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Research Article

The Influence of Body Mass Index, Q-angle and Tibiofemoral Alignment on the Clinical Deficits of Osteoarthritis of the Knee

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Abstract

Background: The underlying determinants of clinical deficits of knee OA remain crucial during objective assessment, which is yet to receive the deserved attention in practice.

Objective: The study determined the influence of BMI, Q-angle and Tibiofemoral alignment (TFA) on pain, stiffness and physical function of patients with knee OA.

Methods: Patients diagnosed with knee OA were recruited at physiotherapy departments of three health care settings in Ghana. The BMI of participants was determined through the standard formula [weight (kg)/height (m) ^{2}]. The measurement of Q-angle and TFA followed routine manual methods with the use of goniometer and tracing sheet. To quantify pain intensity, joint stiffness and physical function of participants, the domains of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was employed. Spearman's correlation coefficient was used to determine the relationships between variables at $p<0.05$.

Results: Fifty-two (52) patients with knee OA (Mean age; 60.2±10.4years) participated in the study. They comprised 9 (17.3%) males and 43 (82.7%) females. Participants' BMI and Q angle were significantly and positively correlated with their physical functioning (rho=0.368; p=0.007) and (rho=0.332; p=0.016) respectively on the domains of WOMAC. However, participants' self-reported pain and stiffness as assessed on WOMAC index were not significantly correlated with BMI, Q angle and clinical TFA.

Conclusion: BMI and Q-angle could considerably influence the overall clinical deficits in patients with knee OA particularly the physical function, thus placing emphasis on routine assessment of these variables in the clinical practice.

Keywords: BMI; Q angle; Tibiofemoral alignment; Osteoarthritis

Background

Osteoarthritis (OA) is one of the most common joint diseases worldwide [1] and it is being closely linked with the diseases of lifestyle. The evolution of OA is slow and could lead to joint stiffness, progressive deformity and loss of function, thereby affecting quality of life [2]. The knee is the most commonly affected weight-bearing joint and it is often accompanied by functional disability [3]. It is generally accepted that pain in the osteoarthritic knee is likely to be heterogeneous, with different causes predominating in different individuals or at different phases of the disease [4]. The prevalence rate of knee OA in the African region is estimated to be 20.2% in males and 30.2% in females aged over 45 years [5]. Specifically, a prevalence rate of 8% was reported among the Togolese [6] while the Arthritic Society [7] revealed a prevalence rate of 7.4% in Ghana. The current trend of upsurge of OA continues to challenge health care providers as regards the potential determinants of functional deficits in the sufferers.

During objective evaluation of knee OA, it is often necessary to assess the alignment of the component bones of the lower extremity. Although various methods of assessment such as light boxes, rulers, and grease pencils have been exchanged for computers using graphics software [8], the hitherto clinical methods are still relevant in poorly resourced clinical settings. In osteoarthritis, the tibio-femoral joint space narrowing is often unsymmetrical, leading to angular deformity of the lower extremity, more commonly of the varus type [8]. Joint malalignment presets early onset of secondary OA and its progression due to abnormal loading [9]. Excess adipose tissue and the subsequent repetitive axial loading at the knee joint have been speculated as the causative events leading to degeneration of articular cartilage and sclerosis of subchondral bone [10].

Specifically, biomechanical factors such as clinical tibiofemoral alignment (TFA) and quadriceps angle (Q-angle) underlie the integrity of the knee joint [11, 12], which are frequently deranged in knee OA. Clinical TFA remains one of the most reliable measures of angular alignment commonly employed to estimate the degree of deformity in patients with various knee pathologies [13]. It represents the knee angle formed when two axes are drawn, one connecting the anterior superior iliac spine and the center of patella and one between the patella and a point measured midway between the medial and lateral malleoli. A good correlation between clinical TFA and anatomical TFA has also been reported in the literature [14]. Anatomical TFA follows the same methodological approach as clinical TFA but it is mostly measured through plain film radiographs [14].

Turcot et al. has previously identified abnormal TFA ($<6^0$ or $>6^0$) as an important risk factor for the progression of knee OA [15, 16]. Q-angle on the other hand, is a clinical measure of lower limb alignment that represents the resultant force orientation of the quadriceps muscles acting on the patella in the frontal plane [17]. It is interpreted as the angle formed by the pull of the quadriceps muscle from the pelvis to the patella and the patella tendon's pull on the tibia [18]. Deviation from the normal range of values (10^0 to 20^0) in supine lying, has been implicated in several knee disorders [19].

