RELATIONSHIPS AMONG SELECTED LOWER EXTREMITY ALIGNMENT VARIABLES IN PATIENTS WITH SYMPTOMATIC OSTEOARTHRITIS OF THE KNEE

CORELAREA VARIABILELOR SELECTATE REFERITOARE LA ALINIAMENTUL MEMBRULUI INFERIOR, LA PACIENȚII CU OSTEOARTRITA GENUNCHIULUI

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Key words: symptomatic osteoarthritis, mal-alignment, lower extremity alignment

Abstract

Background and Purpose: Osteoarthritis (OA) leads to destruction of cartilage and mal-alignment of structures in the knee joint leading to anatomic alterations of the joint. It has been identified that mal-alignment in the lower extremity is a potential factor that increases the risk of acute injury and osteoarthritis. Therefore, the purpose of this study was to determine the relationship among selected lower extremity alignment variables in individuals with osteoarthritis of the knee.

Methods: A total of 40 individuals (mean ± SD age of 56.35 ± 9.70) with knee Osteoarthritis (KOA) were recruited in this cross sectional observational study. Six anatomical alignment characteristics (Quadriceps angle, Tibiofemoral angle, Tibial Torsion, Femoral anteversion, Genu recurvatum, Navicular drop) were measured on the left and right lower extremities of each participant.

Results: There was no significant relationship ($P>0.05$) among the lower extremity alignment variables in subjects with unilateral symptomatic KOA. There was a significant relationship between Femoral anteversion and Genu recurvatum ($r= -0.443$, $p= 0.039$) and between Tibiofemoral angle and Tibial torsion angle ($r= -0.445$, $p= 0.038$) respectively in the left and right limbs of participants with symptomatic bilateral KOA. There was also a significance gender difference for Femoral anteversion ($t= -2.803$, $p= 0.016$) and Navicular drop ($t= 2.335$, $p= 0.038$) in participants with unilateral symptomatic right KOA and significance in gender difference for Quadriceps angle ($t= -2.148$, $p= 0.044$) in the right limb of participants with bilateral symptomatic KOA.

Discussion: Mal-alignment of the lower extremity exists in individuals with unilateral and bilateral symptomatic KOA. Therefore, emphasis should be placed on not only correcting mal-alignments at the knee but also correcting mal-alignment at other segments of the lower extremity so as to further prevent disease progression in the affected and unaffected limb.

Cuvinte cheie: osteoartrita simptomatică, aliniament deficient, extremități inferioare

Rezumat

Introducere și scop: Osteoartrita (OA) conduce la distrugerea cartilajului și alinierea greșită a structurilor din articulația genunchiului, ceea ce duce la modificări anatomice ale articulației. S-a constatat că alinierea defectioasă a extremității inferioare este un factor potențial care crește riscul de leziuni acute și osteoartrită. Prin urmare, scopul acestui studiu a fost de a determina relația dintre variabilele privind aliniamentul extremităților inferioare selectate, la persoanele cu osteoartrita genunchiului.

Metode: Un total de 40 de subiecți (media ± sd vârsta de 56.35 ± 9.70) cu osteoartrita genunchiului (KOA) au fost recrutați în acest studiu transversal observațional. Au fost măsurate șase caracteristici anatomice ale aliniamentului (unghiul cvadricepsului, unghiul tibiofemoral, torsiunea tibială, anteversia femurală, genu recurvatum, coborârea ocului navicular) pentru membrele inferioare stâng și drept ale fiecărui participant.

Rezultate: Nu a existat o corelație semnificativă ($P> 0,05$) între variabilele de aliniament la extremitățile inferioare la subiecții cu KOA simptomatic unilateral. A existat o corelație semnificativă între anteversia femurală și genu recurvatum ($r = -0,443$, $p = 0,039$) și între unghiul tibiofemoral și unghiul de torsiune tibio-lateral ($r = -0,445$, $p = 0,038$) la pacienții cu osteoartrită bilaterală. De asemenea, a existat o diferență de gen semnificativă pentru anteversia femurală ($t = -2,803$, $p = 0,016$) și picătură Navicular ($t = 2,335$, $p = 0,038$) la participanți cu osteoartrită simptomatică unilaterală și semnificație a diferenței de gen pentru unghiul Quadriceps -2.148, $p = 0.044$) la membrul inferior drept, la participanții cu osteoartrită simptomatică bilaterală.

