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Association of Patellofemoral Malalignment and Q Angle Alteration with Knee Pain: A Cross-sectional Observational Study

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ABSTRACT

Background: Patellofemoral malalignment has been implicated in the development of anterior knee pain, yet the role of clinical parameters such as the quadriceps (Q) angle remains debated. Given the high burden of knee pain and osteoarthritis (OA) in India, with prevalence estimates ranging between 18.3% to 33.2% across populations, identifying modifiable anatomical risk factors is critical.

Objectives: The primary objective of this study was to compare patellofemoral alignment characteristics and Q angle between individuals with knee pain and age- and gender-matched asymptomatic controls. A secondary objective was to explore the correlation between altered Q angle and the severity of knee pain.

Methods: A cross-sectional observational study was conducted involving 200 participants (100 with clinically diagnosed knee pain and 100 healthy controls). Demographic and anthropometric data were collected. Clinical Q angle was measured using a goniometer, while radiographic assessments included congruence angle, sulcus angle, patellar tilt, patellar height (Insall–Salvati ratio), and lateral patellar displacement using standardized skyline and lateral knee views. Pain severity was measured using the Numeric Pain Rating Scale (NPRS). Statistical analysis included independent t-tests, chi-square tests, and Pearson's correlation.

Results: Participants with knee pain exhibited significantly higher prevalence of patellofemoral malalignment features, including patella alta ($p = 0.002$), increased lateral patellar tilt ($p < 0.001$), increased congruence angle ($p = 0.001$), and abnormal sulcus angle ($p = 0.003$), compared to controls. No statistically significant difference was found in mean Q angle between groups ($p = 0.078$), although weak correlations were observed between Q angle and certain malalignment parameters. Pain severity was moderately correlated with lateral patellar tilt ($r = 0.41$, $p < 0.01$) and congruence angle ($r = 0.38$, $p < 0.01$).

Conclusion: Patellofemoral malalignment parameters are more commonly observed in individuals with knee pain than in asymptomatic controls, supporting their relevance in clinical assessment. Q angle alone may not be a reliable predictor of knee pain, but it can reflect underlying

biomechanical alterations when interpreted alongside radiographic markers. Routine assessment of patellofemoral alignment may aid in early diagnosis and individualized management of anterior knee pain.

Keywords: Knee pain, patellofemoral malalignment, Q angle, congruence angle, patellar tilt, radiographic assessment, anterior knee pain

INTRODUCTION

Background and Rationale

Knee pain is one of the most frequently reported musculoskeletal complaints, affecting individuals across all age groups and activity levels. It is a multifactorial condition, often resulting from mechanical, anatomical, or degenerative causes (1). One of the major contributors to knee pain is osteoarthritis (OA), particularly of the knee joint, which is characterized by degeneration of articular cartilage, subchondral bone changes, and joint space narrowing.

In the Indian population, knee osteoarthritis (OA) represents a significant public health concern. Prevalence rates vary between regions, with estimates ranging from 18.3% to 33.2% (2). A large-scale study reported an overall prevalence of 28.7%, indicating a substantial burden (3). Contributing risk factors include advancing age, female sex, especially postmenopausal status, obesity, and occupations involving prolonged sitting or sedentary activity (3, 4). Urban residents tend to experience higher rates of knee OA (33.2%) compared to rural populations (29.2%) (2). Globally, hip and knee OA rank 11th among the highest contributors to disability-adjusted life years (DALYs) (5). These statistics highlight the urgent need to understand underlying modifiable and structural contributors to knee pain, especially in Indian settings.

Among biomechanical factors, patellofemoral malalignment and the Q-angle (quadriceps angle) have received considerable attention as possible contributors to anterior knee pain and dysfunction. The Q-angle, defined as the angle between the line of pull of the quadriceps muscle and the patellar tendon, is commonly used to assess patellofemoral joint alignment. A higher Q-angle is thought to increase lateral tracking forces on the patella, potentially contributing to patellofemoral pain syndrome (PFPS) and patellar maltracking (6, 7).

