# Natural History of Pain and Disability among African-Americans and Whites With or At Risk For Knee Osteoarthritis: A Longitudinal Study

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**ABSTRACT**

**Objective:** Compare knee pain and disability between African Americans (AAs) and Whites (WHs), with or at risk of knee osteoarthritis (KOA), over 9 years, and evaluate racial disparities in KOA-related symptoms across socioeconomic and clinical characteristics

**Design:** Osteoarthritis Initiative participants were evaluated annually over 9 years for pain and disability, assessed by the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and a numerical rating scale (NRS) for knee pain severity. Mean annual WOMAC pain, NRS pain, and WOMAC disability levels were estimated by race using mixed effects models, adjusted for age, sex, education, marital status, body mass index, depression, and baseline Kellgren-Lawrence grade score. Race-specific mean WOMAC pain scores were also estimated in analyses stratified by socioeconomic and clinical characteristics.

**Results:** AAs reported worse mean WOMAC pain compared to WHs at baseline (3.69 vs. 2.20; $p \leq 0.0001$) and over 9 years of follow-up, with similar disparities reflected in NRS pain severity and WOMAC disability. Radiographic severity did not account for the differences in pain and disability, as substantial and significant racial disparities were observed after stratification by Kellgren-Lawrence grade. Depression and low income exacerbated differences in WOMAC pain between AAs and WHs by a substantial and significant magnitude.

**Conclusions:** Over 9 years of follow-up, AAs reported persistently greater KOA symptoms than WHs. Socioeconomically and clinically disadvantaged AAs reported the most pronounced disparities in pain and disability.

**Keywords:** Osteoarthritis, knee osteoarthritis, race, outcome measures, pain, longitudinal

## INTRODUCTION

Osteoarthritis (OA) is the third leading cause of years lived with a disability, and the lifetime risk of developing symptomatic knee osteoarthritis (KOA) is one in two[1, 2]. The prevalence and manifestations of KOA may vary across racial groups, however. African-Americans (AAs) have a 1.7 times greater odds of developing radiographic KOA and a 1.5 times greater odds of symptomatic KOA than Whites (WHs)[3]. AA patients with KOA have also reported worse OA-related pain and function on patient-reported outcome measures (PROMs), such as the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) pain and function scores[4, 5]. Population-based samples suggest that racial and ethnic minorities generally report more pain and impairments than non-minorities, not limited to KOA-related pain[6].

Race disparities in OA health outcomes could be related to differences in socioeconomic and clinical characteristics. Poorer socioeconomic status is generally associated with poorer physical and mental health[7]. Low social support has also been related to poorer health-related quality of life (QOL) among OA patients[8]. In a Veterans Affairs study, lower income, but not marital status, was associated with worse arthritis pain and function[9]. Income did not explain racial differences in pain and function in the study, however. In another study, racial differences in KOA symptoms persisted despite adjustment for sociodemographic and radiographic OA severity[5], although these racial differences were no longer significant when further controlled for body mass index (BMI) and depressive symptoms. Higher BMI has also been associated with poorer daily functions in other OA studies[10].

While informative, previous studies on racial differences in pain and function in KOA have certain limitations. The study designs are primarily cross-sectional in nature[4, 5, 9-12]. To our knowledge, no longitudinal study has previously tracked racial differences in KOA symptoms or disability with multiple annual observations over a prolonged period of time. The extent to which the magnitude of racial differences persists or expands over time is unknown. Existing studies are also either limited to research participants with severely symptomatic OA[10-12], an overwhelming proportion of male veterans[4, 10-12], or those recruited in limited geographic locations[4, 5, 9-12].

Osteoarthritis is a chronic disease, and longitudinal studies are necessary to understand whether racial differences in the report of KOA symptoms change over time. PROMs are increasingly used to evaluate patients in clinical practice and to assess the quality of care provided to them[13, 14]. They provide patients' perspectives and are the outcomes of greatest importance to patients. Hence, it is important to understand racial differences in patient-reported pain and disability and whether these differences might change over time. The Osteoarthritis Initiative (OAI), a cohort study of persons with or at high risk of developing symptomatic KOA with annual administration of PROMs, provides a unique opportunity for the longitudinal evaluation of racial differences in pain and disability.

The primary objective was to compare self-reported pain and disability between AAs and WHs with or at high-risk of KOA over nine years of follow-up. The secondary objective was to evaluate racial disparities in KOA-related symptoms over time across socioeconomic and clinical characteristics.

