher scores indicate greater pain intensity (Ekediegwu et al, 2021).

v. **Measurement of the Foot Arch Index:** The measurements were conducted by the principal investigator. The participants were asked to step on talcum powder and then take a step on a sheet of tracing paper; the foot print will now be traced out on a plain paper using a pencil. To achieve the foregoing objectives of the invention, the invention provides a method of measuring and identifying foot arch type according to footprint data. Under a static standing stance, the footprint having a foot contour comprising lateral contour and medial contour, medial ball tangent point and a medial heel tangent point of the footprint, the ball mid-point at the mid-point on a line between the lateral ball

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tangent point and the medial ball tangent point Obtaining a foot centre axial line connecting the ball mid-point and the heel mid-point, the foot centre axial line contacting the foot contour at a distal forefoot point and a proximal heel point was obtained.

Also the width of the central region of the foot print (A), a line segment between the medial common tangent point and the lateral common tangent point, and the width of the heel region (B) a line segment between the perpendicular bisecting the medial arch point and the lateral common tangent point was obtained. The planter arch index (PIA) was calculated by dividing the width of central region of the foot print (A) by the width of the heel region (B), [i.e. PAI = A / B]. According to the foot type index FTI, a foot arch type of the footprint can be identified. For example, the foot arch type can be categorized as one of the five categories, including flat foot, low arch, normal (or regular) arch, little high arch, and high arch. Alternatively, the foot arch type can be categorized as one of the three categories, including flat foot, normal arch and high arch.

vi. **Measurement of the Q - angle:** the Q-angle was measured with a goniometer using the method describe by Latinghouse & Trimbal (2000) with the subject standing in an erect weight bearing position, the knee at or near full extension (but not in hyperextension) and The ASIS, midpoint of the patella and tibial tuberosity were palpated and marked with a non-permanent maker. The marked point of the ASIS and the mid line of the patella were linked with a ruler to ensure accurate alignment of the goniometer (Horton and Hall 1989). The axis of the goniometer was the placed on the midpoint of the patella, with its stationary arm aligned with the tibial tuberosity and movable arm to the ASIS. The Q-angle was the read off as the accurate angle formed in the anterior thigh between the two arms of the goniometer; a line was drawn from ASIS to the midline of the patella to the tibial tubercle. The resultant angle formed by these two lines was measured as Q-angle.

Data Analysis

Data obtained were cleaned and analysed using Statistical package for social science (SPSS) version 21. Descriptive statistic of mean and standard deviation, frequency and percentages were used to summarize the variables. Pearson moment correlation coefficient was used to determine the relationship among Q-angle, knee and foot pain, and foot arch index. The level of significance was set at $\alpha \leq 0.05$.

RESULTS

Anthropometric Characteristics of participants

A total of fifty eight (58) adults with knee OA (males=20 and females =38) participated in this study. The participants' mean height, weight and BMI are shown in table 1. The mean right and left arch indices of the participants are 1.09±0.18 and 1.01±0.16, respectively. The table also shows the mean± standard deviation of the right and left Q-angle to be
21.2±6.92 and 21.53±5.71 respectively

Variations in Foot Arch Index among the Participants

Collectively, majority of the participants had normal arch values (right – 67.2%; left – 55.2%). Among the female participants, majority of the participants had normal arch (right-71.1% and left-68.4%).

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Similarly, among the male participants, most of them had normal arch indices (right – 60.0% and left - 33.3%).

Quadriceps Angle of the Participants

Generally, majority of participants had normal Q-angle (right – 60.3% and left – 51.7%). Among the female participants, most of the participants also had normal Q-angles (right -60.5% and left – 55.3%). Similarly, most of the male participants had normal Q-angles (right – 60.0% and left – 45.0%) as shown in Table 3.

Relationship between Foot Arch Indices and Qangles

There was a non-significant correlation between right arch index and right Q-angle ($r = 0.066$, $p = 0.624$), and non-significant inverse correlation between the left arch index and left Q-angle ($r = -0.171$, $p = 0.199$). Among the male participants, there was also a nonsignificant correlation between the right foot arch index and right Q-angle ($r = 0.059$, $p = 0.804$) and a non-significant inverse correlation between the left arch index and left Q-angle ($r = -0.355$, $p = 0.125$). Similarly, among the female participants, there was a non-significant correlation between right arch index and right Q-angle ($r = 0.160$, $p = 0.480$) and a nonsignificant correlation between left arch index and left Q-angle ($r = 0.096$, $p = 0.560$) as shown in Table 4.