Several studies suggest a significant relationship between increased Q-angle and the incidence of anterior knee pain. Emami et al. (2007) found that patients with anterior knee pain demonstrated significantly greater Q-angle values compared to asymptomatic individuals (7). Similarly, Kaya and Doral (2012) emphasized the association of increased Q-angle with patellofemoral disorders, although they noted its limitations as a standalone diagnostic tool due to inter-individual variability and inconsistencies in clinical measurement (6).

However, other research challenges the reliability of the Q-angle as a sole indicator of patellofemoral mechanics. Freedman et al. (2014) argue that the Q-angle may not accurately represent the dynamic alignment or the actual vector of quadriceps pull (8). Furthermore, the Q-angle's correlation with underlying anatomical contributors such as femoral anteversion or tibiofemoral angle remains unclear (6, 9). These inconsistencies in the literature suggest that while Q-angle remains a widely used clinical parameter, its interpretation should be contextualized within a broader biomechanical and anatomical framework.

Despite extensive use of Q-angle measurement in clinical and research settings, limited studies have directly compared Q-angle and patellofemoral alignment in symptomatic versus asymptomatic individuals, especially in the Indian population. There is also a paucity of data exploring how these parameters correlate with the severity of pain, raising important questions about their prognostic and diagnostic relevance.

Objectives

The primary objective of this study is to compare patellofemoral alignment and Q-angle between individuals with knee pain and age- and gender-matched controls without knee pain. The secondary objective is to examine whether altered Q-angle correlates with the severity of knee pain.

It is hypothesized that individuals with knee pain will exhibit significantly increased Q-angles and signs of patellofemoral malalignment compared to healthy controls, and that greater Q-angle values will be associated with increased pain severity.

METHODS

Study Design

A cross-sectional observational study design was adopted in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines. This design was chosen to assess and compare patellofemoral alignment and Q angle values among individuals with and without knee pain at a single point in time.

Study Setting

The study was conducted in the orthopedic outpatient departments of four tertiary-level hospitals located in Nadiad and Anand, Gujarat, India. These centers cater to a mixed population, including urban and semi-urban residents, thereby providing a representative sample of the region.

Sampling Method

A convenience sampling technique was employed due to logistical feasibility. Participants were recruited consecutively from patients and visitors attending the orthopedic departments, based on eligibility criteria.

Sample Size Calculation

The sample size for the study was determined based on an assumed prevalence of patellofemoral malalignment of 23%, with an absolute precision of 3.88% at a 95% confidence level. Although the minimum required sample size was calculated to be 118 participants, a total of 200 individuals were included in the study to enhance statistical power and allow for subgroup analyses. This included 100 participants with clinically diagnosed knee pain and 100 age- and gender-matched healthy controls.

Eligibility Criteria

Participants were recruited based on clearly defined inclusion and exclusion criteria to ensure homogeneity and reduce confounding. Individuals aged 18 years and above were eligible for inclusion. The case group comprised patients clinically diagnosed with knee pain of patellofemoral, tibiofemoral, or combined origin by an orthopedic surgeon. This diagnosis was based on history and physical examination findings such as localized pain, functional limitations, and clinical maneuvers (10). In contrast, the control group consisted of healthy age- and gender-matched volunteers who reported no current or past history of knee pain. All participants were required to provide written informed consent, indicating their willingness to voluntarily participate in the study.

Exclusion criteria were designed to eliminate confounding anatomical and pathological conditions. Individuals were excluded if they had a recent history of knee trauma, ligamentous injuries, or surgery within the past six months. Similarly, those with structural deformities of the lower extremities, such as genu varum, genu valgum, hip dysplasia, or foot abnormalities, were not considered. Additionally, patients with neurological disorders affecting lower limb function, such as stroke or peripheral neuropathy, were excluded to prevent gait alterations influencing knee biomechanics. Pregnant women were also excluded due to the requirement for radiographic imaging, which could pose fetal risk.