## METHODS

### Study Design, Setting & Participants

Our sample consisted of participants in the OAI study. Study overview, objectives and sample selection have been described (http://oai.epi-ucsf.org/datarelease/StudyOverview.asp). Briefly, the OAI is a prospective longitudinal cohort study of people 45-79 years of age. Individuals with clinically significant KOA and those at high risk of developing clinically significant KOA were recruited between 2004 and 2006 from the University of Maryland School of Medicine and Johns Hopkins University (Baltimore, MD), Ohio State University (Columbus, OH), University of Pittsburgh (Pittsburgh, PA) and Memorial Hospital of Rhode Island (Pawtucket, RI). Participants were assessed annually through 108 months of follow-up. The study was approved by the Institutional Review Board (IRB) of the OAI Coordinating Center at the University of California, San Francisco and by the IRBs of each site. The present study includes all AA and WH OAI participants, with or at increased risk of KOA, including the progression and incidence cohorts. The progression cohort included participants who had symptomatic KOA in at least one knee at recruitment. The incidence cohort included those at risk for KOA with substantial risk factors including frequent knee symptoms, overweight/obesity, history of knee injury or surgery, family history of total knee replacement, Heberden's nodes, and repetitive knee bending, but without symptomatic KOA in either knee. OAI participants without symptoms, risk factors or radiographic evidence of KOA (i.e., the reference "non-exposed" control cohort) were excluded. The "non-exposed" control cohort also had to have absence of radiographic hand and hip OA. Other racial groups were not sufficiently represented to facilitate other race-stratified analyses and were also excluded. Knees with missing Kellgren-Lawrence (K-L) grade scores at baseline and those with total knee replacement surgery prior to enrollment were also excluded.

### Study Variables

*Outcome Measures.* Knee pain and disability were assessed using the 24-item WOMAC, with the pain (range: 0-20) and disability (range: 0-68) subscales, respectively[15]. This measure has good face and construct validity[16], and has high test-retest reliability (Kendall's tau-c 0.48-0.68)[15]. Higher scores indicate more KOA-related symptoms. Knee pain severity in the past 30 days based on a numerical rating scale (NRS) with a range of 0 to 10 was also assessed.

*Covariates.* Race, sex, age, educational attainment, marital status, and annual household income (< or ≥ $50,000, the median household income in the US at the start of the study in 2002) were self-reported at baseline. BMI was calculated and categorized based on the World Health Organization definition. Comorbidity was measured using the Katz-modified Charlson Comorbidity Index Questionnaire[17]. Depression was ascertained using the validated Center for Epidemiologic Studies Depression Scale (CES-D)[18], with scores ≥16 suggesting depression[19]. General physical and mental health were assessed using the Short Form Health Survey (SF-12)[20].

*Other KOA-Related Measures*. The symptoms and QOL subscale measures from the Knee Injury and Osteoarthritis Outcome Score (KOOS) were used to further describe the sample[21]. Subscale scores range from 0 to 100; lower scores indicate more KOA-related symptoms and lower QOL. Baseline radiographs

were centrally read and scored using the K-L system[22, 23] for all participants who had at least one follow-up visit knee x-ray.

Statistical Analysis

Baseline socioeconomic and clinical characteristics were summarized by race at the participant-level. Baseline WOMAC total, pain and disability subscores, pain severity, KOOS Symptoms score, and K-L grade were summarized at the knee-level.

*Primary Analysis.* Mixed effects models[24] were used to estimate mean WOMAC pain, knee pain severity, and WOMAC disability, assessed at the knee-level, for AAs and WHs at each annual clinic visit, with 95% confidence intervals (CI), adjusted for age, sex, education, marital status, BMI, CES-D, and baseline K-L grade. The mixed models included three levels, with annual assessments nested within knee, and knees nested within participant. Models were adjusted for variables that could potentially contribute to racial differences in OA-related symptoms[5, 8-10]. The estimated race-specific annual means and 95%CIs were plotted over nine years of follow-up for each outcome. Surgically replaced knees were censored at the time of surgery. Variance components from unadjusted three-level mixed models were estimated with 95%CIs, including variance between participants in each race group, variance between knees within a person, and variance within a knee over annual repeated measures.

Due to an observed decrease in group mean scores among AAs between baseline and the one-year follow-up visit, change during the first year was directly estimated with statistical comparison of one year change in race group means using a likelihood ratio test for the interaction between race and time.

The primary analysis was stratified by presence/absence of radiographic KOA (K-L ≥2), as previous literature[25, 26] has reported that AAs tend to have higher prevalence of radiographic KOA than WHs, which could contribute to racial differences in PROMs.

*Secondary Analysis.* In order to identify the effects of potential contributors to racial differences in longitudinal pain reporting, race group annual means and 95% CIs of the outcome measures were estimated in analyses stratified by socioeconomic (income, marital status) and clinical (BMI, K-L grade, CES-D) characteristics using mixed effects models, adjusted for age, sex, education, marital status, BMI, CES-D, and baseline K-L grade. They were plotted over nine years of follow-up. The drop in mean WOMAC pain among AAs appeared to be affected by socioeconomic and clinical characteristics, prompting direct estimation of mean change during the first year stratified by socioeconomic and clinical characteristics using baseline and one-year follow-up data for AAs and WHs.

