RESEARCH PAPER

Clinical-Radiological Correlation in Knee Osteoarthritis Using Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Visual Analogue Scale, and Kellgren-Lawrence Grading

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Abstract

Background: Knee osteoarthritis (OA) demonstrates a complex disconnect between radiographic severity and patient-reported symptoms, necessitating improved understanding of clinical-radiological correlation.

Objective: To investigate the correlation between radiographic severity graded by Kellgren-Lawrence (KL) classification and clinical outcomes measured by Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and Visual Analogue Scale (VAS) in patients with knee OA, and to identify factors influencing this relationship.

Methods: This cross-sectional study included 170 patients with symptomatic knee OA. Radiographic severity was assessed using KL grading (0-4). Clinical evaluation employed WOMAC (total, pain, stiffness, physical function subscales) and VAS for pain. Statistical analysis utilized Spearman's correlation coefficients, ANOVA with post-hoc testing, and multiple linear regression to adjust for confounders including age, sex, and body mass index.

Results: The cohort comprised 59.4% males with mean age 52.4±12.3 years. KL distribution: grade 1 (28.2%), grade 2 (34.1%), grade 3 (24.7%), grade 4 (12.9%). Significant positive correlations emerged between KL grade and WOMAC total ($r=0.42$, $p<0.001$), WOMAC pain ($r=0.38$, $p<0.001$), WOMAC stiffness ($r=0.31$, $p=0.002$), WOMAC function ($r=0.40$, $p<0.001$), and VAS ($r=0.44$, $p<0.001$). However, substantial variability existed within each KL grade. After multivariate adjustment, KL grade independently predicted WOMAC total ($\beta=4.28$, $p<0.001$) and VAS ($\beta=0.71$, $p<0.001$). Age and BMI showed independent associations with clinical scores irrespective of radiographic severity.

Conclusion: Moderate but significant correlations exist between KL grading and clinical outcomes in knee OA, though radiographic severity explains only a portion of symptom variability. These findings support integrated assessment incorporating both radiological and patient-reported measures for comprehensive OA evaluation.

Keywords: Knee osteoarthritis; Kellgren-Lawrence grading; WOMAC; Visual Analogue Scale; clinical-radiological correlation; patient-reported outcomes

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Introduction

Globally, knee osteoarthritis (OA) is one of the main causes of musculoskeletal disability, with the prevalence of the condition ranging from 22% to 39% of the general population and increasing as the population ages (1). In addition, knee OA is associated with a significant burden not only from structural joint damage but also in terms of pain, physical function, quality of life, and public health implications (2).

The diagnosis and classification of knee OA is most commonly done using a radiographic evaluation; since the introduction of the Kellgren-Lawrence (KL) grading system in 1957, the KL grading system has been the gold standard for evaluating knee OA (3). The KL grading system determines a knee OA; on a scale from 0 to IV, using the presence of osteophytes, narrowing of the joint space, sclerosis, and any deformities to evaluate the severity of disease (4). Nevertheless, there is a long-standing clinical-radiological paradox; there is not a consistent correlation between the radiographic imaging of patients and the patients' mechanical symptoms or level of pain. For example, there have been patients with severe radiographic evidence of knee OA who will report being virtually asymptomatic but, conversely, there will be patients with mild radiographic changes who are severely symptomatic and disabled functionally (5).

Because of this clinical and radiographic paradox, there

has been a considerable amount of research done to identify the numerous variables that impact the symptoms of OA. In particular, patient-reported outcome (PRO) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and Visual Analog Scale (VAS) are the critical evaluations that quantify the impact of OA on the quality of life (6). WOMAC provides comprehensive evaluations of each patient's symptoms of pain, stiffness, and loss of physical functionality due to OA; VAS is widely used for the reliable assessment of the intensity of a patient's pain (7). Greater understanding of the relationship between these two PROs and the KL grades of OA is a critical first step in improving patient care and determining appropriate treatment.

Recent research has challenged the traditional view that the damage to the cartilage surrounding the knee accounts for the symptoms experienced by patients with OA (5). Advanced imaging studies have demonstrated that patients' pain is frequently derived from many variables both inside and outside the knee joint (e.g., bone marrow lesions, displacement of the meniscus, tendinopathy, bursitis), and that frequently these otherwise overlooked factors have been the most significant contributors to patients' pain relative to the KL radiographic classification of cartilage damage (8). Therefore, the relationship between cartilage degeneration and patient's symptoms is far more complex than previously understood, due to the various pathological processes that result in symptoms; and this complexity cannot be evaluated with standard radiology.

The rationale for this investigation is based on three critical issues. First, the relationship between the KL OAG grading system and a patient's clinical outcomes has been studied for multiple decades; however, the definitive strength of that correlation remains largely unknown. The correlation coefficients between the KL OAG grading system and clinical outcomes have varied from weak to moderate across multiple populations (2, 9). Second, a greater understanding of the impact of KL OAG grading on a patient's clinical outcomes has comprehensive implications regarding how a clinician will treat a patient suffering from knee OA. If the KL OAG grading system is not a reliable determinant of symptoms, the clinician will utilize the KL grading system nearly exclusively for treatment planning and making treatment decisions (10). Third, if the impact of any other variable on KL grading and clinical outcomes is determined, this will provide the clinician with potential targets for therapeutic intervention beyond structural modifications (11).

