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Relationship Between Clarke's Angle and Radiological Severity of Knee Osteoarthritis: A Cross-Sectional Study

Henoch Gugun Parulian Siahaan[1], Yusak Mangara Tua Siahaan[2], Tasya Meidy Pradhana[3]*
[1]Bethesda General Hospital, Serukam, Indonesia
[23]Siloam Hospital Lippo Village, Tangerang, Indonesia

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ABSTRACT

Introduction: Knee osteoarthritis (OA) is a degenerative joint disease causing disability, especially in older adults. Flatfoot, marked by reduced medial arch height, alters lower limb biomechanics and may influence knee OA severity. **Objective:** To evaluate the association between foot arch, measured by Clarke's angle, and knee OA severity based on the Kellgren-Lawrence (K-L) grading to provide clinical insight for guiding management decisions. **Methods:** A cross-sectional study of 57 knee OA patients at Siloam Karawaci Hospital was conducted. Clarke's angle was measured using ink footprints, and K-L grading assessed radiological severity. Statistical tests included Kolmogorov-Smirnov, one-way ANOVA, and Kruskal-Wallis, with $p < 0.05$ considered significant. **Results:** Most participants were female (77.2%) with a mean age of 65.85 ± 9.69 years. OA severity was mostly mild to moderate (K-L 2 and 3). Flatfoot prevalence was 47.4%, and lower Clarke's angles were significantly associated with higher K-L grades ($p = 0.029$). No significant differences in age or BMI were found across severity groups, though BMI trended higher with severity. **Conclusion:** Lower Clarke's angle correlates with increased knee OA severity. Flatfoot may contribute to or result from OA progression. Further research is needed to clarify causation and inform management strategies.

1. INTRODUCTION

Osteoarthritis (OA) is a progressive degenerative disease characterized by pain, swelling, and stiffness that interferes with daily activities.[1] The most frequently affected joints are the weight-bearing joints, such as the knees, hips, and sometimes the hands. [2] Therefore, knee osteoarthritis (KOA) is one of the main causes of global disability and the seventh leading cause of disability after age 70. As life expectancy and obesity increase, the prevalence of KOA continues to rise globally, impacting roughly 7.6% of the world's population. [3,4] Radiological imaging, particularly the Kellgren-Lawrence (K-L) classification system, plays a key role in diagnosing and assessing the severity of KOA. This system evaluates changes in articular cartilage, joint space narrowing, osteophytes, and other indicators of KOA progression.[1]

Foot posture plays an important role in both absorbing and dispersing pressure during walking, influencing the pattern of postural alignment throughout the lower extremities and sustaining normal joint movement. Posture and dynamic foot function are examples of mechanical alterations that aggravate lower limb musculoskeletal disorders. [5,6] Pes planus, more commonly known as flatfoot, is a condition characterized by the disappearance of the medial longitudinal arch in the foot, which can lead to changes in the foot's ability to absorb and distribute forces. [7] One commonly used measure to assess flatfoot is Clarke's angle (CA), which is known for its high sensitivity and specificity.[8] Clarke's angle is obtained by calculating the angle between the medial tangential line and the apex of the medial longitudinal arch concavity. [9] The loss of the medial arch

*Corresponding author
E-mail addresses: tasyameidy12@gmail.com

complex in flatfoot patients will lead to a decrease in foot stability, affecting the biomechanics of the lower leg and lumbar spine, thereby increasing the risk of pain and injury. A closed kinematic chain connects the foot and knee's posture and motion during weight-bearing exercises. Therefore, in individuals with flat feet, this kinematic coupling can lead to excessive knee rotation and damage to the medial cartilage.[10]