*Clinically Important Differences Exploratory Analysis.* Since significant differences in group means are not always clinically important, a post-hoc analysis of clinically important differences (CID) was conducted, applying CID at the knee level, using the following definitions: 1) Minimum CID in WOMAC pain proposed by Angst *et al*[27] (≤-1.5 for improvement; ≥2.2 for worsening); 2) CID in knee pain NRS score proposed by Farrar *et al*[28] (≤-1.7 for improvement; ≥1.7 for worsening); and 3) Minimum CID in WOMAC disability proposed by Tubach *et al*[29] (≤-6.0 for improvement; ≥6.0 for worsening). Generalized linear mixed models for multinomial logistic regression were used to estimate the relative odds of reporting

clinically important improvement and worsening (vs. no minimal CID as referent outcome) for AAs compared to WHs. Since each participant contributed two knees to the analysis, knee was treated as a random effect.

Missing data due to dropout was considered as a potential source of bias. Since mixed models were used to estimate group means, participants with missing follow-up data were included, with implicit imputation potentially mitigating bias from dropout, depending on the dropout mechanism[24]. Models were adjusted for sociodemographic and clinical characteristics, further reducing the potential for bias due to differential dropout.

**RESULTS**

A total of 4,796 OAI participants were initially considered for inclusion. Individuals who did not identify as AA or WH, as well as those with no radiographic evidence of KOA and no risk factors (i.e., the non-exposed control cohort) were excluded (Supplement 1). Among the 9,088 knees considered for analysis, 58 non-native knees (i.e., those that underwent knee replacement surgery prior to baseline) and 538 without a K-L grade score at baseline were not available for analysis. A total of 778 AA and 3498 WH participants were included in the study. There were no Hispanic AAs and only 27 Hispanic WHs. Supplement 2 shows participant retention rate over nine years of follow-up by race, as time to final drop-out. A modestly higher proportion of AAs were lost to follow-up over time than WHs.

AAs, compared to WH, were more often obese and less often reported graduate education or being married (Table 1). They were also more frequently depressed and had lower SF-12 physical summary and mental summary scores. AAs entered the study with evidence of greater KOA severity, reflected by higher mean baseline WOMAC total and knee pain severity scores as compared to WHs, as well as radiographic severity with a K-L grade ≥2.

Pain and Disability from KOA Over 9 Years

On average, WOMAC pain subscale scores were worse among AAs in comparison to WHs after adjustment for age, sex, education, marital status, BMI, depression, and K-L grade at baseline (3.62 [95% CI: 3.44, 3.80] vs. 2.15 [95% CI: 2.06, 2.25]; $p<0.0001$) and in all subsequent follow-up visits (Figure 1). Baseline and annual follow-up mean knee pain severity NRS and WOMAC disability scores were also consistently higher among AAs than among WHs (Figure 1, Supplement 3, Table 2).

A notable drop in mean scores at the second questionnaire administration after one year of follow-up was observed for all three outcome measures among AAs, but not WHs (Figure 1). The mean WOMAC pain levels remained relatively stable between the 1 year and 9 year follow-up visits(Figure 1A; mean annual change: 0.06 [95% CI: 0.06, 0.07] WHs vs. 0.01 [95% CI: -0.01, 0.03] AAs). Similar patterns were found when mean knee pain severity and WOMAC disability scores were compared between AAs and WHs longitudinally (Figure 1B and 1C, Table 2).

Similar results were found with unadjusted models (data not shown). AAs had higher pain and disability scores than WHs at baseline and the first year of follow-up. There was also a significant decrease in pain and disability scores among AAs in comparison to WHs during this first year.

When stratified by radiographic KOA severity (i.e., K-L grade <2 vs. K-L grade ≥2), baseline levels of reported pain and disability were consistently higher for knees with radiographic KOA, but no remarkable differences in trend over time were observed (Figure 2).

Socioeconomic and Clinical Contributors to Racial Differences

Baseline mean WOMAC pain was highest among AAs with an annual household income of <$50,000 per year (4.03 [95% CI: 3.80 to 4.27]) compared to AAs with an annual household income of ≥$50,000 per year and all WHs regardless of income (Supplement 4). This finding persisted at all follow-up visits

(Figure 3A). Decrease in mean WOMAC pain during the first year was greatest among AAs with an annual household income of ≥$50,000 per year (-0.74 [95% CI: -0.98 to -0.51]) compared to all other subgroups categorized by race and income.