Relationship among Q-angles, Knee Pain Intensity and Foot Pain Intensity

There was a non-significant correlation between right knee pain intensity and right Q-angle ($r = 0.19$, $p =0.15$), and a non-significant correlation between left knee pain intensity and left Q-angle ($r = 0.41$, $p = 0.76$). The results for both male and females also showed a similar non-significant correlation between knee pain intensity and Q-angle ($p>0.05$). On the other hand, there was a significant correlation between right foot pain intensity and right Q-angle ($r = 0.41$, $p < 0.001$) but a non-significant correlation between the left foot pain intensity and left Q-angle ($r = 0.49$, $p = 0.76$). Among the male participants, there was a significant correlation between the right foot pain intensity and right Q-angle ($r = 0.45$, $p = 0.05$). Also, among the female participants, there was a significant correlation between right foot pain intensity and right Q-angle ($r = 0.36$, $p = 0.03$) as shown in Table 5.

DISCUSSION

The objective of this study was to ascertain the relationship between foot arch index and quadriceps angle in adults with osteoarthritis. There was no statistically significant relationship between foot arch index and Q-angle on both sides. This finding is consistent with the study by Gross et al., 2011, on the association of flat foot with knee pain and cartilage damage in old adults. The result of his study shows no association between foot morphology and cartilage damage in other knee components. However, pesplanus morphology has been associated with knee pain and medial tibial femoral cartilage damage in older adults (Latafaka et al., 2013). This could be adduced to differences in samples and design of these two studies. While the study by Latafaka et al, 2013 was done among fewer and younger population (Iranian wrestlers), the present study in Nigeria was among larger samples and much older cohorts with knee osteoarthritis.

Also, there was a significant, positive but weak correlation between Q-angle and knee pain on the right side. This may imply that as knee pain worsens among patients with KOA, their Q-angle increases or vice versa. It is possible that people with knee OA in trying to ameliorate their symptoms, adopt painavoidance postures (mal-adaptive mechanisms) that may distort the biomechanics and by extension the Qangle. It is also possible that abnormally large Qangles due to the above explained adaptation mechanism or natural to them, may cause malalignment at the knee joint may cause or further worsen the articular degeneration (Mohammad et al, 2007).

Also there was a significant relationship between Qangle in right (dominant) limb and flat feet deformity. Mohamed et al., 2017, also conducted a study on the relationship between flat-foot deformity and Q-angle in male secondary school students. Their result indicates that there is a significant relationship between flat foot deformity and Q-angle. However, there was no significant relationship between Q-angle and intensity of knee and foot pain among patients with osteoarthritis. Previous study on Q-angle by Mohamed et al. (2007) and Chandan et al. (2018) also reported a significant relationship between knee pain intensity. This report contradicts result from the present study which found no significant relationship between Q-angle and knee pain intensity. This may be as a result of age of the participants because the study was conducted among secondary school student that may not be predisposed to foot pain as compared to the population that participated in this present study.

Result from this study also shows that there was a significant relationship between Q-angle and intensity of foot pain among patient with knee osteoarthritis. This could be as a result of excessive loading of the knee, increasing compressive and/or shear stress on the tibio-femoral or patelo-femoral components. The load is subsequently transferred to the foot which absorbs the mechanical stress of ground contact, shaping the pattern of postural alignment and joint motion at the knee and throughout the lower limb (Williams, 2001). Repeated excessive loading of the foot may stretch ligament beyond their elastic limits, damaging soft tissues and increasing the risk of foot pathologies (Doweling et al., 2001). In a similar report, Hassan et al (2011) carried out a study on lower extremities misalignment and linear relation with Qangle in female athletes. The result of the study showed that there is a significant relationship between foot pain intensity and Q-angle which is consistent with the findings of the present study.