Variables and Operational Definitions

Operational definitions were employed to standardize data collection. Knee pain was defined as self-reported dull, aching, or sharp pain localized around the knee joint,

typically aggravated during activities involving weight-bearing or repetitive motion, such as walking or stair climbing (10). Patellofemoral Pain Syndrome (PFPS) was identified as anterior knee pain that worsens with activities like squatting, stair ascent/descent, or prolonged sitting with flexed knees—commonly referred to as the "movie-goer's sign" (11).

The quadriceps angle (Q angle) was measured to assess patellofemoral alignment. This angle is defined as the intersection between a line drawn from the anterior superior iliac spine (ASIS) to the center of the patella, and a second line extending from the center of the patella to the tibial tuberosity. A larger Q angle may indicate increased lateral tracking of the patella and is considered a potential risk factor for PFPS (6, 7).

Radiographic assessment involved standardized knee imaging, including anteroposterior (AP), lateral, and skyline (Merchant) views. Specific parameters included the sulcus angle, which reflects the depth of the femoral trochlear groove, and the congruence angle, which measures the medial or lateral displacement of the patella within the trochlear groove. Patella alta was diagnosed when the Insall-Salvati ratio exceeded 1.2, indicating a high-riding patella, which can alter patellofemoral biomechanics (8). Patellar tilt and lateral shift were evaluated as signs of maltracking or instability.

Measurement Tools and Instruments

Measurements were conducted using standardized tools to ensure accuracy and reproducibility. A long-arm goniometer was employed to assess the Q angle both in supine and standing positions, ensuring anatomical consistency. A flexible measuring tape was used to accurately locate anatomical landmarks such as the ASIS, patella, and tibial tuberosity. For radiological parameters, measurements were either taken manually using a protractor or digitally using specialized angle measurement software when digital radiographs were available. All data were recorded using a structured data collection sheet designed to capture demographic details, clinical symptoms, and radiographic findings comprehensively.

Data Collection Procedure

After obtaining institutional ethical approval, the study was initiated in the respective orthopedic departments. Eligible participants were identified and screened by a physiotherapist and orthopedic surgeon. After obtaining written informed consent, clinical assessments were performed to measure Q angle and anthropometric details. Radiographs were taken in a standardized manner by radiology technicians, and radiographic measurements were performed by a single examiner trained in musculoskeletal imaging to minimize inter-observer variability.

Data were anonymized and entered into a password-protected database by a trained research assistant. Quality control checks were conducted weekly to ensure consistency in data entry and measurement.

Ethical Considerations

Ethical clearance was obtained from the Institutional Human Ethics Committee prior to study initiation. All procedures conformed to the ethical standards of the Declaration of Helsinki (2013). Written informed consent was obtained from all participants. Confidentiality and anonymity of all collected data were strictly maintained.

Statistical Analysis

All data were analyzed using IBM SPSS version 22.0. Descriptive statistics were used to report means, standard deviations (SD), and frequencies. Normality of distribution was tested using the Shapiro-Wilk test. Between-group comparisons were made using the Independent Samples t-test for normally distributed variables and the Mann-Whitney U test for non-parametric data.

Categorical variables were compared using the Chi-square test. Pearson's or Spearman's correlation coefficients were calculated to assess associations between Q angle and pain

intensity (measured using the Numeric Pain Rating Scale). A p-value <0.05 was considered statistically significant.

RESULTS

Participants

A total of 200 participants were enrolled in the study. Of these, 100 participants were diagnosed with knee pain (experimental group), while the remaining 100 served as age- and gender-matched healthy controls (control group). There were no dropouts or exclusions after recruitment.

Demographic and Clinical Characteristics

The demographic characteristics of both groups are presented in Table 1. The mean age of participants in the experimental group was 47.03 ± 8.7 years, significantly higher than that of the control group (34.29 ± 6.05 years, $p < 0.001$). Gender distribution was similar across both groups, with no statistically significant difference ($p = 0.692$). The mean duration of knee pain in the experimental group was 1.26 ± 1.4 years.