Several prior studies have reported a relationship between flatfoot and severity of KOA, both radiologically and clinically.[10–14] Zhang et al., for example, utilized the K-L grading system and a clinical severity score, revealing that the presence and severity of flatfoot were associated with joint degeneration, femorotibial misalignment, pain, stiffness, and functional limitations.[11] Other studies, such as those by Hakukawa and Patil, utilized Meary's angle to evaluate flatfoot and identified associations with increased KOA severity and poorer knee function. [13,14] Iijima et al. reported that bilateral flatfoot, measured via 3D footprint analysis, was significantly associated with increased knee pain.[12] Similarly, Cheng et al. also demonstrated that the presence of flatfoot significantly aggravated KOA-related symptoms, particularly pain.[10] Despite these findings, few studies have employed a combination of the K–L system with a simpler, more accessible method for evaluating foot posture. Most prior studies relied on advanced imaging or specialized equipment, which may not be easily applicable in routine clinical practice. This study seeks to address this gap by evaluating the variations in Clarke's angle across different KOA severity groups, as classified by the K-L system, to assess the potential link between foot posture and KOA progression. By combining these methods, this research offers a more practical approach for clinicians to assess and manage KOA. The findings may provide valuable insights for guiding clinical decisions, particularly in tailoring interventions to individual foot postures.

In pursuit of this aim, the study was conducted at Siloam Hospital Karawaci, a leading private hospital located in Tangerang, Indonesia. As part of the Siloam Hospitals Group and accredited by the Joint Commission International (JCI), it offers advanced diagnostic and therapeutic services. Its strong reputation in neurology, particularly in pain management, makes it a highly appropriate setting for this study, given its access to patients with musculoskeletal complaints such as KOA.

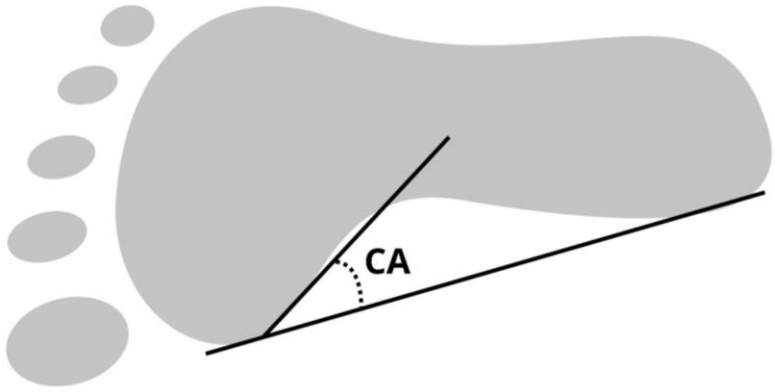
2. MATERIALS AND METHODS

This cross-sectional observational study was conducted at Siloam Lippo Karawaci Hospital and included 57 cooperative patients diagnosed with KOA, all of whom underwent radiological examinations of the knee. Patients were excluded from the study if they presented with knee deformities, autoimmune diseases such as rheumatoid arthritis and systemic lupus erythematosus, a history of trauma, or if they declined to participate.

Participants were recruited using a non-probability consecutive sampling technique from the neurology outpatient department at Siloam Karawaci General Hospital between November and December 2024. Although KOA is a musculoskeletal condition commonly managed by orthopedic and rehabilitation departments, participants were recruited from the neurology outpatient department due to the hospital's specialized pain management services, which are coordinated through the neurology clinic. This department frequently manages patients with chronic musculoskeletal pain, including those with KOA, making it a relevant setting for this study. A structured questionnaire was administered to collect demographic data, including information on gender, age, and the onset of knee pain. A physical examination was conducted to measure height and weight using a standardized digital scale, with Body Mass Index (BMI) calculated using the conventional Quetelet index, defined as body weight divided by height squared (kg/m^2).

To assess the CA, patients were instructed to step onto a water-soluble ink pad with the affected foot and then press it onto drawing paper that already bore their identification for ten seconds. This process was repeated until a clear footprint was obtained. The CA was then measured utilizing a pen, ruler, and stainless steel protractor, specifically analyzing the angle between the medial sole line and the deepest peak of the medial longitudinal arch (Figure 1). A Clarke Angle of ≤42° indicates flatfoot, while a value >42° represents a normal foot arch. [8]

Figure 1.
Measurement of the Clarke angle in flatfoot by calculating the angle between the line connecting the first metatarsal head to the heel and the line connecting the first metatarsal head to the highest point of the arch