It has been suggested that biomechanical changes resulting from abnormal alignment may influence joint loads, mechanical efficiency of muscles, and proprioceptive orientation and feedback from the hip and knee, resulting in altered neuromuscular function and control of the lower extremities [20, 21]. The resulting alterations may have direct clinical consequences on knee pathology which needs further scrutiny particularly in patient with knee OA. Indeed, pain, stiffness and overall decline in function remain the most commonly presented complaints among patients with knee OA. These variables underlie the main rehabilitation potentials for orthopaedic and medical rehabilitation specialists. Despite the enormous documentations in literature favouring biomechanical factors as indicators of various clinical deficits, information regarding the quantification of its influence on pain, joint stiffness and physical function of patients with knee OA remains insufficient. Moreover, varying empirical values for TFA, Q-angle and BMI have been reported even within the same geographical subregion [13] thus underscoring the necessity to investigate the importance of these variables on population-based dimension. The present study thus sought to determine the influence of Q-angle, TFA and BMI on the clinical deficits among patients with the Knee at selected health facilities in Ghana.

Methods

Participants

Patients with unilateral or bilateral Osteoarthritis (OA) of the knee were recruited through convenience sampling from the outpatient units of the Physiotherapy Departments at three referral Hospitals. They were considered for inclusion into the study if they were experiencing activity-related pain on a Numerical Rating Scale score of≥4 and were diagnosed for secondary knee OA by resident physicians. Diagnoses of OA were made by physicians using Kellgren and Lawrence grading of radiographic assessment of OA [22].

Instruments for measurement

The body weight of the participants was measured with a portable bathroom weighing scale calibrated from 0-150kg to the nearest kilogramme. An industrial type stadiometer calibrated in centimeter was used to measure participants' height. The BMI of the participants was determined from the two measures. A medium size goniometer calibrated from 0-180^0 in each direction to the nearest degree was used to measure the Q-angle and TFA.

Outcome measure

The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was used to assess pain, stiffness and physical function of the patients. It consists of 3 subscales with 24 items segregated as follows: pain=5 items, stiffness=2 items and physical functioning=17 items. Responses were based on likert scale in which none=0, mild=1, moderate=2, severe=3 and extreme=4. Thus, overall high scores on WOMAC and on any of the subscales indicate high clinical deficits. The questionnaire is self-administered with an average duration of 12-15 minutes.

Since its introduction, the WOMAC has been widely used as a measure of symptoms and physical disability associated with osteoarthritis of the hip and/or knee. It has been translated and thus validated for use in several populations. A literature review of 43 studies regarding the validation of the WOMAC in various populations indicated that it has strong psychometric properties that support its use in the measurement of physical function [23].

Procedure

Ethical clearance was sought and obtained from the Ethics and Protocol Review Committee of the School of Allied Health Sciences (now School of Biomedical and Allied Health Sciences), College of Health Sciences, University of Ghana. Informed consent was obtained following clear and vivid explanation of the protocol of the study. The privacy of the participants was adequately guaranteed by making sure they were moderately exposed.

Biodata of the participants including sex, age and occupation were collected for documentation. In order to quantify the level of clinical deficits, the printed copies of WOMAC were administered to the participants to measure pain intensity, joint stiffness and physical function associated with knee OA. Participants' weights were taken with each of them wearing light clothing and were barefooted. They stepped on the scale with arms by their sides and looking straight ahead. Participants' heights were also measured in erect standing with arms by the sides and head in neutral position. Each participant was asked to stand closer to the height meter and look straight ahead, an incorporated bar was aligned to touch the vertex of the head and the corresponding calibrations on the height meter. BMI was then calculated by dividing the body weight (Kg) by the square of the height (m^2).

Measurement of tibiofemoral angle

In determining TFA with goniometer, participants were asked to assume supine lying position on a couch with foot pointing directly upwards. After palpating the anterior superior iliac spine (ASIS), center of the patella and centre of ankle joint, pieces of kinesiotape were stuck to the skin areas directly overlying these landmarks. A tracing sheet was wrapped around the lower limb and the pieces of kinesiotape were located and marked on the sheet using a marker. The tracing sheet was unwrapped and the marks were adjoined through two straight lines; one from the center of patella to the centre of ankle and the other line from the center of patella to the ASIS. The measurement protocol was adopted from previous studies [24, 25, 14]**.** The adopted method has been found to be easy and inexpensive [14]**.** The axis of the goniometer was placed on the point denoting the center of patella, the stationary arm is aligned to ASIS whilst the mobile arm points to the line from the center of the ankle. The TFA value was taken as the angle formed by the intersection of the two lines [26].

