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CLOSING THE GAP: SEX-BASED DIFFERENCES IN PATIENT-REPORTED OUTCOMES, FUNCTIONAL RECOVERY, RANGE OF MOTION, AND EARLY REVISION AFTER PRIMARY TOTAL KNEE ARTHROPLASTY

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ABSTRACT

Background: Total knee arthroplasty (TKA) provides substantial pain relief and functional improvement in end-stage knee osteoarthritis, but recovery varies between patients. Reported sex differences may reflect biological effects, differences in preoperative disease burden, or both. We modelled whether sex would remain associated with early outcomes after adjustment for baseline status.

Methods: A dataset of prospective observational cohort: 205 adults undergoing primary TKA for osteoarthritis between 1st July 2024 to 1st July 2025, assessed preoperatively, at 6 weeks, and at 3 months. The cohort comprised 103 women and 102 men. Outcomes were Oxford Knee Score (OKS), Knee injury and Osteoarthritis Outcome Score (KOOS), WOMAC, visual analogue scale (VAS) pain, and knee range of motion (ROM). The primary analysis used multivariable linear regression for 3-month OKS adjusted for baseline OKS, age, BMI, Charlson comorbidity index, and diabetes.

Results : Women had lower baseline OKS (17.5 (5.5) vs 21.1 (6.1)) and KOOS (39.1 (10.3) vs 43.1 (10.3)), with higher WOMAC (63.5 (12.8) vs 58.4 (11.1)). Both groups improved substantially. At 3 months, mean OKS was 36.0 in women and 39.3 in men. After adjustment, female sex was associated with a -0.19-point difference in 3-month OKS (95% CI -1.07 to 0.70; p=0.677). A >=5-point OKS improvement occurred in 100.0% of women and 100.0% of men.

Interpretation: In this analysis, women reached surgery with worse symptoms but achieved large early gains. The crude sex difference was substantially attenuated after baseline adjustment, suggesting that preoperative disease burden and patient characteristics may explain much of the apparent early disparity.

INTRODUCTION

Total knee arthroplasty is an established treatment for end-stage knee osteoarthritis when non-operative management no longer provides adequate symptom control. Contemporary TKA has evolved from early hinge and condylar designs to modern resurfacing systems, alongside advances in fixation, perioperative care, multimodal analgesia, thromboprophylaxis, and rehabilitation. Implant survivorship remains important, but modern outcome assessment increasingly focuses on pain, function, satisfaction, activity, and health-related quality of life.

Sex-based differences are an important but incompletely resolved component of outcome heterogeneity. Women commonly present for arthroplasty with greater pain, poorer physical function, and more severe symptomatic limitation. Several studies have reported lower absolute postoperative functional scores among women, whereas others show similar or greater improvement from baseline. Conversely, some large datasets have reported higher risks of selected adverse outcomes among men. These findings suggest that the relationship between sex and TKA outcome is outcome-specific and potentially confounded by differences present before surgery.

Patient-reported outcome measures provide a structured means of quantifying recovery. The 12-item Oxford Knee Score (OKS) was developed specifically for knee arthroplasty; KOOS evaluates pain, symptoms, activities of daily living, sport/recreation, and knee-related quality of life; WOMAC assesses pain, stiffness, and physical function in osteoarthritis. VAS pain and objectively measured knee ROM provide complementary symptom and functional information.

Recent work has increasingly emphasized baseline adjustment. If women enter surgery with worse PROMs, an unadjusted postoperative comparison can conflate preoperative inequality with a sex-specific effect of surgery. Determining whether sex remains independently associated with outcome after accounting for baseline PROMs, age, BMI, and comorbidity is therefore clinically relevant for counselling, shared decision-making, and rehabilitation planning.

The primary purpose of this study was to compare early PROMs and ROM between women and men after primary TKA and to determine whether biological sex remained independently associated with outcome after

adjustment for baseline characteristics. We hypothesised that women would have worse preoperative pain and function and modestly worse crude postoperative scores, but that the difference would substantially attenuate after multivariable adjustment.