Race group differences in WOMAC pain were not evident by marital status at baseline, though the decrease in mean WOMAC pain during the first year was greatest among AAs who were married (-0.88 [95% CI: -1.11 to -0.64]) (Supplement 4). Thereafter, AAs who were not married had consistently higher mean WOMAC pain scores than AAs who were married and all WHs, with little change observed in annual group means (Figure 3B).

At baseline and in all follow-up visits, mean WOMAC pain was highest among AAs who were obese in comparison to others when categorized by race and BMI category (Figure 3D). Decline in mean WOMAC pain from baseline to year one was greatest among AAs with normal BMI (-0.82 [95% CI: -1.29 to -0.35]) (Supplement 4). AAs with radiographically evident KOA (K-L grade ≥2) reported the greatest pain at baseline (5.12 [95% CI: 4.87 to 5.36]) and throughout all follow-up visits in comparison to others when categorized by race and K-L grade severity (Figure 3E). The most substantial decline over the first year was seen among AAs with K-L grade <2 (-0.65 [95% CI: -0.87 to -0.43]), with little change in group means thereafter (Supplement 4).

Clinically Important Differences

AAs reported consistently higher variability in pain and disability over time compared to WHs, for all three measures (WOMAC pain 7.54 [95%CI: 7.34, 7.74] vs 3.46 [95%CI: 3.42, 3.50]; NRS 4.75 [95%CI: 4.63, 4.88] vs 3.30 [95%CI: 3.26, 3.34]; WOMAC disability 73.55 [95%CI: 71.64, 75.54] vs 32.12 [95%CI: 31.73, 32.51]; Table 3).

Since group means can obscure clinically meaningful change at the individual level, an exploratory analysis was undertaken to consider how many participants reported CID in pain and disability over consecutive annual visits, and whether the odds of reporting CID differed by race. AAs, in comparison to WHs, had significantly higher odds of reporting CIDs at the first year follow-up visit, based on previously published minimum CID criteria for WOMAC pain improvement (OR 2.37 [95% CI: 2.06, 2.74]) and worsening (OR 2.10 [95% CI: 1.74, 2.54]), knee pain severity improvement (OR 1.84 [95% CI: 1.58, 2.13]), and WOMAC disability improvement (OR 2.20 [95% CI: 1.83, 2.65]) and worsening (OR 2.37 [95%CI: 2.00, 2.80]). Further, compared to WHs, AAs had consistently higher odds of reporting clinically important improvement or worsening in WOMAC pain and disability between all consecutive visits, higher odds of reporting clinically important improvement in knee pain severity over eight of nine consecutive annual visits, and higher odds of reporting clinically important worsening in pain severity over six of nine consecutive annual visits (Supplement 5).

**DISCUSSION**

AAs reported higher average levels of pain and disability at baseline and in all follow-up visits, consistent with previous literature[4, 5, 9, 30, 31]. Our study is unique in that we were able to demonstrate that over the course of 9 years of follow-up, there was little change in the year-to-year mean pain and disability scores for either WHs or AAs, with the exception of the first year follow-up among AAs. We found an average decline in knee pain severity between baseline and the first annual follow-up of 0.69 on a 10-point scale among AAs. To put this difference in context, this magnitude of change between group means is in the range of improvement observed for treatment of orthopedic conditions with established analgesics compared to placebo[32]. While AAs may have experienced a substantial improvement of symptoms over the course of a year, it is also possible that the decline reflects adaptation to repeated questionnaire administration, or regression to the mean due to high baseline levels of pain.

In previous cross-sectional studies, AAs with KOA, in comparison to WHs with KOA, generally reported more pain and greater physical disability using various PROMs[4, 5, 9, 30, 31]. A few studies[10-12, 33] did not find racial differences in patient-reported symptoms from OA. However, these studies specifically recruited patients with moderate to severe joint pain. Pain severity has also been reported to be higher among AAs compared to WHs across multiple pain conditions and in experimentally-induced pain[34-37]. These observed racial differences in KOA-related symptoms may be due to a combination of physiological and/or sociocultural factors[38]. AAs may have a different OA pain experience than WHs due to pathophysiologic OA changes or differential environmental sensory stressors, including prior pain sensitization, that disproportionately affect AAs. Previous studies have reported that AAs differ from other cultural groups in how they express and communicate pain[35, 39]. Cultural differences may influence descriptors used to characterize pain experience in terms of quality, intensity and triggers of pain.