Table 1. Demographic and Clinical Characteristics of Participants

Variable	Experimental Group (n = 100)	Control Group (n = 100)	p-value
Mean Age (years)	47.03 ± 8.7	34.29 ± 6.05	<0.001
Gender (M/F)	58 / 42	55 / 45	0.692
Pain Duration (years)	1.26 ± 1.4	N/A	–

Clinical Diagnosis in the Experimental Group

Within the experimental group, 52 participants (52%) were diagnosed with patellofemoral joint pain, 24 (24%) had tibiofemoral joint pain, and 24 (24%) had combined pain involving both compartments (Table 2).

Table 2. Distribution of Knee Pain Diagnosis in Experimental Group

Diagnosis Type	Frequency (n)	Percentage (%)
Patellofemoral Joint Pain	52	52%
Tibiofemoral Joint Pain	24	24%
Combined Pain	24	24%

Radiological Findings and Q Angle Alterations

The prevalence of anatomical deviations and alignment abnormalities was significantly higher in the experimental group compared to the control group for several parameters. Notably, patella alta, congruence angle, sulcus angle, patellar tilt, and patellar shift showed statistically significant differences ($p < 0.001$) as detailed in Table 3.

Although Q angle alteration was present only in the experimental group (5%) and absent in the control group, this difference did not reach statistical significance ($p = 0.059$).

Table 3. Comparison of Patellofemoral Alignment and Malalignment Features Between Groups

Variable	Control Group (%)	Experimental Group (%)	p-value
Q-angle alteration	0%	5%	0.059
Sulcus angle abnormality	11%	32%	<0.001
Congruence angle	18%	45%	<0.001
Patella alta	17%	51%	<0.001
Patella tilt (total)	4%	55%	<0.001
– Medial tilt	2%	20%	–
– Lateral tilt	2%	35%	–
Patella shift (total)	6%	30%	<0.001
– Medial shift	4%	18%	–
– Lateral shift	2%	12%	–

Correlation Analysis

Among patients with knee pain, increased Q angle was weakly but positively correlated with pain intensity (measured by VAS score) ($r = 0.32$, $p = 0.014$), and moderately correlated with the presence of lateral patellar tilt ($r = 0.45$, $p < 0.001$). These findings suggest a potential biomechanical link, though causality cannot be inferred.

DISCUSSION

Principal Findings

This cross-sectional observational study investigated the association between patellofemoral malalignment, Q angle variation, and the presence of knee pain in adult participants. The findings demonstrate a significantly higher prevalence of radiological markers of patellofemoral malalignment—including patella alta, increased congruence angle, abnormal sulcus angle, lateral patellar tilt, and lateral patellar shift—in individuals experiencing knee pain compared to matched controls. While the Q angle was increased in the knee pain group, the difference was not statistically significant. However, the Q angle showed a weak but statistically significant correlation with lateral patellar tilt and pain severity.

These findings suggest that while Q angle alone may not be a reliable standalone predictor of anterior knee pain, it still reflects aspects of lower limb alignment that contribute to patellofemoral biomechanics. More importantly, patellofemoral malalignment features measured radiologically appear to be more directly associated with pain symptoms, offering better diagnostic and therapeutic value.

Comparison with Prior Research

Our results are consistent with prior literature indicating a relationship between structural abnormalities of the patellofemoral joint and knee pain. Emami et al. (2007) reported significantly higher Q angles in patients with anterior knee pain, which they attributed to an increased lateral force vector acting on the patella (7). However, subsequent research, such as Freedman et al. (2014) and Kaya and Doral (2012), has challenged the clinical utility of the Q angle, citing poor correlation with dynamic patellar tracking and joint loading (6,8).

While our study found no statistically significant group difference in Q angle, the observed association between Q angle and patellar tilt supports the view that it may reflect underlying biomechanical imbalances, particularly when considered in combination with other parameters. Nguyen et al. (2009) demonstrated that increased Q angle correlates with altered tibiofemoral alignment and femoral anteversion, supporting the argument that multiple anatomical contributors affect patellar tracking and positioning (9).

Lateral patellar tilt and shift were significantly associated with knee pain in our study. These findings are clinically important because lateral maltracking of the patella increases patellofemoral joint stress, particularly during flexion activities like stair climbing and squatting (12). The resultant cartilage stress and overload can eventually contribute to cartilage degeneration and pain, especially in the context of pre-existing biomechanical vulnerability.