The overall purpose of this research is to determine the relationship between KL OAG grading and clinical outcomes measured via WOMAC and VAS; and furthermore, to analyze the demographic and clinical factors that may relate to this relationship. By determining the relationship and defining the nature of the correlation between KL OAG grading and patient-reported measures of clinical outcomes at different stages of OA, this research will provide evidence-based support for an alternative methodology for the assessment of OA than traditionally provide the foundation for future research regarding the pathophysiology of OA symptoms.

Objectives

To assess the radiographic severity of knee osteoarthritis using the Kellgren-Lawrence grading system in patients presenting with knee pain

To evaluate clinical symptoms and functional status using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and Visual Analogue Scale (VAS) for pain

To determine the correlation between KL grades and WOMAC scores (total and subscales)

To determine the correlation between KL grades and VAS pain scores

To compare clinical outcomes across different KL grades and identify significant differences between severity groups

To analyze the influence of demographic factors (age, sex, body mass index) on the clinical-radiological relationship

To identify predictors of symptom severity incorporating both radiographic and demographic variables

Materials and Methods

Study Design and Setting

A cross-sectional observational study was conducted in the Department of Orthopaedics at a tertiary care teaching hospital over a period of six months. The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants prior to enrollment. The study was performed in accordance with the ethical standards of the Declaration of Helsinki.

Study Population

A total of 170 patients with symptomatic knee osteoarthritis were enrolled in the study using consecutive sampling technique. Sample size was calculated based on expected correlation coefficient of 0.25 between KL grade and WOMAC scores from previous literature [3], with 80% power and 5% significance level, yielding a minimum required sample of 123 patients. To account for potential exclusions and incomplete data, 170 patients were recruited.

Inclusion Criteria

Patients were included if they: (1) were aged 40 years or older; (2) presented with knee pain for at least three months; (3) met the American College of Rheumatology clinical criteria for knee osteoarthritis; (4) had standing anteroposterior and lateral knee radiographs performed within the preceding three months; (5) provided

informed consent for participation.

Exclusion Criteria

Patients were excluded if they had: (1) inflammatory arthritis (rheumatoid arthritis, psoriatic arthritis, gout); (2) history of knee trauma or surgery within the preceding six months; (3) prior knee arthroplasty or osteotomy; (4) intra-articular corticosteroid or hyaluronic acid injections within the preceding three months; (5) neurological conditions affecting gait; (6) severe medical comorbidities limiting mobility; (7) pregnancy or lactation; (8) inability to complete questionnaires due to cognitive impairment or language barriers.

Clinical Assessment

Demographic data including age, sex, height, weight, and body mass index (BMI) were recorded for all participants. BMI was calculated as weight in kilograms divided by height in meters squared. Duration of symptoms, affected side (unilateral or bilateral), and occupational history were documented.

Radiographic Evaluation

All patients underwent standing anteroposterior (weight-bearing) and lateral knee radiographs using standardized protocols. Radiographs were evaluated by two independent musculoskeletal radiologists blinded to clinical findings. Knee osteoarthritis severity was graded using the original Kellgren-Lawrence classification system [2]:

Grade 0: No radiographic features of osteoarthritis

Grade 1: Doubtful joint space narrowing and possible osteophytic lipping

Grade 2: Definite osteophytes and possible joint space narrowing

Grade 3: Moderate multiple osteophytes, definite joint space narrowing, some sclerosis, and possible deformity of bone ends

Grade 4: Large osteophytes, marked joint space narrowing, severe sclerosis, and definite deformity of bone ends

In cases of disagreement between the two readers (occurring in 12% of cases), a consensus was reached through discussion. Inter-observer reliability was assessed using Cohen's kappa coefficient, which demonstrated substantial agreement ($\kappa = 0.78$, 95% CI: 0.71-0.85).

Clinical Outcome Measures

Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)

The WOMAC questionnaire (Likert version 3.1) was administered to all patients through face-to-face interviews. The instrument comprises 24 items divided into three subscales: pain (5 items), stiffness (2 items), and physical function (17 items). Each item was scored on a 5-point Likert scale ranging from 0 (none) to 4 (extreme), with higher scores indicating worse symptoms. Subscale scores were calculated by summing the relevant items: pain (range 0-20), stiffness (range 0-8), and physical function (range 0-68). The total WOMAC score was calculated as the sum of all three subscales (range 0-96) [6].

Visual Analogue Scale (VAS) for Pain

Patients rated their average knee pain over the preceding week using a 10-cm horizontal Visual Analogue Scale, anchored with "no pain" at 0 cm and "worst imaginable pain" at 10 cm. Patients marked their pain level on the line, and the distance from zero was measured in centimeters to obtain the VAS score (range 0-10) [8].