Discuții: Alinierea greșită a membrului inferior există la persoanele cu osteoartrită simptomatică unilaterală și bilaterală. Prin urmare, ar trebui să se pună accent nu numai pe corectarea deficiențelor de aliniament la nivelul genunchiului, ci și pe corectarea alinierii la alte segmente ale extremităților inferioare, astfel încât să se prevină progresia bolii în membrul afectat și neafectat.

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Introduction

Osteoarthritis (OA) is a multifactorial, non-inflammatory disease of synovial joints, characterized by articular cartilage degradation and changes in other joint tissues. [1,2,3,4] It is a chronic localized joint disease and a leading cause of musculoskeletal pain and disability. [5] Osteoarthritis is generally expressed as the gradual impairment of articular hyaline cartilage function, with possible resultant joint pain, joint dysfunction [6,7], a decrease in range of motion, crepitus and weakness of the surrounding muscles of the synovial joint [8]. It commonly affects weight bearing joints in the body such as the hips and knees. [5]

Osteoarthritis also leads to destruction of cartilage, osteophyte formation, reduction in joint space and mal-alignment of structures in the knee joint thus causing altered movement with or without reference to force, mechanical inefficiency of muscles, reduced proprioceptive orientation and altered feedback from the hip and knee resulting in abnormal neuromuscular function and control of the lower extremities [9]. Studies have established that these biomechanical factors are implicated in both onset and progression of KOA [10,11].

According to Kirkley *et al* [12], mal-alignment is induced over a long period by anatomic alterations of the joint and it is the most potent risk factor for structural deterioration and would eventually allow a large area of cartilage loss and bony remodeling thereby causing the joint to become tilted and thus, mal-alignment in the same joint and the lower extremity further develops [10]. For example, in the assessment of tibia torsion which is the angle formed between the transmalleoli axis and transverse axis of the knee joint [13,14,15], abnormal tibia torsion as a result of mal-alignment causes changes in the ankle and knee biomechanics during gait thus affecting external loading of the knee joint which in turn may lead to osteoarthritis [3]. It had also been observed that individuals with osteoarthritis of the knee exhibit altered gait biomechanics [16] and abnormal loading of the unaffected knee of individuals with unilateral KOA implying that patients with a painful joint may accelerate the disease in the other joint due to gait changes [17].

The measures of navicular drop, tibial torsion, quadriceps angle, genu recurvatum, femoral anteversion, and pelvic tilt are often included in lower extremity alignment evaluation and mal-alignments in one or more of these areas have been identified as potential factor that can increase the risk of acute injuries, particularly non-contact anterior cruciate ligament (ACL) injuries, as well as chronic injuries to the lower extremity and osteoarthritis [18]. A previous study by Nguyen and Shultz, [19] identified the relationships among lower extremity alignments in healthy individuals to evaluate dynamic lower extremity function and risk of injury but there is poor understanding as to how these same lower extremity alignments interact in individuals with osteoarthritis. Hence, this study was designed to determine the relationships among selected lower extremity alignments and evaluate the basic interactions among the selected alignments in individuals with OA of the knee.

Changes in alignment are usually ascribed to changes in the articulating surfaces in individuals with KOA. For example, in medial compartment osteoarthritis, focal erosion of this compartment leads to narrowing under load and displacement of the knee center laterally thus causing a varus "bow legged" deformity. Similarly, narrowing of the lateral compartment imparts medial knee displacement causing a valgus "knocked legged" deformity). This implies that deformity of the femur or tibia as a result of changes in the articular surfaces also influences alignment [20, 21]. The interactions among various alignments along the entire lower extremity kinetic chain in individuals with osteoarthritis is poorly understood as studies which examine only a limited number of alignment factors may not adequately provide sufficient information to clinically identify meaningful relationships among all the alignment variables in the lower extremity.

Thus, accounting for a number of alignments of the entire lower extremity rather than a single segment may more accurately describe the relationships among these alignments as one alignment characteristics may cause compensations at other bony segments [22, 23, 19].