Measurement of Q-angle

The Q-angle was also measured with the participants in supine lying. Three landmarks were identified on the involved limb, namely; anterior superior iliac spine (ASIS), center of the patella and tibial tuberosity. After palpation for the selected landmarks, pieces of kinesiotape were stuck to the skin areas directly overlying the desired landmarks. A tracing sheet was wrapped around the affected lower limb and the pieces of the kinesiotape were marked on the sheet. The tracing sheet was unwrapped and two straight lines were drawn to connect ASIS to centre of patella and the other to connect the centre of the patella and tibial tuberosity. The axis of the goniometer was placed on the mark denoting the centre of patella.The stationary arm was aligned to ASIS whilst the moving arm was aligned along the straight line to the tibial tuberosity. The angle formed at the intersection of the two lines was measured as the Q-angle in degree [26].

Data analysis

The data were analysed statistically using the Statistical Package for Social Science (SPSS) version 20.0. The BMI, Q-angle, and TFA were summarized using the descriptive statistics. Spearman's correlation coefficient was used to determine the relationships between variables at $p<0.05$.

Results

Fifty-two (52) participants diagnosed with knee osteoarthritis (OA) took part in the study. They comprised 9 (17.3%) males and 43 (82.7%) females with a mean age of 60.2±10.4years. The mean BMI, clinical TFA and Q-angle were 30.0± 6.2 Kg/m^2, 7.7±3.2^o and 17.6±4.7^o respectively. Nineteen (36.5%) of the female participants were obese. Nine (17.3%) of them had left knee OA compared to 16 (30.8%) with right knee OA while 27 (51.9%) presented with bilateral knee OA. The anthropometric and biomechanical data are presented in (Table 1).

Table 1. Anthropometric and biomechanical data of participants.

Variables	N	Minimum	Maximum	Mean± SD
Age of participants (years)	52	30.0	84.0	60.2±10.4
Weight of participants (Kg)	52	54.0	149.0	80.5±18.0
Height of participants (m)	52	1.5	1.7	1.6±0.1
Body Mass Index (Kg/m^2)	52	20.5	51.5	30.0±6.2
Quadriceps Angle (°)	52	9.0	30.0	17.6±4.7
Tibiofemoral Alignment (°)	52	3.0	18.0	7.6±3.2

Table 2. Sex distribution of Body Mass Index, Q-angle and Tibiofemoral alignment of the participants.

Classification of Variables	Male (%)	Female (%)	Total (%)
BMI (Kg/m^2)			
Obese (>30)	3 (5.8)	19 (36.5)	22 (42.3)
Overweight (25.0-29.9)	4 (7.7)	19 (36.5)	23 (44.2)
Normal (18.5-24.9)	2 (3.9)	5 (9.6)	7 (13.5)

Table 2 shows sex distribution of BMI, Q-Angle and TFA of the participants. Obese and overweight females were the most prevalent among the participants, 19 (36.5%) each out of the total participants. Forty-five (86%) of the participants were either overweight or obese. Greater proportion of the participants 25 (48.1%) had normal Q-angle (15^0-20^0). Four (7.7%) males had Q-angle below the normal range (< 15^0) compared to their female peers, 3 (5.8%) who had greater than the normal range (>20^0). Fourteen (26.9%) of the total participants had their Q-angle above normal range whilst 13 (25%) had theirs below the normal (< 15^0). Majority of the participants 25 (48.1%) had valgus alignment (TFA>7^0) compared to 10 (19.2%) participants who presented with varus alignment (TFA<5^0).

Spearman's correlation coefficient analysis showed that BMI and Q-angle were significantly and positively related with physical functioning domains of WOMAC index (rho=0.368; p=0.007 and rho=0.332; p=0.016 respectively). This implies that increased Q angle and BMI scores are accompanied by increased scores on the WOMAC subscale of physical functioning (lower function). Similarly, BMI and Q angle were positively and significantly correlated with overall score of WOMAC Index. However, participants' pain and stiffness were not significantly correlated with BMI, Q angle and clinical TFA.

Discussion

The main focus of this study was to explore the influence of body mass index (BMI), tibiofemoral Alignment (TFA) and Q-angle on the clinical presentations of knee OA among Ghanaians. Results showed that BMI and Q-angle were the significant predictors of the overall clinical deficits in the sampled participants. Additionally, clinical TFA had no significant influence on any of the dependent variables in WOMAC subscales.