A radiographic assessment of KOA severity was conducted using the K-L grading system, a standardized classification based on characteristic radiographic features. A blinded, experienced radiologist independently evaluated all radiographs to ensure consistency and accuracy in grading. This system categorizes KOA into five grades[15]:

1. Grade 0: Normal joint with no signs of osteoarthritis.
2. Grade 1: Possible small bone spurs (osteophytes) but no clear joint space narrowing
3. Grade 2: Definite osteophytes and possible joint space narrowing.
4. Grade 3: Moderate multiple osteophytes, definite joint space narrowing, and possible bone changes.
5. Grade 4: Severe osteoarthritis with large osteophytes, significant joint space narrowing, bone deformity, and sclerosis.

Statistical Analysis

IBM's Statistical Package for the Social Sciences (SPSS) software version 27 was utilized to process and analyze the collected research data. The Kolmogorov-Smirnov test was applied to evaluate the normality of the numerical data. For normally distributed variables, the mean and standard deviation were used to present univariate analysis. For non-normally distributed data, the median and interquartile range (IQR) were reported. Additionally, categorical variables were presented as frequencies and percentages. Bivariate analysis of the factors influencing the severity of KOA, as categorized by the K-L classification, was conducted using one-way Analysis of Variance (ANOVA) for normally distributed data and the Kruskal-Wallis test for non-normally distributed data. In this study, statistical significance was established with a two-tailed p-value of less than 0.05.

Research ethics

This study was conducted in accordance with ethical principles and was approved by the Ethics Committee of the Faculty of Medicine, Pelita Harapan University, under approval number 280/K-LKJ/ETIK/XI/2024. All responders voluntarily consented to participate after being informed of the study's objectives, methods, and benefits. Written informed consent was obtained from all responders before their inclusion in the study.

3. RESULTS

A total of 57 patients with KOA, predominantly female (77.2%), with an average age of 65.85 ± 9.69 years, were included, demonstrating an average weight of 61.18 ± 11.38 kg and height of 154.93 ± 7.69 cm. The median symptom onset duration was 12 months (IQR: 3.00, 24.00 months), with bilateral KOA being most common (56.1%), followed by right (24.6%) and left (19.3%) knee involvement. Most patients were classified as obese (54.4%) based on BMI, with smaller proportions in normal (24.6%), overweight (14.0%), and underweight (7.0%) categories. KOA severity, assessed via the K-L grading system, was primarily moderate (K-L 3: 38.6%) or mild (K-L 2: 36.8%), with fewer cases of early (K-L 1: 10.5%) or severe KOA (K-L 4: 14.0%). Foot posture, evaluated through CA mean: 39.22 ± 10.54 degrees, revealed that nearly half of the patients (47.4%) had flatfoot, suggesting a notable prevalence of abnormal foot posture that may influence knee alignment and joint function in this KOA population.

Table 1.
Demographic characteristics of the research population. (N=.57)

Subject characteristics	n	%
Age	65.85 ± 9.69	
Weight (kg)	61.18 ± 11.38	
Height (cm)	154.93 ± 7.69	
Body mass index	25.07 ± 5.33	
Onset duration (months), Median (IQR)	12.00 (3.00, 24.00)	
Gender		
Male	13	22.8
Female	44	77.2
Knee involvement		
Right	14	24.6
Left	11	19.3
Bilateral	32	56.1
Kellgren-Lawrence grade		
K-L 1	6	10.5
K-L 2	21	36.8
K-L 3	22	38.6
K-L 4	8	14.0
Clarke's angle (°)		
Flatfoot	27	47.4
Non- flatfoot	30	52.6

The demographic and clinical characteristics of the patients were analyzed across the four K-L KOA severity groups. There were no significant differences in age (p = 0.316), weight (p = 0.110), and height (p = 0.159) among the different K-L severity groups. However, a trend was observed toward increasing BMI with higher KOA severity, with patients in K-L 4 having the highest BMI (28.67 ± 4.43); however, this difference was not statistically significant (p = 0.067). A significant finding was observed in CA, where the angle decreased as the severity of KOA increased. Patients in the K-L 1 group had the highest CA (46.00 ± 7.87°), while patients in the K-L 4 group had the lowest (31.06 ± 8.65°), and this difference was statistically significant (p = 0.029).