Materials and methods

Participants

The study population for this cross sectional observational survey consisted of forty (40) individuals (females = 31; males = 9) referred (by Orthopaedic surgeons) with diagnosis of unilateral and bilateral symptomatic KOA - grade 1 and grade 2 according to the Kellgren and Lawrence (1957) grade score and who did not suffer from any other ailment of clinical significance. Participants were recruited from the Orthopaedic Outpatient Physiotherapy Clinics of the Lagos University Teaching Hospital (LUTH) Idi-Araba, National Orthopaedic Hospital, Igbobi, Lagos and Gbagada General Hospital, Gbagada, Lagos.

Individuals with a reported history of Knee dislocations, recent traumatic knee injury, inflammatory joint disease, rheumatoid arthritis, obvious knee deformity, history of neurological disorders, cognitive and proprioceptive impairment with disease severity of <1 using the Kellgren and Lawrence scale were excluded from the study.

Sampling technique

Participants were selected using the non-probability purposive sampling technique. They were recruited according to their availability and willingness to participate in the study. Of the 52 participants screened, 12 were found ineligible (based on the exclusion criteria) for the study and were excluded (figure 1). Sample size was determined using Cohen sample size determination formula.

Research protocol

Prior to the commencement of this study, ethical approval was sought for and obtained (ADM/DCS/HREC/APP/108) from Health Research Ethical Committee of LUTH, Lagos Nigeria. The purpose of the study was clearly explained to the participants and only those who consented were recruited into the study. Also, all participants were screened by obtaining details of their medical history including; age, sex, height and weight. The severity of KOA was assessed using Kellgren and Lawrence (K/L) radiographic grading system/scale include: Grade 0- no radiological features of OA are present; Grade 1- doubtful joint space narrowing and possible osteophytic lipping; Grade 2- the presence of definite osteophyte and possible joint space narrowing on anteroposterior weight bearing radiograph; Grade 3- multiple osteophytes, definite joint space narrowing, sclerosis, possible bony deformity; Grade 4- large osteophytes marked joint space narrowing, severe sclerosis and definite bony deformity [24].

Thereafter, six selected anatomical alignment characteristics were measured on the left and right lower extremities of the participants. These lower extremity characteristics were based on commonly identified variables which have been suggested to change the biomechanics of the degenerating or affected knee [19]. These include:

Femoral anteversion: This was measured using a universal goniometer and the Craig test, with the participants in prone position on a plinth. The limb to be measured was placed in 90 degrees of flexion. The hip was then rotated medially and laterally while the greater trochanter area was being palpated until it was placed in the outward most point in the lateral aspect of the hip (the greater trochanter being parallel to the plinth at this point). Finally, the angle between the long axis of the tibia in true vertical and the shaft of the tibia was measured using the Universal Goniometer (EZ Read Jamar ® 0°-360°, Taiwan). [25]

Quadriceps angle: This measurement was taken in standing position. The anatomical landmarks (Anterior superior iliac spine, mid patella and tibia tubercle) were located through palpation and then marked with a water-soluble marker. The participants were then instructed to assume Romberg anatomical stance position with the knees extended and without voluntary quadriceps contraction. The anatomical landmarks already marked will be then joined by the use of a meter rule (Butterfly, China) and a marker. With the pivot of the goniometer placed on the mid-point of the patella, the stationary arm on the line adjoining the anterior superior iliac spine to the mid-point of the patella, and the moveable arm placed over the line adjoining the tibia tubercle to the mid-point of the patella thus the Q-angle was measured. [26]

Tibiofemoral angle: The participants were instructed to assume a supine position on the plinth. One arm of the goniometer was aligned to an imaginary line drawn from the anterior superior iliac spine to the middle of the patella (femoral alignment) and the second arm aligned to a line joining the middle of the patella to the middle of the ankle (center point between medial and lateral malleoli), tibia alignment. The center of patella served as the fulcrum for the goniometer. The acute angle that was sustained between the femoral shaft (femoral alignment) and the tibial shaft (tibial alignment) was recorded as the tibiofemoral angle in degrees. [27]

Genu recurvatum: This was measured with the participants in weight bearing position from the lateral side. Thus, the participants were instructed to stand in anatomical position sideways. The long axis of the thigh (from the tip of the trochanter to the midpoint of the lateral femoral condyle) was drawn. The long axis of the leg was also drawn from the middle of the lateral tibial condyle and the lateral malleolus. The angle between these two lines was measured as the angle of recuvatum. [28]