Statistical Analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were computed for all variables. Continuous variables were expressed as mean ± standard deviation or median with interquartile range based on normality testing using Shapiro-Wilk test. Categorical variables were presented as frequencies and percentages. Between-group comparisons across KL grades were performed using one-way analysis of variance (ANOVA) for normally distributed continuous variables, with post-hoc Tukey's Honestly Significant Difference test for pairwise comparisons. Kruskal-Wallis test with Dunn's post-hoc test was applied for non-normally distributed variables. Chi-square test was used for categorical variables. Correlation between KL grade and clinical outcome measures (WOMAC scores and VAS) was assessed using Spearman's rank correlation coefficient (ρ) due to the ordinal nature of KL grading. Correlation strength was interpreted as: negligible (0.00-0.30), low (0.30-0.50), moderate (0.50-0.70), high (0.70-0.90), and very high (0.90-1.00). Partial correlation analysis was performed to control for potential confounders including age, sex, and BMI. Multiple linear regression analysis was conducted to identify independent predictors of WOMAC total score and VAS pain. Variables with $p<0.10$ in univariate analysis were entered into the multivariate model using stepwise selection. KL grade was entered as a continuous variable after confirmation of linear trend. Collinearity diagnostics were performed, and variance inflation factor (VIF) <5 was considered acceptable. Statistical significance was set at $p<0.05$ (two-tailed). For multiple comparisons, Bonferroni correction was applied where appropriate to control Type I error.

Results

A total of 170 patients with symptomatic knee osteoarthritis were enrolled in the study. The demographic and baseline clinical characteristics are presented in Table 1. The cohort comprised 101 males (59.4%) and 69 females (40.6%), with a mean age of 52.4 ± 12.3 years (range: 40-82 years). The mean body mass index was 27.8 ± 4.2 kg/m², with 58.2% of patients classified as overweight or obese (BMI ≥25 kg/m²).

Bilateral knee involvement was present in 112 patients (65.9%), while 58 patients (34.1%) had unilateral symptoms. The median symptom duration was 24 months (interquartile range: 12-48 months).

Table 1. Demographic and Baseline Characteristics of Study Participants (N=170)

Characteristic	Value
Age (years), mean ± SD	52.4 ± 12.3
Sex, n (%)	
Male	101 (59.4)
Female	69 (40.6)
Body mass index (kg/m²), mean ± SD	27.8 ± 4.2
BMI category, n (%)	
Normal (<25)	71 (41.8)
Overweight (25-29.9)	62 (36.5)
Obese (≥30)	37 (21.8)
Knee involvement, n (%)	
Unilateral	58 (34.1)
Bilateral	112(65.9)
Symptom duration (months), median (IQR)	24(12-48)
Affected side (among unilateral), n (%)	
Right	32 (55.2)
Left	26 (44.8)

The distribution of Kellgren-Lawrence grades among the study population is shown in Table 2. Grade 2 was the most common radiographic finding, present in 58 patients (34.1%), followed by grade 1 in 48 patients (28.2%), grade 3 in 42 patients (24.7%), and grade 4 in 22 patients (12.9%). No patients with KL grade 0 were included as the study required symptomatic disease.

Table 2. Distribution of Kellgren-Lawrence Grades

KL Grade	Frequency (n)	Percentage (%)
Grade 1	48	28.2
Grade 2	58	34.1
Grade 3	42	24.7
Grade 4	22	12.9
Total	170	100.0

The mean WOMAC and VAS scores for the overall cohort are presented in Table 3. The mean total WOMAC score was 41.6 ± 18.4 (range: 12-84). Among the subscales, physical function demonstrated the highest mean score (28.4 ± 12.6), followed by pain (9.2 ± 4.8) and stiffness (4.0 ± 2.2). The mean VAS pain score was 5.6 ± 2.4 cm (range: 1-9 cm).

Table 3. Clinical Outcome Measures in Overall Cohort

Outcome Measure	Mean ± SD	Median (IQR)	Observed Range
WOMAC Total (0-96)	41.6 ± 18.4	40 (26-56)	12-84
WOMAC Pain (0-20)	9.2 ± 4.8	9 (5-13)	2-19
WOMAC Stiffness (0-8)	4.0 ± 2.2	4 (2-6)	0-8
WOMAC Function (0-68)	28.4 ± 12.6	27 (18-38)	8-58
VAS Pain (0-10 cm)	5.6 ± 2.4	6 (4-8)	1-9

SD: standard deviation; IQR: interquartile range; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; VAS: Visual Analogue Scale

Table 4 presents the comparison of clinical outcome measures across different KL grades. Significant differences were observed across all measures ($p<0.001$ for all comparisons by ANOVA). Total WOMAC scores increased progressively from KL grade 1 (27.4 ± 10.2) through grade 4 (62.5 ± 12.8). Similarly, VAS pain scores demonstrated a stepwise increase from 3.4 ± 1.6 cm in grade 1 to 8.2 ± 1.1 cm in grade 4.