Table 2.
Factors Influencing Knee Osteoarthritis Severity Based on the Kellgren-Lawrence. (N=.57)

Variable	Kellgren-Lawrence Severity				p-value
	KL 1 (n=6)	KL 2 (n=21)	KL 3 (n=22)	KL 4 (n=8)	
Age (years)	58.83 ± 9.76	65.05 ± 11.36	66.95 ± 8.95	67.75 ± 8.41	0.316
Weight (kg)	59.33 ± 12.31	56.91 ± 10.59	63.31 ± 11.01	66.75 ± 10.31	0.110
Height (cm)	159.33 ± 6.31	153.00 ± 6.29	156.45 ± 9.03	152.14 ± 5.63	0.159
BMI (kg/m^2)	23.39 ± 4.86	23.33 ± 6.29	25.88 ± 4.03	28.67 ± 4.43	0.067
Onset (months)	26.08	27.19	30.50	31.81	0.837
Clarke's angle (CA)	46.00 ± 7.87	41.43 ± 8.68	37.85 ± 11.62	31.06 ± 8.65	**0.029***

An asterisk (*) indicates statistical significance at the 0.05 level (α = 0.05)

4. DISCUSSION

KOA is a common degenerative joint disease characterized by the progressive deterioration of articular cartilage, leading to pain, stiffness, and functional impairment. Osteoarthritis was ranked seventh as the cause of years lived with disability (YLD), and the morbidity associated with KOA is significant, as it often results in decreased quality of life and increased disability, particularly among older adults. [16–18] The prevalence of OA globally rose by 113.25% and kept rising as life expectancy and obesity rates rose, according to statistics from the Global Burden of Disease. [19] This study revealed that the average age of the participants was 65.85 ± 9.69 years, with a predominantly female population (77.2% female vs. 22.8% male). This finding is consistent with prior research, which has shown that knee OA is most common in women and older adults, particularly those over the age of 60. [20–22] This trend may be attributed to several biological and biomechanical factors. In women, the decline of estrogen after menopause is known to reduce cartilage protection and accelerate joint degeneration.[23] In older adults, age-related cartilage wear, decreased regenerative capacity, and increased pro-inflammatory cytokines are key contributors to the onset and progression of KOA.[23,24]

The analysis revealed no statistically significant differences in demographic variables, including age, weight, height, BMI, or duration of onset, across the different K-L severity groups. However, there was a trend of increasing BMI with greater KOA severity, with patients in the K-L 4 group exhibiting the highest BMI (28.67 ± 4.43). Although this trend did not reach statistical significance (p = 0.067), it is consistent with prior evidence indicating a strong link between overweight or obesity and KOA. Overweight and obesity are strongly linked to an increased risk of KOA, with a systematic review showing that obesity elevates the risk by nearly threefold.[25,26] Overweight and obesity contribute to KOA through both mechanical and metabolic pathways. Mechanically, excess body weight increases joint loading, particularly in weight-bearing joints such as the knees. It is estimated that each additional kilogram of body weight adds approximately four kilograms of pressure on the knee joint during ambulation, accelerating cartilage degradation and joint stress. [27] Moreover, adipose tissue releases pro-inflammatory cytokines such as IL-6, TNF-α, and leptin, which contribute to joint inflammation and cartilage degradation. [28,29]

A key aim of this study was to evaluate the relationship between KOA severity and foot posture, specifically using the CA as a metric. Our analysis revealed a statistically significant inverse association between CA and the K-L grade severity. Patients in the K-L 1 group showed the highest CA (46.00 ± 7.87°), while those in the K-L 4 group exhibited the lowest (31.06 ± 8.65°), with this difference being statistically significant (p = 0.029). This suggests that foot posture, as indicated by CA, may play a role in the progression of KOA, either as a contributing factor or as a compensatory adaptation to joint degeneration.