Tibia torsion: The participants were instructed to lie prone on the plinth with the knee flexed to 90 degrees. The center of each malleoli was marked then these points were connected by a line across the plantar surface of the sole. A line perpendicular to it was then drawn. The angle between the thigh axis and a line perpendicular to the transmalleolar axis was measured, which is equal to the tibial torsion. [29]

Navicular drop: This was measured with the participants in standing position so there was full weight-bearing through the lower extremity and ensuring the foot was in the subtalar joint neutral position ("talar head congruent"). The location of the navicular tuberosity was marked. The participants were then instructed to relax and then the amount of sagittal plane excursion of the navicular (the start and end position of the navicular) was marked and on an index card placed along the inside of the foot and then the distance between both points was measured with a ruler. [30]

All standing measurements were taken in standardized stance with the left and right feet equally spaced to width of the left and right acromioclavicular process and toes facing forward. They were instructed to look straight ahead during all standing measures with equal weight over both feet. Each measurement was repeated 3 times. [19]

Data analysis

Data collected was analyzed using Statistical Package for Social Sciences (SPSS) version 20. Demographic data was summarized using descriptive statistics of mean, standard deviation and percentages. Inferential statistics of Pearson's Product Moment Correlation Coefficient was used to determine the relationships among the individual lower extremity alignment variables (femoral anteversion, quadriceps angle, tibiofemoral angle, genu recurvatum, tibia torsion and navicular drop) in the subjects studied and Independent samples t test to analyze gender differences. Level of significance for all inferential tests was set at the level of $p < 0.05$.

Results

The result of the correlation coefficient for the right symptomatic limb (Table 2) in subjects with unilateral symptomatic right knee osteoarthritis showed that there was no significant relationship among the lower extremity alignment variables. The result of the correlation coefficient for the left symptomatic limb (Table 2) in subjects with unilateral symptomatic left knee osteoarthritis showed that there was no significant relationship among the lower extremity alignment variables. The result of the correlation coefficient for the left limb lower extremity alignment variables in subjects with symptomatic bilateral knee osteoarthritis (Table 3) showed that there was no significant relationship among the lower extremity alignment variables except between Femoral anteversion angle and Genu recurvatum angle ($r= -0.443$, $p= 0.039$). The result of the correlation coefficient for the right limb lower extremity alignment variables in subjects with symptomatic bilateral knee osteoarthritis (Table 3) showed that there was no significant relationship among the lower extremity alignment variables except between Tibiofemoral angle and Tibial torsion angle ($r= -0.445$, $p= 0.03$).

The result of the correlation coefficient between the right symptomatic limb and left asymptomatic limb (Table 4) in male subjects with unilateral symptomatic right knee osteoarthritis showed that there was no significant relationship among the lower extremity alignment variables. But, (Table 4) in female subjects with unilateral symptomatic right knee osteoarthritis there was significant relationship among the lower extremity alignment variables in the right symptomatic limb and left asymptomatic limb; TibioFemoral angle (r value=0.723*, p value=0.012), Femoral Anteversion (r value= 0.805^{**}, p value= 0.003) & Navicular Drop (r value= 0.793^{**}, p value = 0.004).

Gender difference

Independent *t* test revealed that there was a significant gender difference in Femoral anteversion ($t= -2.803$, $p= 0.016$) and Navicular drop ($t= 2.335$, $p= 0.038$) between male and female participants with unilateral symptomatic right knee osteoarthritis (Table 5). There was no significant gender difference in the other lower extremity alignment variables (Quadriceps angle, Tibiofemoral angle, Tibial torsion and Femoral anteversion). Independent *t* test revealed that there was significant gender difference in the Quadriceps angle ($t= -2.148$, $p= 0.044$) between male and female participants right limb with symptomatic bilateral knee osteoarthritis (Table 5). There was no significant gender difference in the other lower extremity alignment variables (Tibiofemoral angle, Tibial torsion, Femoral anteverion, Genu recurvatum and Navicular drop).