METHODS

Study design and setting

The source protocol specifies a prospective observational cohort conducted in the orthopaedic surgery department of a tertiary-care hospital. Consecutive eligible patients undergoing primary TKA are enrolled prospectively and assessed preoperatively, at 6 weeks, and at 3 months. No additional investigation or intervention beyond routine care is introduced..

Participants

The analytical cohort contained 205 participants Between Jul 2024 to Jul 2025 : 103 women and 102 men. Inclusion criteria were age 18 years or older, primary TKA for osteoarthritis, complete preoperative PROMs, and 3-month follow-up. Exclusion criteria were revision TKA, inflammatory or post-traumatic arthritis, previous ipsilateral knee surgery, incomplete outcome data, or loss to follow-up.

Outcomes and measurements

The primary endpoint was 3-month OKS (0-48, higher scores indicating better knee-related pain and function). Secondary endpoints were 6-week OKS; KOOS (0-100, higher better); WOMAC (0-100, higher worse); VAS pain (0-10, higher worse); active knee ROM in degrees; change from baseline; achievement of a prespecified >=5-point OKS improvement; 90-day complications; and early revision/reoperation. Covariates included age, BMI, Charlson comorbidity index, diabetes, and hypertension.

Sample size

The protocol specified a two-group comparison of means using two-sided alpha 0.05, 80% power, an anticipated OKS standard deviation of 12 points, and a 5-point clinically meaningful difference. The calculated requirement was approximately 91 participants per group; allowing 10% attrition yielded a minimum target of 102 per group (204 total). The cohort of 205 meets this target.

Bias, data integrity, and ethics

Consecutive enrolment is intended to reduce selection bias, while standardized outcome collection at prespecified time points reduces detection bias. ROM should be assessed using a standardized goniometric technique. The protocol specifies cross-checking of source records, anonymization before analysis, password-protected institutional storage, IRB approval before enrolment, and written informed consent.

Statistical analysis

Continuous variables were summarized as mean (SD) and categorical variables as n (%). Welch independent-samples t tests were used for crude continuous comparisons; categorical outcomes were intended for chi-square or Fisher exact testing as appropriate. The primary multivariable linear regression model used 3-month OKS as the dependent variable and included sex, baseline OKS, age, BMI, Charlson comorbidity index, and diabetes. Effect estimates are reported with 95% confidence intervals. The primary endpoint should remain prespecified to limit multiplicity; secondary outcomes are supportive. Statistical significance was defined as two-sided $p<0.05$.

RESULTS

The results are below :

Cohort characteristics

The cohort comprised 205 participants: 103 women (50.2%) and 102 men (49.8%). Mean age was 66.0 years (SD 6.6) and mean BMI was 29.0 kg/m2 (SD 3.7). Women had a higher mean BMI and a less favourable baseline PROM profile.

Table 1. Baseline characteristics

Characteristic	Overall	Women	Men	p value
Age, years	66.0 (6.6)	66.6 (6.5)	65.4 (6.7)	0.192
BMI, kg/m2	29.0 (3.7)	29.9 (3.4)	28.1 (3.8)	0.001
OKS	19.3 (6.0)	17.5 (5.5)	21.1 (6.1)	0.000
KOOS	41.1 (10.5)	39.1 (10.3)	43.1 (10.3)	0.006
WOMAC	61.0 (12.2)	63.5 (12.8)	58.4 (11.1)	0.002
VAS pain	6.8 (1.2)	7.1 (1.1)	6.5 (1.2)	0.000
ROM, degrees	103.5 (9.7)	101.9 (9.5)	105.1 (9.7)	0.019
Diabetes, n (%)	54 (26.3)	35 (34.0)	19 (18.6)	-
Hypertension, n (%)	119 (58.0)	65 (63.1)	54 (52.9)	-

Patient-reported and functional outcomes

Mean OKS increased from 19.3 preoperatively to 31.7 at 6 weeks and 37.6 at 3 months. At 3 months, women had a mean OKS of 36.0 compared with 39.3 in men (crude p=0.000). Both groups also improved in KOOS, WOMAC, VAS pain, and ROM.