The three previous studies that evaluated changes in KOA-related pain and function with multiple repeated observations over a long follow-up period were based on samples with little diversity. Peters *et al*[40] and Dieppe *et al*[41] conducted longitudinal studies evaluating cohorts with KOA over 7 and 8 years in the United Kingdom, respectively, and both studies reported overall worsening in average pain and function over time. Using group-based modeling, Leffondre *et al*[42] found 4 outcome trajectory patterns in knee/hip osteoarthritis pain in a Canadian sample: regularly increasing, regularly decreasing, stable, and unstable with fluctuations. Collins *et al*[43] also used group-based modeling but applied it to 6 years of OAI data, from which they identified 5 distinct WOMAC pain trajectories. None of these trajectories were characterized by substantial increase or decrease in pain over time, although an improvement in WOMAC pain between baseline and year one in these pain trajectories was noted. These study analyses were not stratified to examine differences by race, nor were those of any of the other longitudinal KOA studies[40-43].

Lower socioeconomic status and poor social support have been previously linked to having worse clinical outcomes among OA patients[7-9]. Hence, it is not surprising that AAs with lower household income and those who were not married reported the highest baseline pain severity from KOA in our

study. AAs who had higher income and were married had greater improvement in KOA-related pain during the first year. Perhaps having a better socioeconomic profile and more social support may improve access to healthcare and other resources that alleviate KOA symptoms, especially impacting AAs.

In parallel, obesity and depressed mood have been linked to worse WOMAC scores among KOA patients[10, 44]. In another cohort study, racial differences in KOA-related pain and function were no longer significant when adjusted for BMI and depressive symptoms[5]. Our study additionally showed that AAs with normal BMI and the mildest knee radiographic severity had a greater decline in KOA-related pain after the first visit. Having a better overall health profile is likely supportive in improving KOA-related symptoms among AAs.

Evaluation of group means longitudinally obscures within-person variability in pain and disability. Our study uniquely found that AAs were more likely than WHs to report both clinically relevant improvement and worsening of KOA pain and disability throughout the entire nine-year study period. The higher variability in symptom reporting among AAs over time may be interpreted as CID when using established cut-points, and may also be a consequence of higher reported symptom levels reported by AAs, as fluctuations in symptoms are to be expected over time among participants with higher pain levels. Self-report pain measures may be subject to differences in interpretation in a variety of populations based on sociodemographics, varying English proficiency ,and levels of cognitive impairment[34]. Although the metric properties of both WOMAC and the NRS for pain in different languages have been tested and validated[45-48], we are unaware of any study that has specifically examined the validity and reliability of the WOMAC and NRS between AAs and WHs in the US. Of note, there are eight different validated English language versions of the WOMAC that have been used across the world (www.womac.org). The need for multiple English versions suggests that cultural differences may lead to variations in symptom and disability reporting among individuals with knee OA. Our finding that there was more within-person variability in OA pain and disability among AAs when using the multi-item WOMAC pain and disability scales instead of the single-item NRS may also suggest that there may be cultural differences between AAs and WHs in the interpretation of these PROMs.

Our findings must be considered in the context of other limitations. The OAI is not a population-based study; participants with or at risk for KOA based on radiographic findings and risk factor profiles were recruited, limiting generalizability. The results of our study may also not be generalizable to patients with other types of OA or other PROMs used in the assessment of individuals with OA. Nevertheless, we were able to characterize racial differences in the reporting of KOA-related symptoms among those with or at high risk of KOA over nine years of follow-up, with consistent evidence of increased within-person variance in pain reporting among AAs.

PROMs are increasingly utilized in ambulatory care settings to track clinical course, determine response to prescribed therapies and evaluate the quality of care provided. Our findings underscore the need for greater communication between AA patients and their healthcare providers regarding patient reporting of KOA-related symptoms. Providers should be cognizant of possible race differences in patient-reported OA-related symptoms. In parallel, PROMs are accepted as primary endpoints in

randomized controlled trials of pharmacologic and non-pharmacologic interventions and are commonly used in observational studies to assess differences in outcomes. Investigators should be aware of potential fluctuations in participant-reported KOA pain among AAs, irrespective of treatment regimen. Clinical trial eligibility may also be biased for or against AAs who report higher osteoarthritis-related symptoms at baseline.

In summary, self-reported KOA-related pain and disability were persistently greater among AAs than among WHs over nine years of follow-up. Socioeconomically and clinically disadvantaged AAs reported the most pronounced disparities in pain and disability.

**Contributors**

CKK conceived the study. CKK and DR were responsible for the acquisition of the data. DR and ELA were responsible for the analyses. ERV wrote the first draft of the manuscript. All authors interpreted the data, critically revised the manuscript for important intellectual content and approved the final version of the manuscript.

**Conflict of Interest**

None of the authors declare any potential conflicts of interest in regard to this manuscript. Potential conflicts outside of this work: CKK has received grants from Abbvie and EMD Serono and consulted for Astellas, EMD Serono, Thusane, Express Scripts and Novartis. EV consulted for Astra Zeneca.