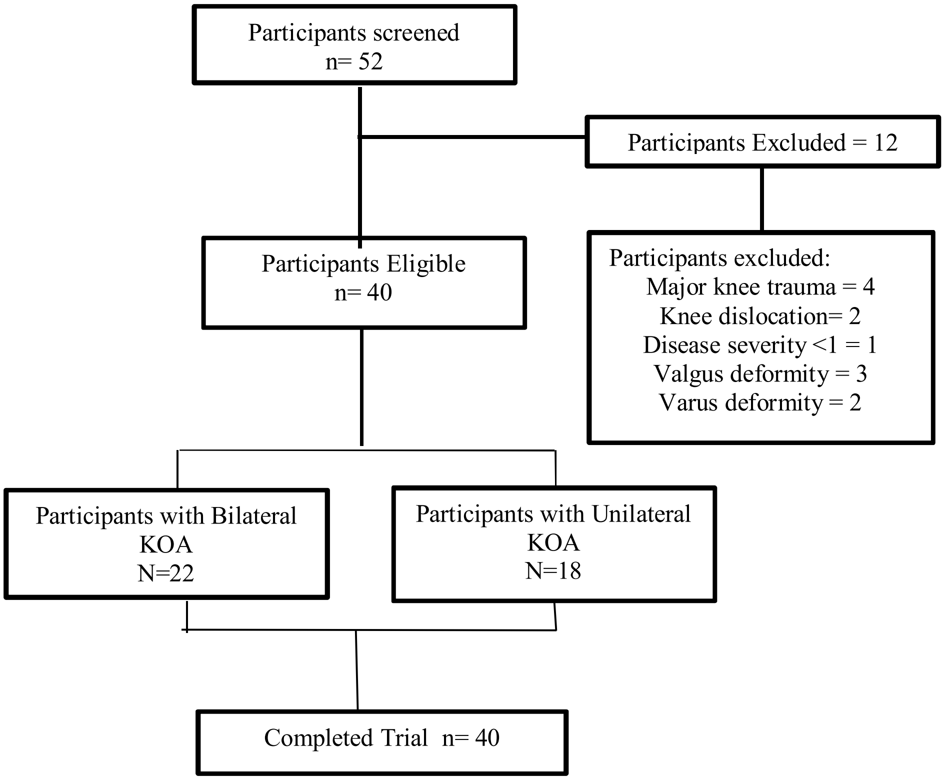

Figure 1: Flow of Participants in the study

Table 1: Physical Characteristics of the Participants

Variables	**Total (X ± SD)**	**Unilateral (X ± SD)**	**Bilateral (X ± SD)**
Age (years)	56.35±9.70	52.11±10.36	59.82±7.75
Weight (kg)	82.50±14.49	80.41±15.64	81.39±20.03
Height (m)	1.64±1.28	1.73±1.76	1.62±2.17
BMI (kg/m^2):	30.7±4.38	29.69±5.06	31.08±4.26
BMI Categories			
18.5-25(Normal weight)	5 (12.5)	3 (60)	2 (50)
25-29 (Over weight)	12 (30)	6 (50)	6 (50)
≥30 (Obese)	23 (57.5)	9 (39.1)	14 (60.9)

Table 2: Correlation matrix for the right symptomatic limb lower extremity alignment variables in participants with unilateral symptomatic right KOA

	Q angle		**TF angle**		**TT angle**		**FA angle**		**GR angle**		**N drop**	
	r-value	p-value	r-value	p-value	r-value	p-value	r-value	p-value	r-value	p-value	r-value	p-value
Right Lower Extremity Variable												
Q angle	1	0	-0.307	0.266	0.220	0.220	0.275	0.322	-0.096	0.733	-0.255	0.360
TF angle	-0.307	0.266	1	0	0.086	0.086	-0.125	0.657	0.151	0.592	-0.212	0.448
TT angle	0.220	0.430	0.086	0.761	1	0	-0.221	0.428	0.426	0.113	0.161	0.566
FA angle	0.275	0.322	-0.125	0.657	-0.221	0.428	1	0	-0.191	0.496	-0.266	0.339
GR angle	-0.096	0.733	0.151	0.592	0.426	0.113	-0.191	0.496	1	0	0.064	0.821
N drop	-0.255	0.360	-0.212	0.448	0.161	0.566	-0.266	0.339	0.064	0.821	1	0
Left Lower Extremity Variable												
Q angle	1	0	-0.824	0.384	0.282	0.818	0.838	0.367	-0.120	0.923	-0.762	0.449
TF angle	-0.824	0.384	1	0	0.311	0.798	-0.382	0.751	0.662	0.540	0.995	0.065
TT angle	0.282	0.818	0.311	0.798	1	0	0.759	0.451	0.919	0.259	0.407	0.733
FR angle	0.838	0.367	-0.382	0.751	0.759	0.451	1	0	0.441	0.710	-0.286	0.816
GR angle	-0.120	0.923	0.662	0.540	0.919	0.259	0.441	0.710	1	0	0.735	0.475