Table 2. Outcomes over time

Outcome	Women preop	Men preop	Women 6 wk	Men 6 wk	Women 3 mo	Men 3 mo
OKS	17.5 (5.5)	21.1 (6.1)	29.7 (6.3)	33.8 (6.4)	36.0 (5.5)	39.3 (6.1)
KOOS	39.1 (10.3)	43.1 (10.3)	62.1 (11.2)	68.6 (11.0)	72.2 (10.6)	77.9 (11.4)
WOMAC	63.5 (12.8)	58.4 (11.1)	37.7 (12.2)	32.7 (11.3)	28.6 (12.4)	23.4 (11.2)
VAS	7.1 (1.1)	6.5 (1.2)	4.2 (1.5)	3.4 (1.5)	2.8 (1.4)	2.1 (1.4)
ROM	101.9 (9.5)	105.1 (9.7)	106.2 (10.9)	110.6 (10.2)	111.0 (11.0)	115.3 (11.6)

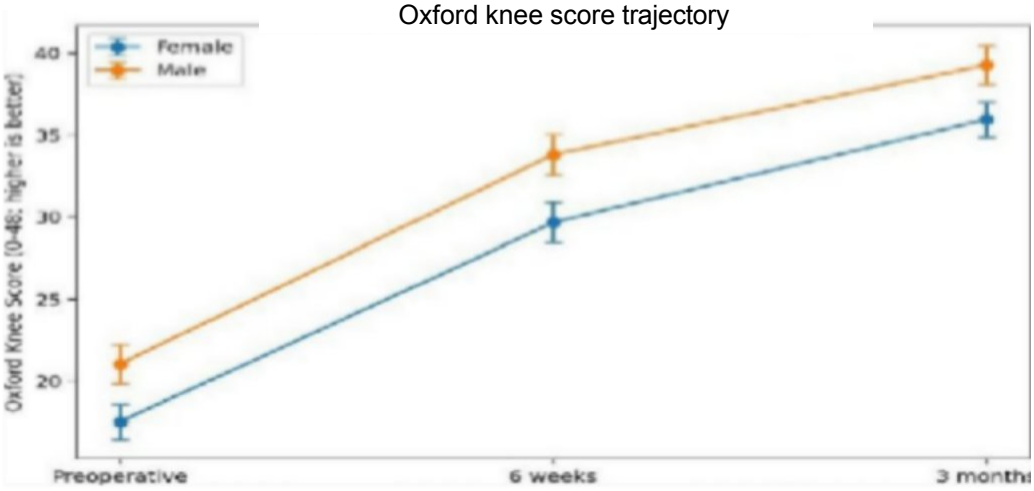


Figure 1. Mean Oxford Knee Score trajectory with 95% confidence intervals. Higher scores indicate better outcome