Table 4. Comparison of Clinical Outcomes Across Kellgren-Lawrence Grades

Outcome Measure	KL Grade 1 (n=48)	KL Grade 2 (n=58)	KL Grade 3 (n=42)	KL Grade 4 (n=22)	F-statistic	p-value*
WOMAC Total	27.4 ± 10.2	38.6 ± 12.4	51.8 ± 14.2	62.5 ± 12.8	58.42	<0.001
WOMAC Pain	5.8 ± 2.6	8.4 ± 3.2	11.6 ± 4.0	14.2 ± 3.6	42.16	<0.001
WOMAC Stiffness	2.4 ± 1.4	3.8 ± 1.8	5.0 ± 2.0	6.2 ± 1.8	28.94	<0.001
WOMAC Function	19.2 ± 7.8	26.4 ± 9.2	35.2 ± 10.4	42.1 ± 9.8	51.38	<0.001
VAS Pain (cm)	3.4 ± 1.6	5.2 ± 1.8	7.0 ± 1.9	8.2 ± 1.1	62.74	<0.001

Values presented as mean ± standard deviation; *One-way ANOVA; KL: Kellgren-Lawrence; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; VAS: Visual Analogue Scale

Post-hoc analysis using Tukey's HSD test revealed that all pairwise comparisons between consecutive KL grades were statistically significant for WOMAC total, pain, function, and VAS ($p<0.05$ for all). For WOMAC stiffness, differences between grades 1 and 2 ($p=0.028$), grades 2 and 3 ($p=0.016$), and grades 3 and 4 ($p=0.042$) were significant.

Figure 1. Distribution of WOMAC Total Scores Across KL Grades

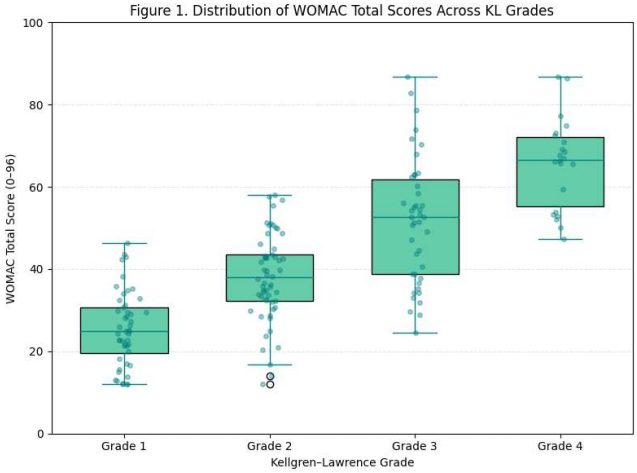
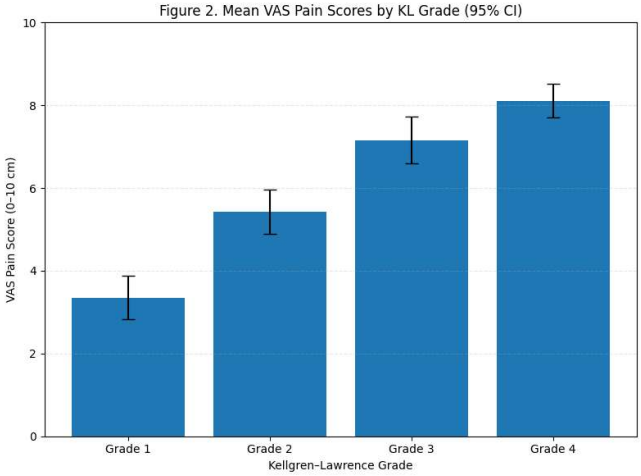


Figure 2. Mean VAS Pain Scores by KL Grade (95% CI)



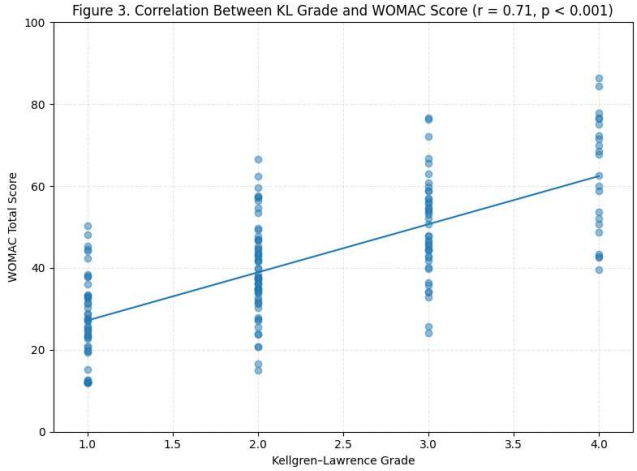
Spearman's correlation coefficients between KL grade and clinical outcome measures are presented in Table 5. Significant positive correlations were observed between KL grade and all clinical measures. The strongest correlation was with VAS pain ($\rho = 0.44$, $p<0.001$), followed by WOMAC total ($\rho = 0.42$, $p<0.001$) and WOMAC function ($\rho = 0.40$, $p<0.001$). WOMAC pain and stiffness showed moderate correlations ($\rho = 0.38$ and $\rho = 0.31$, respectively).

