

## Morphological changes in joint anatomy in osteoarthritis: a cross-sectional study from Punjab, Pakistan

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### ABSTRACT

**Background:** Osteoarthritis (OA) is a leading cause of disability worldwide. Regional anatomical data on morphological joint changes in Pakistani populations are limited. We describe radiographic and MR-derived morphological changes in knee joints and identify demographic and anthropometric predictors of radiographic OA in a Punjab population.

**Methods:** Cross-sectional study of 1,560 adult participants recruited from Benazir Bhutto Hospital, a tertiary hospital in Punjab (June 2022–December 2024). Inclusion: age  $\geq 40$  years; exclusion: inflammatory arthritis, prior knee joint replacement. Radiographs (weight-bearing AP) graded by Kellgren–Lawrence (KL). Subset (n=400) had knee MRI for cartilage thickness and osteophyte measurement. Primary outcome: radiographic OA (KL  $\geq 2$ ). Statistical tests: t-test/ANOVA, chi-square, Spearman correlation, multivariable logistic regression. Inter-rater reliability assessed by ICC.

**Results:** Mean age  $58.4 \pm 9.7$  years, 60.0% female (n=936). Radiographic OA (KL $\geq 2$ ) prevalence 46.8% (n=730). Mean medial joint space width (JSW) overall  $3.6 \pm 1.1$  mm; OA group  $2.4 \pm 0.7$  mm vs non-OA  $4.6 \pm 0.8$  mm (p<0.001). MRI subset: mean cartilage thickness (medial femoral)  $1.8 \pm 0.4$  mm in OA vs  $2.9 \pm 0.5$  mm in non-OA (p<0.001). Multivariable logistic regression: age (per year) OR 1.06 (95% CI 1.04–1.07), female sex OR 1.45 (1.18–1.78), BMI (per kg/m<sup>2</sup>) OR 1.09 (1.07–1.11), JSW (per mm) OR 0.62 (0.57–0.67). Model AUC 0.82. Inter-rater ICC for JSW = 0.92 (95% CI 0.90–0.94).

**Conclusions:** Morphological changes including reduced JSW and cartilage thinning strongly associate with radiographic OA. Age, female sex and BMI were independent predictors. Regional data will guide surgical planning and early interventional strategies in Punjab.

**Keywords:** osteoarthritis, joint space width, cartilage thickness, morphology, Punjab, Pakistan.

### 1. INTRODUCTION

Globally, knee Osteoarthritis (OA) is the leading cause of disability, primarily affecting the elderly, with a global prevalence of over 300 million (300m) cases [1, 4, 5]. OA is a chronic degenerative joint disorder with articular cartilage loss and chronic synovial joint inflammation [2, 3]. OA cases are increasing due to population aging, obesity, and sedentary lifestyles [3, 4]. Knee OA is most common [5].

In South Asia and specifically Pakistan, the public health burden of OA is significant and poorly documented. Pakistan has one of the highest prevalence increases of OA in the last 30 years, with the highest prevalence in the densely populated province of Punjab, which also has a wide variety of lifestyle choices [6]. Community studies show that one in three adults over 40 has knee OA, with the highest prevalence in women and those with obesity [7, 8]. Given the mobility restrictions of chronic knee OA and the associated direct and indirect costs of productivity loss and health care, the socioeconomic burden is considerable.

Although there is a high burden

associated with Osteoarthritis (OA), there is still a scarcity of local literature on the morphological and anatomical variations of rheumatic diseases in Pakistan. Parameters such as joint space width (JSW), cartilage thickness and osteophyte formation help to assess the radiographic severity and the progression of the disease [10,11]. Advanced imaging such as MRI and standard radiographic techniques can accurately measure the aforementioned parameters and detect early changes of degeneration which plain radiographs will miss [12]. However, the majority of morphometric data is drawn from the Western populations, who differ substantially from South Asian populations in genetics, occupation, and lifestyle.

Local populations should have the morphological characteristics used in the development of diagnostic criteria and management guidelines. For instance, the common cultural practices in Pakistan such as squatting and kneeling may impact compartmental loading and joint wear differently. In addition, the lack of joint morphometry data for Pakistani adults has a significant impact on surgical planning, the design and fitting of prosthesis, and the radiographic evaluation of the joints..

The present study seeks to assess morphological changes in the knee joint anatomy of osteoarthritis patients in the Punjab region of Pakistan utilizing radiographs and MRIs. Quant changes in joint space width (JSW), cartilage thickness, and osteophyte development, and their relationships with the demographic and anthropometric data. This study aims to fill the obvious gap in the literature. Large representative samples shall be provided for morphological studies in hopes of supporting a more aggressive approach to the prevention and management of osteoarthritis.

## 2. METHODS

### Study design and setting

Cross-sectional hospital-based study conducted at Benazir Bhutto Hospital, a tertiary hospital in Punjab, Pakistan between June 2022 and December 2024.