The mean age of the participants was 60.2±10.4 years which supports the established close connection between ageing and an increase incidence of symptomatic OA. According to a previous report, the incidence of diagnosed symptomatic knee OA appears to be highest among adults between the ages of 55 and 64 years [27]. A greater proportion of participants (82.7%) were women compared to men (17.3%) which fall in line with the previous findings in which about 13% of women and 10% of men aged 60 years and older have symptomatic knee OA [28].

The participants' BMI had a significant positive relationship with physical function scores on the WOMAC index. This result follows the same trend with previous trials in which radiographic knee OA in patients with high BMI were found to show greater likelihood of knee pain compared to their peers with normal BMI [29, 30]. Indeed, increased knee joint loads are present in patients with knee OA and the interaction between axial alignment and dynamic knee joint loading, is especially pronounced in patients with high body mass index [21]. Similarly, Felson *et al* reported that participants with symptomatic knee OA had higher BMI levels compared to their asymptomatic counterparts [31]. Majority (86.5%) of the participants in this study were either overweight or obese which lends credence to the outcome of this study. The biomechanical theory concludes that obesity leads to repetitive application of increased axial loading on the knee joint with consequent degeneration of articular cartilage and sclerosis of subchondral bone [10]. The direct significant relationship between BMI and physical function of the patients may be linked with the consequence of fear avoidance theory of pain. Investigators have suggested that fear of pain and activity driven by the anticipation of pain and increased injury, rather than the noxious sensory stimuli associated with pain itself, results in strong negative reinforcement for the persistence of avoidance behavior, paving way for putative functional disability in people with persistent pain [32]. Although, there was no significant relationship between BMI and self-reported pain by the participants, its positive significant correlation with overall scores on WOMAC tends to support the theory. These findings are in conformity with that obtained from a study by Sharma et al in which BMI was identified as one of the factors placing individuals with knee OA at greater risk of a poor function outcome in addition to joint laxity, malalignment and proprioceptive inaccuracy [33]. Current evidence suggests that cytokines associated with adipose tissue, including leptin, adiponectin, and resistin, may influence OA through direct joint degradation or control of local inflammatory processes [34]. These cytokines have been found in elevated levels in the synovial fluid and plasma of obese OA patients and their manifestations have been directly associated with the degree of cartilage degeneration [35- 37].

Results from this study also established a significant positive relationship of Q-angle with physical function as well as the overall scores on WOMAC index. A study by Horton, revealed Q-angle as an important concept in patellofemoral joint function [38]. Theoretically, any alteration in alignment that increases Q-angle is thought to increase the lateral force on the patella such that a higher Q-angle increases the lateral pull of the quadriceps femoris muscle on the patella and potentiates patellofemoral disorders [39]. In the present study, only 14 (26.9%) of the sampled patients had their Q-angle above the normal value (20^{o}). Although, an excessively large Q-angle is usually an indicator of some structural malaligment, an apparently normal Q-angle will not necessarily ensure the absence of knee disorder [39]. This submission highlights the present finding. Additionally, it has been reported that greater Q-angle may result from movement of the patellar medially or movement of tibia tuberosity laterally or both with greater tibiofemoral angle and femoral internal rotation which may result from an increased pelvic angle, changing the orientation of the acetabulum [40]. Given the identified close tie between these variables and the potential for any of them to differentially influence the Q-angle, examining Q-angle in isolation for its effect on lower extremity motion may not be sufficient to identify individuals at risk for lower extremity disorders.

The impacts of BMI and Q angle might have contributed to the present outcome. These findings attest to the fact that patient-reported measures of knee function in general are important for the comprehensive assessment of rheumatology conditions in both clinical and research contexts.

Limitations of the study

There are several limitations in this study. Firstly, convenience-sampling method adopted may not be robust enough. A randomized controlled trial could be a better choice for future research. Secondly, the sample size was small as only fifty-two participants were recruited. Thus, these findings should be considered with caution whilst a larger sample size is proposed to confirm a more profound interaction among the measured variables particularly in different populations. Lastly, in view of the influence of axial loading on knee OA, measurement of variables in double stance would have been more appropriate.

Conclusion

In conclusion, body mass index and Q-angle substantially contribute to the clinical deficits of the knee Osteoarthritis among the sampled participants. It thus follows that the assessment of the two factors must be seriously considered by physiotherapists and orthopaedic physicians while managing knee OA.

Competing interests

The authors declare that they have no competing interests.

Authors' contribution

AB and **EB** conceived and designed the study, drafted and transform the manuscript for intellectual consumption. **JD** involved in data collection and analysis. **OYB** assisted in the sequence alignment and drafting of the manuscript. All authors read and approved the final manuscript.

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