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**TABLES**

**Table 1. Baseline characteristics by race**

| Characteristic | White | African American |
|---|---|---|
| | Participant-level | |
| | (n=3498) | (n=778) |
| Age, years, mean(sd) | 61.89 (9.3) | 59.04 (8.5) |
| Sex, male, n (%) | 1560 (44.6) | 241 (31.0) |
| BMI, mean(sd) | 28.21 (4.7) | 31.11 (4.8) |
| Normal | 912 (26.1) | 74 (9.6) |
| Overweight | 1427 (40.8) | 248 (32.0) |
| Obese | 1159 (33.1) | 452 (58.4) |
| Education, n (%) | | |
| Less than or equal to high school | 454 (13.0) | 217 (28.6) |
| Some college or college graduate | 1555 (44.6) | 378 (49.7) |
| Some graduate school or graduate degree | 1478 (42.4) | 165 (21.7) |
| Household Income, >50K | 2248 (66.6) | 276 (38.2) |
| Marital status, married, n (%) | 2546 (73.0) | 293 (38.6) |
| Charlson Comorbidity Score, mean(sd) | 0.35 (0.8) | 0.56 (1.0) |
| CES-D, n (%) | 6.07 (6.4) | 8.76 (8.2) |
| No depression (CES-D<16) | 3203 (92.1) | 614 (81.9) |
| Mild to severe (CES-D ≥ 16) | 276 (7.9) | 136 (18.1) |
| SF-12 Physical summary scale, mean(sd) | 49.86 (8.4) | 44.76 (10.2) |
| SF-12 Mental summary scale, mean(sd) | 53.94 (7.6) | 52.18 (9.5) |
| KOOS Quality of Life Score, mean(sd) | 68.89 (21.1) | 57.00 (23.6) |
| | Knee-level | |
| | (n=6946) | (n=1546) |
| WOMAC Total Score, mean(sd) | 9.86 (12.7) | 21.13 (19.8) |
| WOMAC Pain Subscore, mean(sd) | 1.97 (2.8) | 4.32 (4.3) |
| WOMAC Stiffness Subscore, mean(sd) | 1.34 (1.5) | 2.25 (1.9) |
| WOMAC Disability Subscore, mean(sd) | 6.55 (9.1) | 14.60 (14.4) |
| Pain Severity in past 30 days, mean(sd) | 2.36 (2.5) | 4.01 (3.1) |
| KOOS Symptom Score, mean(sd) | 88.11 (13.7) | 79.88 (18.0) |
| K-L Grade, n (%) | | |
| 0 | 2693 (38.8) | 449 (29.0) |
| 1 | 1329 (19.1) | 219 (14.2) |
| 2 | 1744 (25.1) | 568 (36.7) |
| 3 | 937 (13.5) | 267 (17.3) |
| 4 | 243 (3.5) | 43 (2.8) |

BMI: Body Mass Index; CES-D: Center for Epidemiologic Studies Depression; K-L grade: Kellgren–Lawrence grade; KOOS: Knee Injury and Osteoarthritis Outcome Score; WOMAC: Western Ontario and McMaster Universities Arthritis Index

**Table 2. Baseline to 12 month change in WOMAC pain subscore, WOMAC disability subscore, and knee pain severity in past 30 days, by race**

| Measure | | White | | African American | | |
|---|---|---|---|---|---|---|
| WOMAC Pain Subscore | month | n | mean (95% CI) | n | mean (95% CI) | p-value |
| | Baseline | 3498 | 2.15 (2.06, 2.25) | 778 | 3.62 (3.44, 3.80) | <.0001* |
| | 12 | 3427 | 2.01 (1.91, 2.10) | 743 | 3.04 (2.86, 3.22) | <.0001* |
| | Δ | | -0.14 (-0.21, -0.07) | | -0.58 (-0.73, -0.42) | <.0001† |
| Knee Pain Severity in Past 30 days | Baseline | 3493 | 2.47 (2.38, 2.55) | 778 | 3.45 (3.30, 3.61) | <.0001* |
| | 12 | 3421 | 2.33 (2.25, 2.42) | 738 | 2.78 (2.62, 2.94) | <.0001* |
| | Δ | | -0.13 (-0.20, -0.07) | | -0.67 (-0.82, -0.53) | <.0001† |
| WOMAC Disability Subscore | Baseline | 3487 | 7.04 (6.72, 7.36) | 777 | 12.19 (11.58, 12.80) | <.0001* |
| | 12 | 3419 | 6.31 (5.98, 6.63) | 740 | 10.59 (9.98, 11.21) | <.0001* |
| | Δ | | -0.72 (-0.95, -0.51) | | -1.60 (-2.08, -1.11) | <.0001† |

Means estimated with mixed effects models adjusted for age, sex, education, marital status, BMI, CES-D, and baseline K-L grade

*Wald test for the difference between White and African American group mean scores
†Likelihood ratio test for the interaction between time and race