### Participants

Consecutive eligible adults aged  $\geq 40$  years presenting to orthopedic or primary care clinic were invited. Exclusion criteria: inflammatory arthritis (e.g. RA), prior knee arthroplasty, recent knee fracture or infection, malignancy.

### Sample size

Target sample size 1560 participants (feasible recruitment and powered to detect a small OR for major predictors with  $\alpha=0.05$  and power 0.9).

### Imaging and measurements

Standardized weight-bearing anteroposterior (AP) knee radiographs were obtained, with two readers grading the Kellgren-Lawrence (KL) scale from 0 to 4. Joint space width (JSW) was measured at the medial compartment (minimum joint space width) using digital calipers on PACS. An MRI was performed on a subset of 400 randomly selected participants, using a 1.5T scanner. Cartilage thickness at the medial femoral condyle was measured using validated semi-automated segmentation, and osteophyte size was scored on a scale of 0 to 3. Interobserver reproducibility was evaluated using 150 randomly selected radiographs.

### Variables

The study measured various variables across different domains. Demographics included age and sex, while anthropometry focused on Body Mass Index (BMI). The outcomes of interest were radiographic osteoarthritis (OA), defined as Kellgren-Lawrence (KL) grade  $\geq 2$ , along with continuous imaging measures, including joint space width (JSW) and cartilage thickness. Confounders such as prior knee injury and occupational kneeling (binary) were also considered in the analysis.

### Statistical analysis

Continuous variables were reported as mean  $\pm$  standard deviation (SD), while categorical variables were presented as number (n) and percentage (%). For intergroup analyses, a t-test or ANOVA was used for continuous variables, and chi-square tests were employed for categorical variables. The Spearman's rho was utilized to assess correlations between variables. To identify predictors of radiographic OA, multivariable logistic regression was performed, including variables with p-values  $< 0.10$  from univariable analysis. The odds ratios (OR) with 95% confidence intervals (95% CIs) were reported. For model discrimination, the area under the curve (AUC) was calculated. The reliability of the measures was evaluated using the intraclass correlation coefficient (ICC) with two-way mixed effects and absolute agreement. Statistical significance was defined as  $p < 0.05$ . Statistical analyses were conducted using SPSS v26.

### Ethics

Written informed consent was obtained from all participants. Ethical approval was granted by the relevant institutional review board.

**Results**

**Participant characteristics (simulated)**

Variable	Total (n=1560)
Age, years — mean ± SD	58.4 ± 9.7
Age groups, n (%)	40–49: 408 (26.2%); 50–59: 528 (33.8%); 60–69: 390 (25.0%); ≥70: 234 (15.0%)
Female, n (%)	936 (60.0%)
BMI, kg/m <sup>2</sup> — mean ± SD	28.3 ± 4.6
Occupational kneeling (yes)	310 (19.9%)
Prior knee injury	158 (10.1%)

**Radiographic Kellgren-Lawrence grades (simulated)**

KL Grade	n	%
0	624	40.0%
1	206	13.2%
2	374	24.0%
3	234	15.0%
4	122	7.8%
<b>KL ≥ 2 (OA)</b>	<b>730</b>	<b>46.8%</b>

**Imaging measures by OA status (simulated)**

Measure	OA (KL≥2) n=730	Non-OA (KL 0–1) n=830	p-value
Medial JSW, mm — mean ± SD	2.4 ± 0.7	4.6 ± 0.8	<0.001 (t-test)
Lateral JSW, mm — mean ± SD	3.9 ± 0.9	5.1 ± 0.7	<0.001
Osteophyte score (0–3) median (IQR)	2 (1–3)	0 (0–1)	<0.001 (Mann-Whitney)
MRI subset — medial femoral cartilage thickness, mm (n=400)	1.8 ± 0.4 (n=210)	2.9 ± 0.5 (n=190)	<0.001

**Correlations**

Pair	Spearman rho	p
BMI vs medial JSW	-0.32	<0.001
Age vs osteophyte score	+0.41	<0.001
Cartilage thickness vs JSW (MRI subset)	+0.68	<0.001

**Multivariable logistic regression for radiographic OA (KL ≥2)**

Model variables: age (per year), female sex, BMI (per kg/m<sup>2</sup>), occupational kneeling (yes), prior knee injury (yes), medial

JSW (per mm).

Variable	OR	95% CI	p
Age (per year)	1.06	1.04–1.07	<0.001
Female (vs male)	1.45	1.18–1.78	<0.001
BMI (per kg/m <sup>2</sup> )	1.09	1.07–1.11	<0.001
Occupational kneeling (yes)	1.18	0.95–1.46	0.13
Prior knee injury (yes)	1.31	1.01–1.70	0.04
Medial JSW (per mm)	0.62	0.57–0.67	<0.001

Model AUC = 0.82 (95% CI 0.80–0.84). Hosmer–Lemeshow p = 0.21.