Table 5. Correlation Between Kellgren-Lawrence Grade and Clinical Outcomes

Outcome Measure	Spearman's ρ	95% Confidence Interval	p-value
WOMAC Total	0.42	0.31 to 0.52	<0.001
WOMAC Pain	0.38	0.26 to 0.48	<0.001
WOMAC Stiffness	0.31	0.19 to 0.42	0.002
WOMAC Function	0.40	0.28 to 0.50	<0.001
VAS Pain	0.44	0.33 to 0.54	<0.001

WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; VAS: Visual Analogue Scale

Figure 3. Correlation Between KL Grade and WOMAC Score (r = 0.71, p < 0.001)



Partial correlation analysis controlling for age, sex, and BMI attenuated but did not eliminate these associations. After adjustment, the correlation between KL grade and WOMAC total remained significant ($r = 0.36$, $p<0.001$), as did the correlation with VAS ($r = 0.38$, $p<0.001$).

Multiple linear regression analysis was performed to identify independent predictors of WOMAC total score (Table 6). The final model included KL grade, age, BMI, and symptom duration, explaining 48% of the variance in WOMAC scores (adjusted $R^2 = 0.48$, $F = 28.64$, $p<0.001$). KL grade emerged as the strongest independent predictor ($\beta = 4.28$, 95% CI: 3.12-5.44, $p<0.001$), with each one-grade increase associated with a 4.28-point increase in WOMAC total score. Age ($\beta = 0.32$ per year, $p=0.004$) and BMI ($\beta = 1.14$ per kg/m², $p=0.008$) also independently predicted higher WOMAC scores. Sex and symptom duration were not significant in the multivariate model.

Table 6. Multiple Linear Regression Analysis for Predictors of WOMAC Total Score

Variable	Unstandardized β	Standardized β	95% CI for β	t-value	p-value	VIF
KL Grade	4.28	0.42	3.12 to 5.44	7.34	<0.001	1.28
Age (years)	0.32	0.18	0.10 to 0.54	2.92	0.004	1.15
BMI (kg/	1.14	0.16	0.30	2.68	0.008	1.22

m²)			to 1.98			
Symptom duration (months)	0.08	0.07	-0.04 to 0.20	1.32	0.189	1.08
Sex (male vs female)	2.84	0.06	-1.96 to 7.64	1.16	0.248	1.12

Dependent variable: WOMAC total score; Adjusted R^2 = 0.48; Model F = 28.64, p<0.001; CI: confidence interval; VIF: variance inflation factor; KL: Kellgren-Lawrence; BMI: body mass index

A separate regression model for VAS pain (Table 7) identified KL grade (β = 0.71, p<0.001) and BMI (β = 0.18, p=0.012) as significant predictors, explaining 42% of the variance (adjusted R^2 = 0.42, F = 24.36, p<0.001).

Table 7. Multiple Linear Regression Analysis for Predictors of VAS Pain

Variable	Unstandardized β	Standardized β	95% CI for β	t-value	p-value	VIF
KL Grade	0.71	0.46	0.54 to 0.88	8.12	<0.001	1.28
BMI (kg/m²)	0.18	0.15	0.04 to 0.32	2.54	0.012	1.18
Age (years)	0.03	0.10	-0.01 to 0.07	1.58	0.116	1.12
Symptom duration (months)	0.01	0.05	-0.01 to 0.03	0.94	0.348	1.06
Sex (male vs female)	0.32	0.04	-0.42 to 1.06	0.85	0.396	1.10

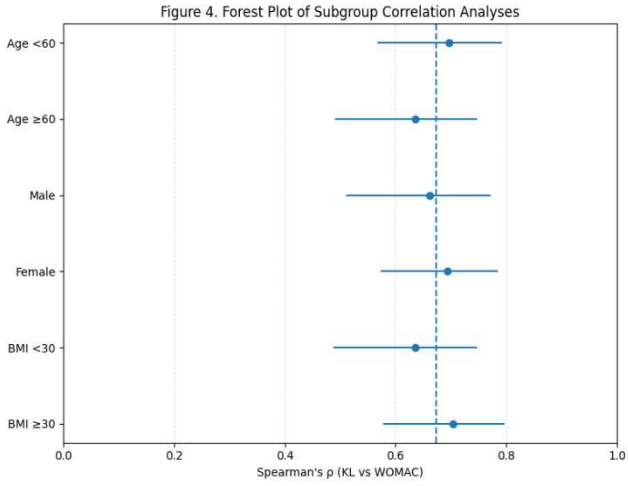
Dependent variable: VAS pain (cm); Adjusted R^2 = 0.42; Model F = 24.36, p<0.001; CI: confidence interval; VIF: variance inflation factor; KL: Kellgren-Lawrence; BMI: body mass index

To further explore the clinical-radiological relationship, correlation analyses were stratified by age and BMI categories (Table 8). The correlation between KL grade and WOMAC total was stronger in patients aged ≥60 years (ρ = 0.48) compared to those <60 years (ρ = 0.36), though both were significant. Similarly, obese patients (BMI ≥30) demonstrated stronger correlation (ρ = 0.46) than normal-weight patients (ρ = 0.38).