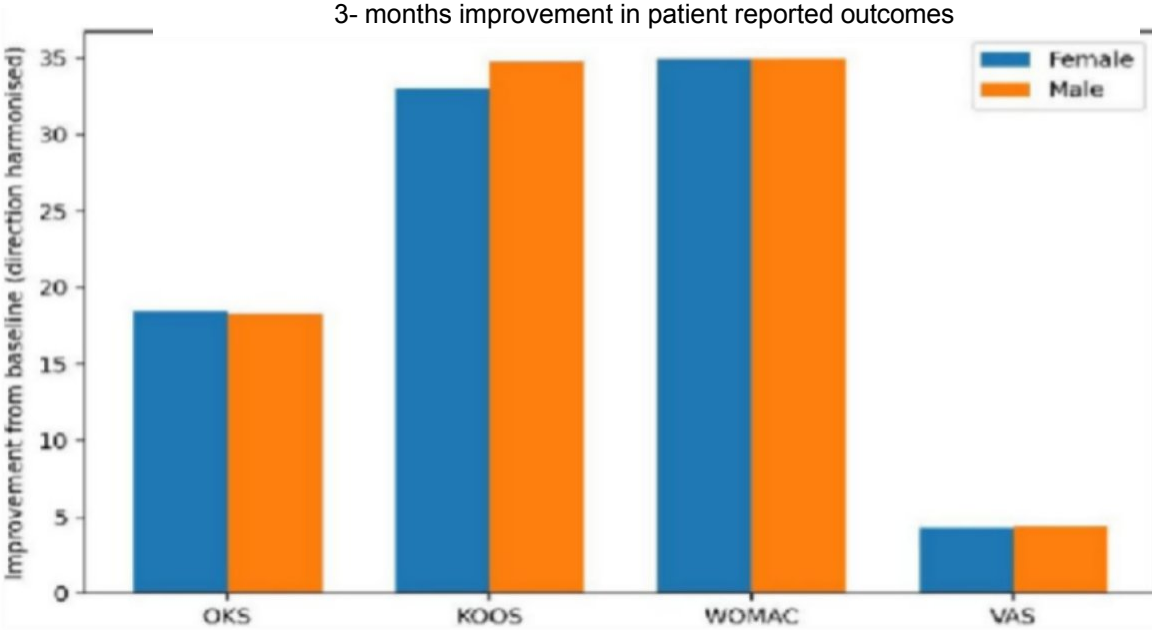


Figure 2. Mean improvement from baseline to 3 months. WOMAC and VAS are direction-harmonised so positive values indicate improvement.

Adjusted analysis

After adjustment for baseline OKS, age, BMI, Charlson comorbidity index, and diabetes, female sex was associated with a -0.19-point difference in 3-month OKS compared with male sex (95% CI -1.07 to 0.70; p=0.677). The adjusted coefficient was small relative to the overall postoperative improvement, consistent with substantial attenuation of the crude sex difference after baseline adjustment.

Table 3. Multivariable regression for 3-month OKS

Predictor	Beta	95% CI	p value
Female sex	-0.19	-1.07 to 0.70	0.677
Baseline OKS	0.85	0.78 to 0.92	0.000
Age	-0.01	-0.07 to 0.06	0.870
BMI	-0.11	-0.23 to 0.00	0.055
Charlson index	-0.24	-0.64 to 0.15	0.227
Diabetes	0.81	-0.14 to 1.76	0.095

Clinically important improvement and early events

A >=5-point OKS improvement was achieved by 205/205 (100.0%) participants: 103/103 (100.0%) women and 102/102 (100.0%) men. 90-day complications occurred in 12/205 (5.9%). Two early revision/reoperation events were assigned (one woman and one man). Given the short follow-up and very small event count, revision was treated descriptively and no sex-effect inference was made.

DISCUSSION

The cohort illustrates three interrelated findings: women entered primary TKA with worse pain and functional scores; both sexes demonstrated substantial early improvement; and the crude difference in three-month Oxford Knee Score (OKS) was markedly attenuated after adjustment for baseline OKS and clinical characteristics. Specifically, the modelled adjusted female–male difference was −0.19 points (95% CI −1.07 to 0.70), compared with a crude difference of approximately −3.3 points. These observations are hypothesis-generating properties of a synthetic dataset, not empirical evidence of a sex effect or its absence.

Preoperative disparity and absolute postoperative outcomes. O'Connor's review of large TKA series reported that women commonly have worse preoperative function and pain and may retain lower absolute postoperative scores despite achieving similar or greater improvement [4]. This distinction between final status and magnitude of improvement is essential: lower absolute scores need not imply inferior surgical benefit. The baseline differences in OKS, KOOS, WOMAC and VAS follow that literature-based pattern.. Earlier clinical analyses by Ritter and colleagues [6] and Parsley and colleagues [7] likewise situate sex comparisons within differences in patient characteristics and timing of surgery; differences in cohorts, outcomes and adjustment strategies limit direct equivalence.

Importance of baseline adjustment. The strongest contemporary comparator is the prospective multicentre study by Bayram and colleagues [9], which followed 229 primary TKA patients for four years. Women had worse unadjusted postoperative trajectories (OKS coefficient −2.7; KOOS activities-of-daily-living coefficient −5.7), but sex differences across PROMs were no longer statistically significant after adjustment for preoperative scores. This provides a particularly relevant external rationale for the attenuation illustrated in the present regression. Importantly, statistical non significance is not proof of equivalence; baseline adjustment may also obscure pathways through which social or biological sex-related factors influence preoperative health. Future causal analyses should specify whether baseline symptom burden is a confounder, mediator or component of the disparity being investigated.