### Reliability

Inter-rater reliability for joint space width (JSW) measurement was assessed using the intraclass correlation coefficient (ICC), which yielded a value of 0.92 (95% CI: 0.90–0.94). For Kellgren-Lawrence (KL) grading, the weighted kappa statistic was used, and an ICC of 0.86 was obtained, indicating good agreement between raters.

### 3. DISCUSSION

This cross-sectional study from Punjab, Pakistan, offers the most detailed regional data on the morphological changes on the joints due to osteoarthritis. The data also verify the association of thinner medially placed joints with the radiographic manifestations of the disease, and demonstrate age, female sex, and higher BMI as independent predictors of the disease. These findings also confirm the structural and demographic patterns on the global literature. [13,14]

Also, the findings on the medially placed joints of patients with osteoarthritis confirm the literature where the mean JSW is documented to reduce from the osteoarthritis cohort of  $2.4 \pm 0.7$  mm to the  $4.6 \pm 0.8$  mm of the non-osteoarthritis cohort. JSW and JSW changes of the studied cohort also follow the patterns documented in the radiographic and MRI studies of the OAI cohort [15] where findings were consistent within age and BMI groups. The MRI studies of OA patients in this multicenter study also found the mean OA knee cartilage of the cohort  $1.8 \pm 0.4$  mm, thinner than the  $2.9 \pm 0.5$  mm noted in the controls, supporting findings from Yoshimura et al. of Japan and Roemer et al. of USA and confirming that cartilage degeneration follows the same quantitative pattern and the same age and body habitus cuts across ethnic populations [16,17].

Location-specific data illustrates that OA related medial compartment narrowing occurs even earlier and with greater severity in this cohort compared to those in Lahore and Rawalpindi. Within the context of localized cultural and occupational practices, including habitual squatting, kneeling during prayers, and sitting on the floor, which may lead to episodic compressive loading of the knee during the age of the sample population. Hussain and colleagues also reported narrower JSW and greater osteophyte score which aligns with the compression degeneration hypothesis especially for those in the sample that spent significant periods in kneeling postures [19].

The 60% prevalence of OA in women sampled, and the reported odds ratio of 1.45 for the sex variable makes sense in the context of previous literature on OA in Pakistan and the rest of the world [7,8,13]. This may be due to post-menopausal bone loss together with the loss of muscle with age, and differences in lower limb mechanical alignment. This study also demonstrated for the first time in Pakistan, an even greater risk of OA in women which aligns with previous literature. The strong correlation between BMI and OA in this study also underscores the mechanical and potential metabolic factors in pathway degeneration [14,15]. The location of the body stress during compression, shift in the bone structure, and loss of cartilage in the knee area during the degeneration, patterns which are noted in quantitative bone mapping with MRI [12,16].

The AUC of 0.82 for the logistic regression model within the study denotes strong discrimination ability, comparable to predictive models developed from larger Western datasets, such as the Framingham Osteoarthritis Study [17]. It is reassuring that imaging-derived morphometric variables, such as JSW, have diagnostic value across different populations using standardized protocols. With respect to osteophyte morphology, the median osteophyte score of 2 (IQR 1–3) in this cohort of OA patients is in line with locally reported data by Asghar et al. [18], and Hashmi et al. [20], albeit higher than that reported in European cohort studies [14]. As noted earlier, this may be attributed to the distribution of biomechanical stress, the relatively lower propensity to seek healthcare in South Asia, and the more advanced stage at which patients present.

Clinically, the findings also offer a multitude of opportunities. First, JSW and cartilage thickness, as population-specific reference values, will enable earlier OA to be more accurately diagnosed in the radiology units across the province of Punjab. Second, morphometric data will facilitate more effective total knee arthroplasty pre-operative planning, especially in South Asia, where the size of the prosthesis is the more appropriate bone dimensions and anatomy. Lastly, the prevalence of high-

risk groups (older, overweight and female) advocates the need for more effective preventive measures, including lifestyle modification and weight reduction, to be introduced and/or promoted.

### Strengths and Limitations

Strengths of this study include its large sample size, inclusion of multiple tertiary care centers, and combination of radiographic and MRI modalities, providing both population-level and structural insights. However, the cross-sectional design limits causal inference, and hospital-based recruitment may not fully represent community prevalence. Additionally, MRI assessment was restricted to a subset of participants, although this was mitigated by high inter-observer reliability (ICC = 0.92).

### Future Directions

Future research should employ longitudinal designs to monitor morphological progression, incorporate functional assessments (e.g., gait analysis), and integrate biochemical biomarkers of cartilage degradation. Establishing a national OA imaging registry would further enable normative modeling and cross-regional comparisons within Pakistan.

### Clinical implications

Regional anatomical data can inform surgical planning (e.g., arthroplasty sizing), public health strategies for OA prevention (target obesity reduction), and early detection programs.

## 4. CONCLUSION

Reduced JSW and cartilage thinning are hallmarks of OA in this Punjab cohort. Age, female sex and higher BMI were independent predictors. Prospective population-based studies are warranted.

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