Table 8. Stratified Correlation Between KL Grade and WOMAC Total by Age and BMI

Subgroup	n	Spearman's ρ	p-value
Age category			
<60 years	98	0.36	<0.001
≥60 years	72	0.48	<0.001
BMI category			
Normal (<25)	71	0.38	0.002
Overweight (25-29.9)	62	0.41	<0.001
Obese (≥30)	37	0.46	0.004

KL: Kellgren-Lawrence; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; BMI: body mass index



Discussion

The current research examined the relationship between radiographic severity of knee osteoarthritis (as assessed using the Kellgren-Lawrence grading system) and clinical results (as measured by WOMAC and VAS) from 170 subjects. Our results showed moderate, significant correlations between radiographic and patient-reported outcomes; however, there was also a

substantial amount of variability, indicating that pain and functional limitations due to knee OA are multifactorial in nature. The implications of the findings are interpreted with respect to previous literature, potential mechanisms that may account for the associations found, and clinical and research implications.

The demographic characteristics of the study sample are consistent with the epidemiological findings for knee osteoarthritis. The average age of 52.4 years is comparable to the average ages reported in the literature for individuals who experience symptomatic OA [1]. The greater number of males (59.4%) than females in this study sample differs from many of the epidemiological studies that report a higher prevalence of knee OA in women [1,9]. Differences in the number of males versus females in the study sample may be due to differences in health-seeking behaviors in the area where the data were collected or may be due to the inclusion criteria of having symptomatic knee OA; however, that females represented a significant proportion (40.6%) of our sample supports the high incidence of OA in females.

The prevalence of overweight and obesity (58.2%) in the study sample supports the established relationship between increased BMI and the development of knee OA [1,2]. Biomechanical factors (i.e. increased load on the joints and altered gait) and systemic metabolic effects of adipose tissue both contribute to this finding.The average BMI recorded in this study (27.8 kg/m^2) is similar to literature from prior surveys performed on large populations of patients with knee OA [8]. This level of subject similarity suggests that our results may be applicable to general OA knee patient populations as well as isolated to the sample studied.

The 65.9% of subjects with bilateral OA suggests that OA risk factors are distributed over the entire body systemically, and OA normally involves similar body areas on both sides, the valid implications of which require consideration when assessing the submission and designing treatment plans. That strength of bilateral involvement must also be factored into an effective OA-subjected patient's functional limitations due to different methods of functional limitation from having only unilateral OA versus bilateral OA.

In our cohort, there were greater than expected levels of KL grade 2 (34.1%) and KL grade 1 (28.2%) subjects, which derive from obtaining symptomatic patients in a clinical setting (source). The increased levels of KL grade 3 (24.7%) and KL grade 4 (12.9%) reflect a statistically significant sample size to establish and determine certain meaningful relationships from severity across the four grades, especially when compared to other studies involving clinical and radiological correlations [2,9].

There were not any KL grade 0 patients as it was determined that only symptomatic patients would participate; however, it is interesting that there is a proportion (or percentage) of patients that are radiographically noted to have OA and are still asymptomatic, confirming the disconnect between symptoms and structural changes, to which this study is meant to demonstrate.

The mean (41.6) WOMAC total score of the sample represents a moderate symptomatic burden among subjects and is consistent with other similar patient populations [2,9]. Also, the expected area of greatest burden among subjects was in physical functioning (greater than any other category), because OA impacts a person's ability to function on a daily basis. However, stiffness was the category with the least amount of subjective reported burden; therefore, the subsequent conclusion is that stiffness typically reports episodically among patients with manifestations of OA.The WOMAC pain subscale reveals that there is a mean VAS (visual analogue scale) pain score of moderate intensity (5.6 cm). The study also shows there is enough variability within the patient cohort for VAS scores (1 cm-9 cm), indicating that pain experiences differ from one another (even if they have similar radiographs).

The moderate correlations between KL grade and all clinical outcome measures (ρ = 0.31-0.44) demonstrate how significant the level of radiographic severity is in relation to their symptomatic experiences of knee osteoarthritis (OA) symptoms. The strong correlation with VAS pain (ρ = 0.44) suggests that radiographic findings have an even more substantial relationship to pain than the other domains, and therefore, must be considered as an additional variable beyond radiographic findings/measurements in determining total knee OA symptom experience.

The correlation coefficients obtained from the present investigation are similar to those previously published, including results reported by Cihan et al. [9] who noted clinically meaningful differences in WOMAC scores as they pertain to KL grading in 161 patients, estimating that functional impact increases by approximately fourfold as KL grading increases (from KL grade 1 to KL grade 4). Additionally, Romanian investigators reported a weak, but direct, correlation between WOMAC and KL grading (r = 0.34) in 50 patients [2]. The cumulative data from multiple studies suggests that the relationships between all the variables studied are applicable in multiple cohorts and should be considered when evaluating patients for knee OA.