Key: Q angle = Quadriceps angle; TF angle = Tibiofemoral angle; TT angle = Tibial Torsion angle;

N Drop	-0.762	0.449	0.995	0.065	0.407	0.733	-0.286	0.816	0.735	0.475	1	0

FA angle = Femoral anteversion angle; GR angle = Genu recurvatum angle; N drop = Navicular drop

Table 3: Correlation matrix for the left lower extremity alignment variables in subjects with symptomatic bilateral knee osteoarthritis

	Q angle		**TF angle**		**TT angle**		**FA angle**		**GR angle**		**N drop**	
	r-value	p-value	r-value	p-value	r-value	p-value	r-value	p-value	r-value	p-value	r-value	p-value
Left Lower	***Extremity***	***Variable***										
Q angle	1	0	0.136	0.547	-0.049	0.827	0.192	0.391	0.004	0.986	-0.016	0.944
TF angle	0.136	0.547	1	0	0.287	0.195	0.298	0.178	0.182	0.418	-0.035	0.877
TT angle	-0.049	0.827	0.287	0.195	1	0	-0.396	0.068	0.150	0.505	-0.022	0.922
FR angle	0.192	0.391	0.298	0.178	-0.396	0.068	1	0	-0.443	0.039*	-0.049	0.829
GR angle	0.004	0.986	0.182	0.418	0.150	0.505	-0.443	0.039*	1	0	0.285	0.198
N drop	-0.016	0.944	-0.035	0.877	-0.022	0.922	-0.049	0.829	0.285	0.198	1	0
Right Lower	***Extremity***	***Variable***										
Q angle	1	0	0.351	0.110	-0.272	0.220	-0.204	0.362	-0.051	0.822	0.142	0.528
TF angle	0.351	0.110	1	0	-0.445	0.038*	0.267	0.230	0.219	0.328	-0.255	0.252
TT angle	-0.272	0.220	-0.445	0.038*	1	0	-0.045	0.844	0.045	0.842	0.349	0.112
FR angle	-0.204	0.362	0.267	0.328	-0.045	0.844	1	0	-0.152	0.499	-0.053	0.815
GR angle	-0.051	0.822	0.219	0.252	0.045	0.842	-0.152	0.499	1	0	0.255	0.251
N Drop	0.142	0.528	-0.255	0.110	0.349	0.112	-0.053	0.815	0.255	0.251	1	0

* Correlation is significant at P<0.05 level (2-tailed).

Key: Q angle = Quadriceps angle; TF angle = Tibiofemoral angle; TT angle = Tibial Torsion angle; FA angle = Femoral anteversion angle; GR angle = Genu recurvatum angle; N drop = Navicular drop

Table 4: Comparison between right and left limbs of male and female participants with unilateral symptomatic right KOA

	Q angle R		**TF angle R**		**TT angle R**		**FA angle R**		**GR angle R**		**N drop R**	
	r-value	p-value	r-value	p-value	r-value	p-value	r-value	p-value	r-value	p-value	r-value	p-value
Male Lower Extremity Variable												
Q angle L	0.792	0.208	0.039	0.961	-0.445	0.555	0.990**	0.010	-0.397	0.603	-0.821	0.179
TF angle L	0.417	0.583	-0.652	0.348	-0.996**	0.004	0.502	0.498	-0.357	0.643	-0.615	0.385
TT angle L	-0.705	0.295	0.921	0.079	0.846	0.154	-0.463	0.537	-0.215	0.785	0.792	0.208
FA angle L	0.993**	0.007	-0.494	0.506	-0.424	0.576	0.764	0.236	0.304	0.696	-0.942	0.058
GR angle L	0.625	0.375	-0.672	0.328	-0.052	0.948	0.085	0.915	0.880	0.120	-0.495	0.505
N drop L	-.0351	0.649	0.831	0.169	0.147	0.853	0.211	0.789	-0.881	0.119	0.276	0.724
Female Lower Extremity Variable												
Q angle L	0.369	0.265	0.100	0.770	-0.011	0.973	0.105	0.759	-0.632*	0.037	0.532	0.092
TF angle L	-0.217	0.522	0.723*	0.012	0.138	0.686	-0.145	0.671	-0.122	0.720	-0.415	0.204
TT angle L	0.296	0.377	0.211	0.534	0.457	0.157	-0.139	0.683	0.067	0.845	-0.095	0.781
FA angle L	-0.288	0.390	-0.207	0.542	-0.123	0.719	0.805**	0.003	-0.076	0.824	0.190	0.577
GR angle L	0.521	0.100	-0.094	0.784	0.117	0.731	0.194	0.569	0.271	0.420	0.432	0.184
N Drop L	0.415	0.204	-0.149	0.662	0.168	0.622	-0.103	0.763	-0.369	0.264	0.793**	0.004