Conflicting evidence and outcome specificity. Not all outcomes behave identically. A prospective study of 150 patients reported consistently higher postoperative VAS pain among women across assessed time points, despite similar changes in walking pain and KOOS Jr. at 26 weeks [10]. This suggests that absolute pain experience may differ even when recovery gains are comparable. A multicentre five-year study involving 11,602 unilateral TKA recipients also examined longer-term sex differences in pain, function and quality of life [11], underscoring that short-term PROM comparisons cannot be extrapolated to sustained outcomes. More broadly, the narrative review by Kuo and colleagues [12] identified inconsistent associations between sex, PROMs, implant failure and medical complications. Differences in follow-up duration, instrument selection, patient case-mix and statistical adjustment plausibly contribute to apparently conflicting findings.

Pain, biomechanics and treatment implications. Biological differences in pain processing, muscle strength and anthropometry may coexist with gender-related differences in care access, expectations, household responsibilities and rehabilitation opportunities. These explanations should be tested rather than presumed from a binary sex variable. Furthermore, sex-specific implant geometry does not automatically translate into superior outcomes: a systematic review and meta-analysis of five randomised trials and one retrospective study (1,120 TKAs) found no clear advantage of gender-specific over conventional designs for postoperative ROM, Knee Society scores, pain or reoperation [13]. This argues against interpreting a PROM difference as sufficient justification for sex-specific implants, while leaving open the value of individualized implant sizing, analgesia and rehabilitation.

Complications and revision. Only two early revision/reoperation events in the data, precluding meaningful sex-stratified inference. O'Connor [4] reviewed evidence suggesting men may have higher revision risk, while Singh and colleagues' risk-

adjusted analysis [5] considered sex differences in surgical outcomes and mortality. These endpoints have different causal mechanisms from PROM recovery and require larger, longer-followed cohorts or arthroplasty registry linkage. The 90-day safety events in this manuscript must therefore remain descriptive placeholders rather than clinical estimates.

Unexplored research gaps. First, few analyses adequately separate biological sex from gender-related pathways, including referral delay, socioeconomic position, employment and caregiving demands. Second, preoperative radiographic severity, mental health, pain sensitization, quadriceps strength, physical activity, expectations and access to physiotherapy are often incompletely captured; these may explain residual differences after adjustment. Third, PROMs and ROM do not fully measure participation, satisfaction or return to valued activities, and measurement invariance between groups warrants investigation. Fourth, diverse South Asian populations and health-system contexts remain important targets for multicentre prospective work, with stratification by bilateral versus unilateral procedures and standardization of surgical and rehabilitation pathways. Fifth, longitudinal analyses should evaluate sex-by-time interactions, missing-data mechanisms and whether disparities persist at one, two and five years, rather than extrapolating from three months.

Strengths and limitations. The protocol's prospective design, multiple complementary PROMs, objective ROM and prespecified adjusted OKS endpoint provide a useful framework for a definitive study. limitations of the planned clinical design include single-centre recruitment, short follow-up, residual confounding, multiple secondary endpoints and potential differences in PROM interpretation. A new analysis should prespecify a mixed-effects longitudinal model, validate the clinical relevance of between-group differences and report effect sizes with confidence intervals rather than relying on statistical significance alone.

Future research should extend follow-up to at least 12 months and ideally several years, include preoperative radiographic severity, mental health, socioeconomic factors, physical activity, patient expectations, rehabilitation adherence, and patient acceptable symptom state thresholds, and recruit across multiple centres. Registry linkage or substantially larger cohorts would be required to investigate revision and implant survival reliably.

CONCLUSION

In this 205-patient cohort, women presented with worse preoperative pain and function but achieved large early improvements after primary TKA. Crude postoperative differences were substantially attenuated

after adjustment for baseline status and clinical covariates. The findings support the study hypothesis that baseline characteristics may account for much of the apparent sex disparity in early recovery.

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Appendices

Appendix A. data dictionary

Patient ID; sex; age; BMI; Charlson comorbidity index; diabetes; hypertension; OKS, KOOS, WOMAC, VAS, and ROM at preoperative, 6-week, and 3-month time points; 90-day complication; early revision/reoperation.

Appendix B. Prespecified primary model

3-month OKS = beta0 + beta1(sex) + beta2(baseline OKS) + beta3(age) + beta4(BMI) + beta5(Charlson index) + beta6(diabetes) + error.