The relationship between foot posture and KOA severity is supported by existing literature. Several prior studies demonstrated a substantial association between the existence and severity of flatfoot with the severity of KOA, both clinically and radiologically (based on K-L grading). [10–14] Additional studies, including those by Reilly et al., Abourazzak et al., and Pazit et al., have reported that individuals with KOA are more likely to exhibit pronated foot postures compared to those without KOA. [30–32]

The relationship between foot posture and KOA is well-documented. However, the underlying mechanisms remain unclear, particularly regarding whether flatfoot posture serves as a contributing risk factor or a compensatory adaptation to the joint changes associated with KOA. As a contributing risk factor, flatfoot posture may influence the progression of KOA through biomechanical alterations. The biomechanics of the foot allow it to absorb and transfer forces from the ground. The ground reaction force passes through the forefoot and is directed toward the medial and central portions of the knee. Therefore, alterations in foot rotation, particularly medial or lateral disturbances, may influence knee kinetics. In the case of flatfoot, the loss of the medial longitudinal arch, characterized by forefoot abduction and hindfoot eversion, may accelerate KOA severity. [33–36] One hypothesis suggests that foot pronation reduces the knee adduction moment, which may redistribute joint loads to alleviate stress on specific compartments.[37,38] However, this redistribution can simultaneously increase cartilage stress, promoting degeneration. Conversely, flatfoot posture may represent a compensatory adaptation to the changes associated with OA. Patients with KOA frequently develop genu varum malalignment, which disrupts normal lower-limb biomechanics. [39–41] To maintain a plantigrade posture during weight-bearing activities, the foot compensates by pronating.

Our study suggests that addressing flatfoot deformity using orthoses in combination with an unloader knee brace, which is now widely used in clinical practice, may help alleviate KOA symptoms by optimizing lower limb biomechanics and redistributing joint loads. Additionally, our study reveals a significant inverse relationship between CA and KOA severity, indicating that flatter foot postures are linked to more advanced disease stages. Although orthoses may improve the knee varus angle, their effectiveness in relieving pain and restoring function remains inconsistent.[42] However, adding custom arch support to a standard lateral wedge insole may enhance foot and knee symptom relief [43], as the custom arch support helps in better aligning the foot's biomechanics, reducing overpronation, and redistributing forces more effectively. This improved alignment not only relieves stress on the foot but also reduces abnormal loading on the knee joint, potentially alleviating symptoms of KOA[44]. Similarly, the unloader knee brace reduces the knee adduction moment (KAM), thereby promoting more balanced load distribution across the knee joint. This adjustment helps improve joint alignment and may reduce stress on the affected compartment. Although pain reduction has been observed with the use of knee braces, their impact on functional outcomes and joint stiffness remains variable and warrants further investigation.[45,46]

This study has several limitations that should be considered when interpreting the results. First, the cross-sectional design prevents the establishment of causality between foot posture and KOA. Longitudinal studies are necessary to determine whether foot posture acts as a contributing risk factor or compensatory adaptation over time. Although CA is a well-established method to assess foot posture, it remains a subjective measure influenced by examiner technique and patient positioning. However, to minimize this limitation, all assessments in this study were performed by a single clinician following a standardized protocol to ensure consistency. Future studies should include more objective and quantitative assessments of foot posture, such as 3D scanning or pressure mapping.

Additionally, while an experienced radiologist performed radiographic grading to ensure validity, the study did not control for physical activity levels, comorbidities, or footwear history, which may influence both foot posture and KOA progression. The relatively small sample size may also limit the generalizability. Despite these limitations, the study offers valuable insights into the potential relationship between foot posture and knee osteoarthritis (KOA). The findings have important clinical implications, particularly for early screening and biomechanical interventions, which can be easily implemented in clinical settings. By highlighting the association between foot

posture and KOA severity, this study contributes to a deeper understanding of modifiable factors in KOA management..

5. CONCLUSION

In conclusion, the significant relationship between CA and the severity of KOA, as measured by the K-L grading system, highlights the importance of considering foot posture in the management of KOA. This study suggests that flatfoot posture may play a dual role, both as a contributing risk factor and a compensatory adaptation to OA-related joint changes. While flatfoot may exacerbate knee loading and accelerate disease progression, it also serves as an adaptive mechanism to maintain stability in the presence of joint malalignment.

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