* Correlation is significant at P<0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Key: Q angle = Quadriceps angle; TF angle = Tibiofemoral angle; TT angle = Tibial Torsion angle; FA angle = Femoral anteversion angle; GR angle = Genu recurvatum angle; N drop = Navicular drop

Table 5: Comparison between right and left limbs of male and female participants with unilateral and Bilateral symptomatic right KOA

	Unilateral symptomatic Right KOA				**Bilateral Symptomatic Left and Right KOA**			
	Male (n=4) (X ± SD)	**Female (n=11) (X ± SD)**	**t-value**	**p-value**	**Male (n=3) (X ± SD)**	**Female (n=9) (X ± SD)**	**t-value**	**t-value**
Unilateral Right KOA					***Bilateral Left KOA***			
Q angle	17.80±2.46	20.79±3.57	-1.531	0.150	20.10±4.61	21.03±3.96	-0.372	0.7414
TF angle	7.65±0.40	7.07±2.26	0.496	0.628	9.10±2.85	7.56±2.33	1.036	0.313
TT angle	5.50±5.19	4.63±3.66	0.368	0.719	5.63±4.36	4.06±3.21	0.756	0.459
FR angle	22.65±6.44	35.18±9.44	-2.428	0.030*	27.96±16.17	33.38±11.18	-0.740	0.468
GR angle	5.55±1.47	3.63±1.71	1.981	0.069	6.10±4.61	4.62±2.21	0.926	0.366
N Drop	3.72±1.26	2.16±1.04	2.440	0.030*	4.50±0.17	3.45±1.09	1.568	0.133
					Bilateral Right KOA			
Q angle					17.20±3.65	21.87±3.48	-2.148	0.044*
TF angle					7.30±4.49	7.74±2.83	-0.231	0.819
TT angle					5.43±4.04	5.23±3.57	0.090	0.929
FR angle					27.53±18.63	31.56±11.45	-0.525	0.605
GR angle					6.10±4.43	4.47±2.19	1.047	0.308
N Drop					2.97±1.15	3.04±0.79	0.150	0.882

* Correlation is significant at P<0.05 level (2-tailed).

Key: Q angle = Quadriceps angle; TF angle = Tibiofemoral angle; TT angle = Tibial Torsion angle; FA angle = Femoral anteversion angle; GR angle = Genu recurvatum angle; N drop = Navicular drop

Discussion

It was observed in this study that the right limb (83%) was more affected than the left (17%) in the category of subjects with symptomatic unilateral knee osteoarthritis. This could be because the right limb is the more mobile limb and is used for activities involving mobilization and manipulation as reported by Velotta *et al,* [31] who discovered that the right leg was the preferred leg especially for subjects that are right leg dominant (80-90%). This further corroborates the report of Gentry and Gabbard, [32] that human beings are typically right leg dominant for activities requiring mobilization and left leg dominant for activities requiring postural stability and strength.

It was reported in this study that for subjects with symptomatic bilateral knee osteoarthritis, one limb was reported to be more painful and stiff than the other limb; 31.8% complained that the right limb was more painful and stiff, 27.3% complained that the left limb was more painful and stiff while 40.9% complained that both limbs had equal amount of pain and stiffness. The differences in pain intensity and stiffness levels in either the right, left or both knees may be as a result of continued usage and weight bearing of the more dominant limb.