Patella alta, as observed more frequently in the symptomatic group, may delay patellar engagement with the femoral trochlea during knee flexion, increasing the risk of instability and maltracking (13). An increased sulcus angle (indicative of a flatter trochlear groove) and a higher congruence angle were also significantly associated with knee pain. These structural abnormalities may contribute to patellar instability, a known precursor to patellofemoral pain syndrome and early degenerative changes (14).

Clinical Implications

The findings emphasize the need for a comprehensive assessment of patellofemoral joint alignment, particularly in patients presenting with anterior knee pain. Clinicians often rely on Q-angle measurements in isolation, which may lead to underrecognition of more significant alignment issues. Radiographic evaluation of

patellar height (e.g., Insall-Salvati ratio), tilt, and shift should be incorporated into the diagnostic pathway, especially in chronic or refractory cases.

Rehabilitation strategies should focus not only on symptomatic relief but also on biomechanical correction. Strengthening of the quadriceps, particularly the vastus medialis obliquus (VMO), and hip stabilizers has been shown to improve patellar tracking and reduce pain in patients with patellofemoral disorders (12, 15). Patellar taping and neuromuscular re-education may further enhance outcomes by optimizing patellar alignment during movement.

Public Health Context

Knee osteoarthritis (OA), particularly among older adults and postmenopausal women, poses a significant public health burden in India. Prevalence estimates range from 18.3% to 33.2%, with higher rates observed in urban regions (2, 3). Biomechanical malalignment, such as patellofemoral abnormalities, may serve as early modifiable risk factors that precede symptomatic OA. Early identification and intervention in patients with alignment-related knee pain could delay the onset of degenerative joint disease and reduce disability and healthcare costs.

Moreover, awareness and prevention programs focusing on modifiable factors such as obesity, physical inactivity, and postural habits could complement clinical strategies aimed at preserving knee joint health in the Indian population (16).

Strengths and Limitations

A major strength of this study is its use of both clinical and radiological parameters to comprehensively assess patellofemoral alignment. The inclusion of a matched control group and standardized measurement techniques increases the internal validity of the findings.

However, several limitations must be acknowledged. The cross-sectional nature of the study precludes causal inferences between malalignment and knee pain. The sample was drawn from orthopedic clinics, which may limit generalisability to the broader community. Additionally, dynamic assessment tools such as motion analysis or real-time ultrasonography were not used, potentially overlooking dynamic misalignment during functional activities. Confounding factors such as physical activity level, BMI, and lower limb muscle strength were not controlled and should be considered in future studies.

Future Directions

Longitudinal studies incorporating dynamic assessment of patellar kinematics, muscle function, and patient-reported outcomes are needed to establish temporal relationships between patellofemoral malalignment and the development of knee pain or osteoarthritis. Furthermore, interventional trials testing targeted rehabilitation programs for individuals with identified malalignment could provide evidence for preventive strategies in high-risk populations.

CONCLUSION

This study highlights a significant association between patellofemoral malalignment and the presence of anterior knee pain in adults. Radiological parameters such as patella alta, increased congruence angle, abnormal sulcus angle, lateral patellar tilt, and lateral patellar shift were more prevalent among individuals with knee pain compared to healthy controls. Although the Q angle alone did not differ significantly between groups, its correlation with certain malalignment features suggests a limited but contributory role in reflecting underlying biomechanical imbalances.

These findings underscore the importance of a comprehensive evaluation of patellofemoral alignment in patients presenting with knee pain. Reliance solely on clinical measures like the Q angle may be inadequate. Radiographic assessment should be considered essential in diagnosing and planning management strategies for patellofemoral pain syndromes. Early identification of malalignment could enable

targeted interventions, such as corrective physiotherapy, neuromuscular training, and patient education, that may help prevent chronicity and long-term joint degeneration. Future research should aim to explore the dynamic aspects of patellofemoral kinematics, evaluate longitudinal outcomes, and assess the efficacy of alignment-specific rehabilitation approaches in diverse populations.

Declaration by Authors

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