CES-D: Center for Epidemiologic Studies Depression Scale; K-L grade: Kellgren–Lawrence grade; WOMAC: Western Ontario and McMaster Universities Arthritis Index

**Table 3. Estimated variance components between African-Americans and Whites**

| Outcome measure | Variance between participants | (95%CI) | Variance between knees | (95%CI) | Variance within knee | (95%CI) |
|---|---|---|---|---|---|---|
| **WOMAC Pain** | | | | | | |
| AA | 8.72 | (7.75,9.88) | 2.39 | (2.08,2.77) | 7.54 | (7.34,7.74) |
| WH | 3.32 | (3.12,3.54) | 1.51 | (1.42,1.60) | 3.46 | (3.42,3.50) |
| **NRS** | | | | | | |
| AA | 3.93 | (3.46,4.49) | 1.44 | (1.25,1.67) | 4.75 | (4.63,4.88) |
| WH | 2.29 | (2.15,2.45) | 1.10 | (1.03,1.18) | 3.30 | (3.26,3.34) |
| **WOMAC Disability** | | | | | | |
| AA | 112.50 | (100.58,126.69) | 21.37 | (18.52,24.94) | 73.55 | (71.64,75.54) |
| WH | 45.96 | (43.49,48.64) | 11.39 | (10.67,12.19) | 32.12 | (31.73,32.51) |

NRS: Numerical Rating Scale; WOMAC: Western Ontario and McMaster Universities Arthritis Index

**FIGURES**

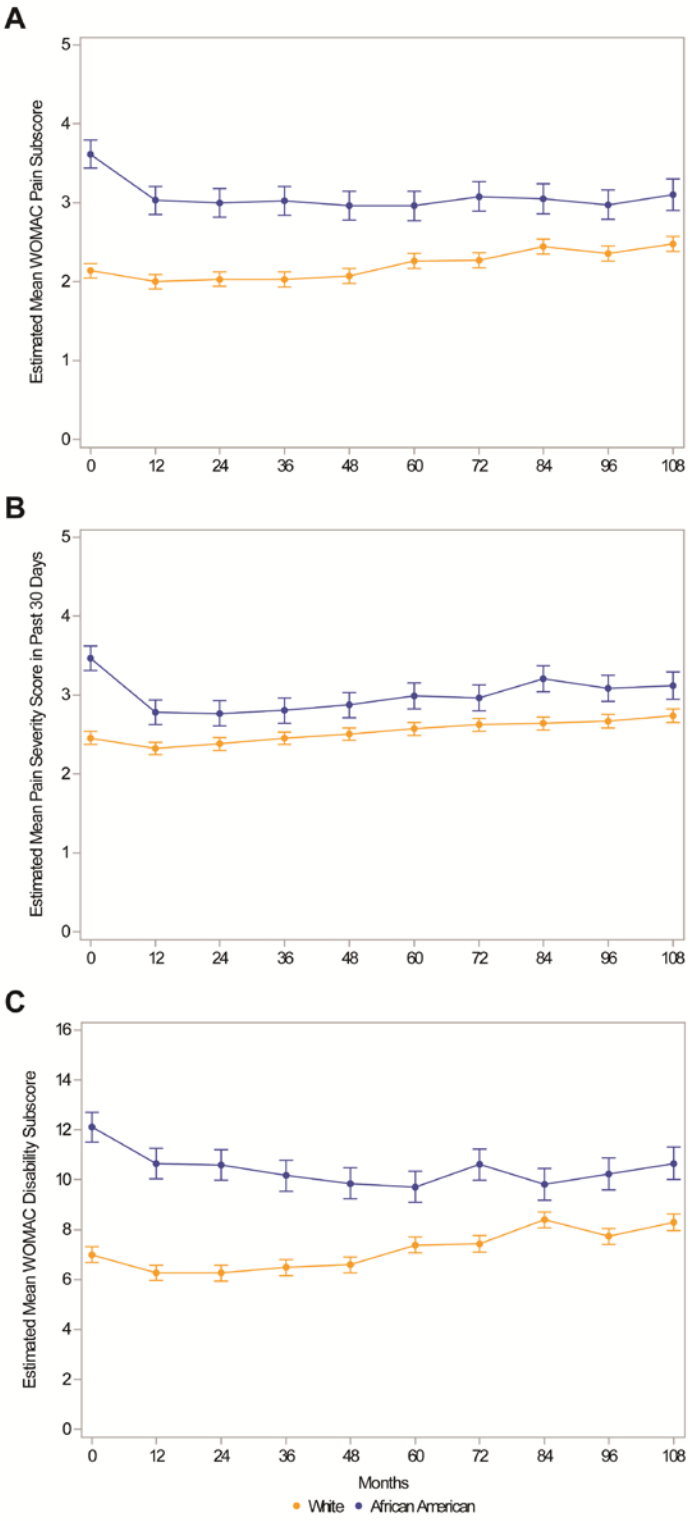



Figure 1. Means (with 95% CI) plot of KOA-related measures by race estimated with mixed effects models, adjusted for age, sex, education, marital status, BMI, CES-D, and baseline K-L grade. A. WOMAC Pain; B. Knee Pain Severity; C. WOMAC Disability.