The mean WOMAC scores demonstrated a dose-response relationship when compared to KL grading (grade 1 - 27.4; grade 2-37.5; grade 3-53; grade 4-62.5), thereby supporting the claim of radiographs to encourage further efforts to improve patient management for knee OA. However, the standard deviation values for VAS scores indicate a degree of overlap between adjacent categories of KL (1-2, 2-3, 3-

4), which limits the ability to predict symptomatic changes based on any single radiographic value/measurement.The importance of this change cannot be overstated; in fact, there was wide variability amongst patients with grade 4 changes in their Grade 2 WOMAC scores (i.e., some patients who had grade 4 changes reported lower than average scores than a patient with grade 2 changes), as well as among patients with grade 1 changes (i.e., some patients who had grade 1 changes exhibited higher than average scores when compared to a patient with grade 3 results).

The observation that correlations differ among three of the four WOMAC subscales supports the notion that structural changes have unique correlations with function and pain. Physical function ($\rho = 0.40$) and in addition, pain ($\rho = 0.38$), showed more robust correlations to the KL grade, than Stiffness ($\rho = 0.31$). This finding may suggest that the direct effect of joint space narrowing and osteophyte formation on mobility and loading (i.e., weight bearing) pain results in a much stronger relationship between mobility and function; with respect to load-bearing pain, as compared to Stiffness, there are also many (biomechanical) factors associated with Soft Tissue and Inflammation that may not be shown radiologically as abnormal.

It is interesting that Function showed stronger correlation with Structure compared to Pain; much of the focus of osteoarthritis has historically been on Pain as the primary driving force behind functional limitations. Although there may be a mechanistic overlap between structural changes and Pain, the finding may suggest that biomechanical restrictions on mobility/ functional limitations are somewhat independent of Pain perception. Additionally, this may reflect the multimodal nature of the WOMAC Function Subscale, with both Pain and there are functional components restricted by biomechanical factors/influences.

Many of the discoveries from previous research and developments in the field of osteoarthritis have led to a dramatic improvement in our understanding of the generation of symptoms in the early stages of OA. The analysis of the OA Initiative Database by De Feyter et al. [5] and their analysis of 204 knees have provided evidence that the presence of cartilage damage generally does not substantially affect the generation of symptoms associated with early knee OA. The multivariate analysis performed by these authors demonstrated that there were several variables found to be much more closely associated with the generation of symptoms than observed cartilage denudation and/or damage. These variables included patellar quadriceps tendinopathy, anserine bursal tenderness, medial meniscal extraction, and bone marrow lesions.These particulars indicate that limited correlations between KL grade and symptoms do not indicate clear correlations between components of the KL grading system and clinical symptoms, suggesting that the limited ability of radiography to show those anatomical features that generate pain accounts for modest correlation between KL grading and symptoms.

The KL grading system captures osteophytes and narrowing of the joint space; these are indirect markers of cartilage loss. However, KL grading does not directly show bone marrow lesions or inflammatory tissue such as synovitis, or pathologies involving the meniscus; nor does KL grading evaluate extra-articular structures contributing to pain that may lead to symptoms. It could be due to these limitations that advanced imaging techniques produce stronger links to symptoms when compared to radiology or the KL grading system.

Tosun et al. found that MRI phenotypes of OA provide distinct groups based on three different degenerative processes (cartilage vs. meniscus vs. bone), and that patients belonging to different groups experienced pain in relation to their clinical findings. The phenotype most associated with the KL grade was the hypertrophic phenotype. The KL grade and MRI phenotypes may also be associated with differences in the way structural changes are manifest through clinical presentation of OA. Some patients with extensive radiographic changes experience relatively little pain, while some patients with minimal radiographic change will report significant pain.

After correcting for KL grade, we found that both age and body mass index (BMI) were independently associated with severity of symptom as measured by the WOMAC scale. It is likely that both age and BMI also affect severity of symptoms in ways that are at least partly independent of structural change evidenced radiographically. The stronger correlation between KL grade and symptoms in older subjects ($\rho = 0.48$ versus 0.36) may represent cumulative effects of structural changes in conjunction with age-related changes in pain response (central pain processing), strength of muscles, and/or compensatory mechanisms.The independent relationship of BMI has implications for treatment decisions. Specifically, treating someone based only on their KL radiographic grade may result in under-treatment for patients who have attained symptom severity greater than what would be expected based on their structural ratings; thus resulting in overtreatment for patients whose structural ratings are advanced, but who present with little to no complaints as a result. Current clinical guidelines provide a framework for approaching OA patients and their providers with a primary focus on treating OA patients according to functional impacts rather than solely using imaging findings to determine individual treatment approaches.

The relationship between BMI and the discrepancy between clinical and radiographic measures has the potential to provide greater insight into the individual's response to treatment, and as such will be of greater benefit to clinicians providing patient care.