The findings of this study revealed that there was no significant relationship among the selected lower extremity alignment variables in the affected or symptomatic limbs (left or right) of the subjects with symptomatic unilateral knee osteoarthritis. The observed absence of relationship may be due to mal-alignment as a result of joint and alignment alterations as supported by Sharma *et al.* [10], who found out that cartilage loss and bony remodeling causes the joint to become tilted and thus, mal-alignment develops. In the asymptomatic limbs, there was also no relationship among the lower extremity alignment variables. The absence of relationship may be due to joint overloading or even an early onset of osteoarthritis and in comparison with healthy individuals (asymptomatic limbs) the presence of relationships among the lower extremity alignment variables is due to alignment in the absence of osteoarthritis. [19] This study agrees with Metcalfe *et al,* [17] and Kirkley, [12] who reported that abnormal loading of the unaffected knee of subjects with unilateral knee osteoarthritis would eventually lead to anatomic joint alterations, structural deviations of the joint and mal-alignment over a period of time and that individuals with a painful (symptomatic) joint may accelerate the disease of the other joint.

The findings of this study revealed a significant relationship between TibioFemoral angle, Femoral Anteversion & Navicular Drop of females in the right symptomatic limb and left asymptomatic limb among the other lower extremity alignment variables in females with right symptomatic knee osteoarthritis. This agrees with a previous study with 2 year follow-up, that showed 34% of patients with unilateral disease subsequently developed disease in the contra-lateral knee, however follow up was relatively short and the study was restricted to females only. [38]

The findings of this study revealed a significant relationship between Genu recurvatum and femoral anteversion among the lower extremity alignment variables in the left affected limb of subjects with symptomatic bilateral knee osteoarthritis and a significant relationship between Tibiofemoral angle and Tibial torsion in the right affected limb of subjects with bilateral symptomatic knee osteoarthritis. In comparison with alignment relationships in healthy individuals as conducted by Nguyen and Shultz, [19] there was no relationship between Genu recurvatum and femoral anteversion or between Tibiofemoral angle and Tibial torsion as seen in subjects with bilateral knee osteoarthritis. It is possible that alignments which had no relationship previously may begin to have relationships as a result of mal-alignment present in the lower extremity. This study agrees with Riegger-Krugh *et al,* [33] who reported that mal-alignments can correlate as a method of compensation especially in the lower extremity.

The findings of this study revealed a gender difference in Femoral anteverion (females showing greater mean values) and navicular drop (males showing greater mean values) between male and female subjects with unilateral symptomatic right knee osteoarthritis. Increase in femoral anteversion causes internal rotation of the femur and internal rotation of the femur is associated with greater knee valgus. Thus increase in femoral anteversion increases the tendency of developing dynamic valgus at the knee. [34]

This study further corroborates the report of Takai *et al*, [35] and Eckhoff *et al*, [36] that osteoarthritis is associated with femoral anteversion and agrees with Nguyen and Shultz, [37] who conducted a study on healthy individuals and found out that females tend to demonstrate greater Femoral anteversion, Genu recurvatum, Quadriceps angle, Tibiofemoral angle and Anterior pelvic tilt. Although, this same study by Nguyen and Shultz, [37] did not identify gender differences in static alignment of the lower legs, ankles, or feet (tibial torsion, navicular drop, standing rearfoot angle) in healthy individuals. The reason for this gender difference is not adequately understood.

The findings of this study showed that no gender difference was observed with any of the lower extremity alignment variables (Quadriceps angle, Tibiofemoral angle, Femoral anteversion, Genu recurvatum, Tibial torsion and Navicular drop) in the left limbs of subjects with bilateral symptomatic osteoarthritis and the reason contributing to this result is not entirely known as previous studies [28, 37] carried out on healthy individuals found significant gender relationships among some of the lower extremity alignment variables.

The findings of this study revealed a gender difference in Quadriceps angle for the right limbs of male and female subjects with symptomatic bilateral osteoarthritis with females having greater mean values. Increase in quadriceps angle indicates a tendency for added biomechanical stress during strenuous or repetitive activities using the knee. Thus this study disagrees with Deshbhratar, [3] who found that females with knee osteoarthritis had a decrease in quadriceps angle when compared to healthy age matched female individuals as a result of altered muscle pull around the knee joint, genu varum and tibial torsion.

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