The mean left Q-angle of the participants in this study was greater than the left. Also females had larger Q-angle than the male participants, and were more often affected by knee osteoarthritis pathology. This is possibly due to an increased pelvic width which can influence the biomechanics of the knee joint by creating an abnormally large valgus angle which may subsequently lead to wear and tear of the joint leading to knee osteoarthritis. However, Previous studies (Sra et al., 2008 and Ali et al., 2017) revealed higher Q-angle on the dominate knee joint compared to other side. Other related studies (Han and Foldspan 1997; Livingston 2002; Spaulding 2002 & Byl 2000) on Q-angle have equally shown that the mean Q-angle on the right knee joint was greater than that on the left knee joint. The difference in these reports compared to the present study may be linked to the study population. While majority of the comparing studies recruited normal young adults, this study was among young adults. Studies have shown that the prevalence of knee osteoarthritis in this environment is higher on the right knee than the left (Akinpelu et al., 2011). It is therefore possible that the pain avoidance behaviour (postures) may cause the centre of gravity of the patient to shift to the un-/lessaffected limb (usually the left). This distortion in biomechanics may be fingered for the observed

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greater prevalence of abnormal Q-angle on the left than the right side. It is therefore recommended that a biomechanical analysis of Q-angle among patients with unilateral left or right knee osteoarthritis be carried out to authenticate the veracity of this deductive logical reasoning.

Relative to the Q-angles, few studies have focused on the variability in foot arch index and its gender preponderances. In this present study, the foot arch index was greater on the left foot compared to the right foot and more among female than male participants. Other studies (Ashok et al., 2017, PitaFernandez et al., 2015 Dunn et al., 2004, Nguyen et al., 2010) have reported similar findings. It is important to highlight that the present study is not without its limitations. The cross sectional nature of this study does not permit a cause-and-effect relationship to be established between the variables analysed. Also, Osteoarthritis is of a multi-factorial origin and there could be other contributing factor which could possibly be anatomical, biomechanical and neuromuscular factors that were not controlled for.

Table 1: Anthropometric Characteristics of participants (n=58)

Variables	Mean ±Standard deviation
Height(meters)	1.62±0.83
BMI(Kg/ meter2)	28.92±4.75
Weight(kg)	78.16±13.42
Age(years)	62.37±13.49
Right Arch Index	1.09±0.18
Left Arch Index	1.01±0.16
Right Q-angle	21.2±6.92
Left Q-angle	21.53±5.71

Table 2: Variations of Foot Arch Indices of the Participants (N = 58).

Variables	Categories	Frequency (Percentage) Right Arch	Left Arch
General	Normal arch	39 (67.2)	32 (55.2)
	Low arch (PP)	19 (32.8)	26 (44.8)
	High arch (PC)	0 (0.0)	0 (0.0)
	Total	58(100)	58(100)
Female	Normal arch	27(71.1)	26(68.4)
	Low arch (PP)	11(28.9)	12(31.6)
	High arch (PC)	0 (0.0)	0 (0.0)
	Total	38(100.0)	38(100.0)
Male	Normal arch	12(60.0)	6(33.3)
	Low arch (PP)	8(40.0)	14(77.7)

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High arch (PC)	0(0.0)	0(00.0)
Total	20(100.0)	18(100.0)

Key: PP- Pes Planus, PC- Pes Cavus

Table 3: Variation of Q-angle among participants

Variables	Frequency (Percentage) Categories	Right	Left
General	Normal 35 (60.3)		30 (51.7)
	Abnormal	23 (39.7)	28 (48.3)
	Total 58 (100.0)		58 (100.0)
Female	Normal	23 (60.5)	21 (55.3)
	Abnormal 15 (39.5)		17 (44.7)
	Total 38 (100.0)		38 (100.0)
Male	Normal 12 (60.0)		9 (45.0)
	Abnormal 8 (40.0)		11 (55.0)
	Total 20 (100.0)		20 (100.0)

Table 4: Relationship Between Foot Arch Indices, and Q-angle among the Participants

Correlation Coefficient (p – value)

Group	Type of Correlation	Right Foot Arch Index	Left Foot Arch Index
All Participants	Pearson's Correlation	0.066 (0.624)	-0.171 (0.199)
	Partial Correlation	0.670 (0.621)	-0.156 (0.215)
Male Participants only	Pearson's Correlation	0.059 (0.804)	-0.355 (0.125)
Female Participants only	Pearson's Correlation	0.160 (0.480)	0.096 (0.560)

CONCLUSION

There is a significant relationship between Q-angle and foot pain intensity. Based on kinematic chain system, foot deformity may result in lateral patella rotation which increases the Q-angle and may possibly predispose the knee to osteoarthritis. Evaluating foot arch indices and Q-angle may bring additional information for assessing and treating patients with knee osteoarthritis. Therefore Physiotherapy evaluation of these patients should also be directed towards the assessment of their Qangle and foot arch indices.

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Vol. 12 No. 1 | Imp. Factor: 6.760
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