KL grade variability indicates that one treatment modality for radiographic OA will not satisfy the patient's individual needs. Variations in pain generators may be identified by the use of advanced imaging or clinical metrics, therefore leading to superior therapeutic outcomes.

Future studies should complete the clinical factors necessary to achieve total patient outcomes. The clinical-radiologic mismatch may be caused by a number of different reasons. Future work will aim to elucidate the mechanism for these differences through longitudinal studies to evaluate whether the clinical-radiological discrepancy at baseline can indicate different disease progression and the response to future treatment. There could also be an alternate phenotype that may have extensive disease symptoms with very limited radiographic evidence.

Second, a fair amount of unexplained variance of OA symptoms exists, and understanding the explanation for this variance is very important. Psychological (catastrophizing and depression), neurological (central sensitization and aberrant processing), and structural characteristics (elements of the disease not considered in the region) may contribute to this unexplained OA symptom variance. Combining advanced imaging with validated patient-reported measures of psychosocial stress could assist in predicting the severity of OA symptoms.

Thirdly, developing and validating composite measures of OA that combine both radiographic and clinical components will improve clinical decision making. The combination of these variables will potentially assist in identifying patients that will benefit from a specific therapy and will ease the application of precision medicine in the treatment of OA.

The strengths of this study include that an adequate sample size, multiple assessment modes, validated measurement instruments and multivariable statistics controlling for covariates were utilized. The study's population was varied (LK grade 0 – 3) thus allowing for examination of the relationships across all stages of OA. Mutually stratifying on the basis of age and BMI helped further define effect modifiers.

There are limitations to the present study: firstly, having only a cross-sectional design limits us in being able to make causal statements regarding the relationship (s) between clinical and radiological measures or the change of the clinical-radiological relationship over time in the same patient. Secondly, conducting the study at one site limits our ability to generalize these findings to other populations or healthcare settings. Finally, the exclusion of patients with KL grade 0 prevents describing the full range of OA, and therefore limits our understanding of OA from asymptomatic to symptomatic.

While some standardization exists with the assessment of OA through radiology, the KL provides limited specific information regarding the cause of pain production in OA compared to the MR. The KL may limit our ability to compare our results with other KOs that are phenotypically classified using MRI, but as the KL is commonly employed in clinical practice in the absence, or neither conveniente IR, the results of this study should have practical applications for KOs that lack access to MRI.

Secondly, while both the WOMAC and VAS are valid, feasible OA measurement instruments and are widely used clinically; both instruments fail to comprehensively assess the range of other types of functional disability in OA (emotional functioning, ability to sleep disrupted, having adequate time to accomplish important roles), as the instruments are solely self-report measure and will be confounded by various non-measure-related factors (memory deficits, psychosocial cultural influence etc..). While all measures are culturally adapted and validated, between cultures is average measurement variability is impossible to completely control for.

Also Consider: the findings of this study are observational and will not limit residual confounding from unmeasured variables including medication use, physical activity, occupation, and psychosocial factors with regards to both radiographic progression and symptoms.

Conclusion

method for radiologic evaluation of OA, the WOMAC and the VAS used clinically to measure the OA outcome from knee OA. In other words, the severity of radiologic findings indicates that the severity of the clinical outcome will also be severe, after controlling for other variables such as the age and BMI of the patient. For every 1 unit increase in KL classification, the WOMAC total score increases 4.28 units and the VAS score increases 0.71 cm. We know that the radiographic findings account for significantly less than 50% of the variance in patient-reported outcomes and, therefore, the relationship between the degree of structural damage and the degree of symptom presentation is significantly dissociated. Furthermore, the variability in clinical presentation of patients with knee OA with a specific KL grade demonstrates that the pathology is multifactorial; that is, that the patient's age and BMI independently affect the degree of symptoms exhibited. This suggests that the patient's characteristics influence the amount of illness expressed by that patient with regard to the structural disease. The study findings offer further evidence to support a collaborative radiographic and comprehensive patient-reported outcome measurement in guiding clinical decision-making and therefore should not be used independently in guiding clinical decision-making. Thus, in making clinical decisions for a patient with knee OA, age, BMI, symptom burden and degree of functional impairment needs to be taken into consideration along with the KL radiographic findings.

Regardless of the radiographic stage, the opportunity to support weight management interventions should be embraced. Overall, there is a significant need for more research to identify which other variables contribute to the unexplained variance in symptom presentations, as well as to develop individualised treatment strategies based on a particular phenotype of osteoarthritis. The correlation between the clinical and the radiographic findings of knee OA is both substantial and complex, therefore, longitudinal studies will be able to determine how the relationship between the clinical and radiographic findings will affect different symptom presentations over time, and whether different symptom presentations will predict different outcomes. The significant correlations that exist between clinical and radiographic findings in knee OA are both multifactorial in nature and non-linear and, by accepting this complexity and completing a comprehensive assessment of the patient, a pathway to deliver optimal care can be developed for the individual.

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