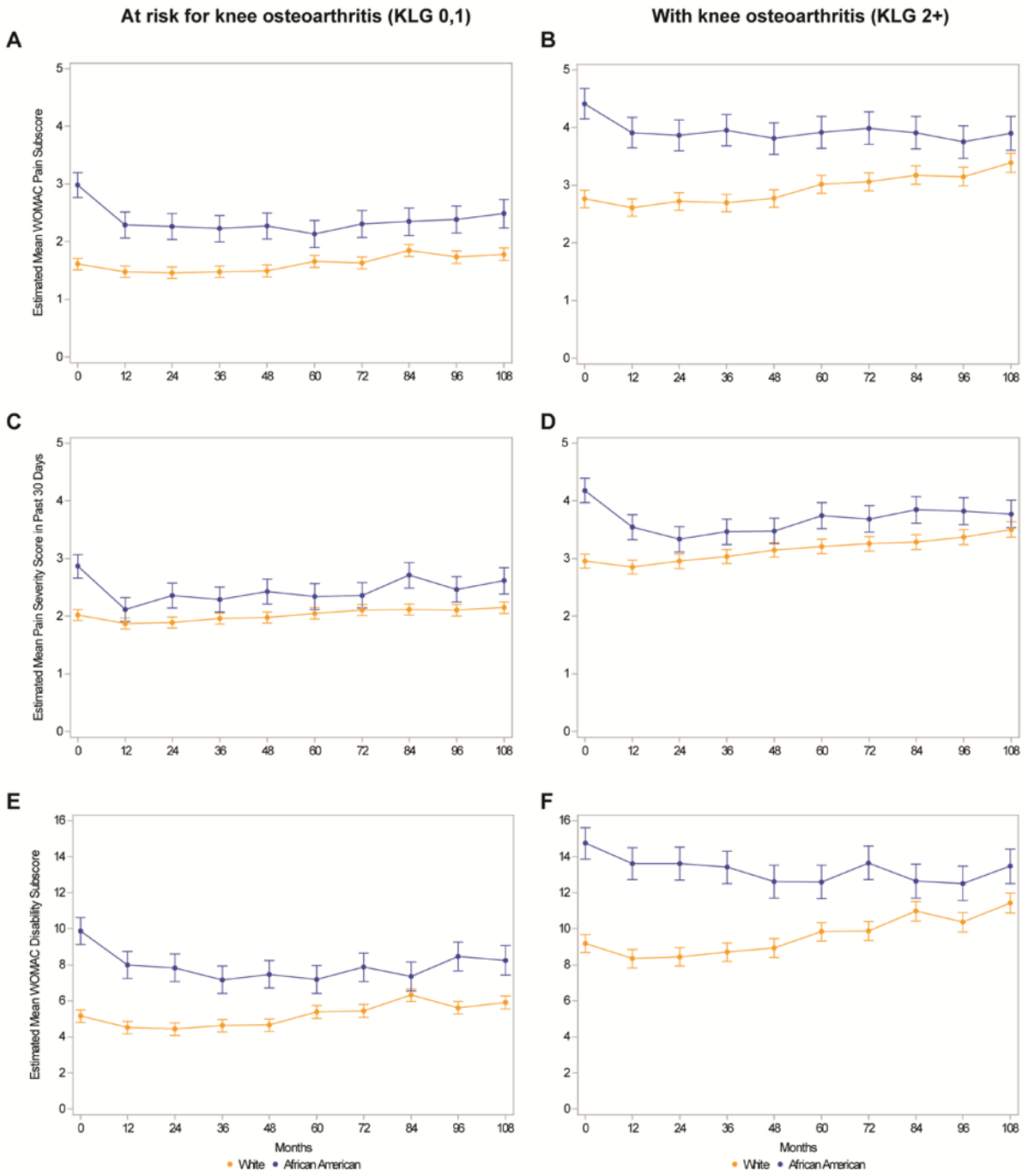



Figure 2. Means (with 95% CI) plot of KOA-related measures by race estimated with mixed effects models, stratified by radiographic KOA at baseline. A. WOMAC Pain, K-L<2; B. A. WOMAC Pain, K-L≥2; C. Knee Pain Severity, K-L<2; D. Knee Pain Severity, K-L≥2; E. WOMAC Disability, K-L<2; F. WOMAC Disability, K-L≥2.

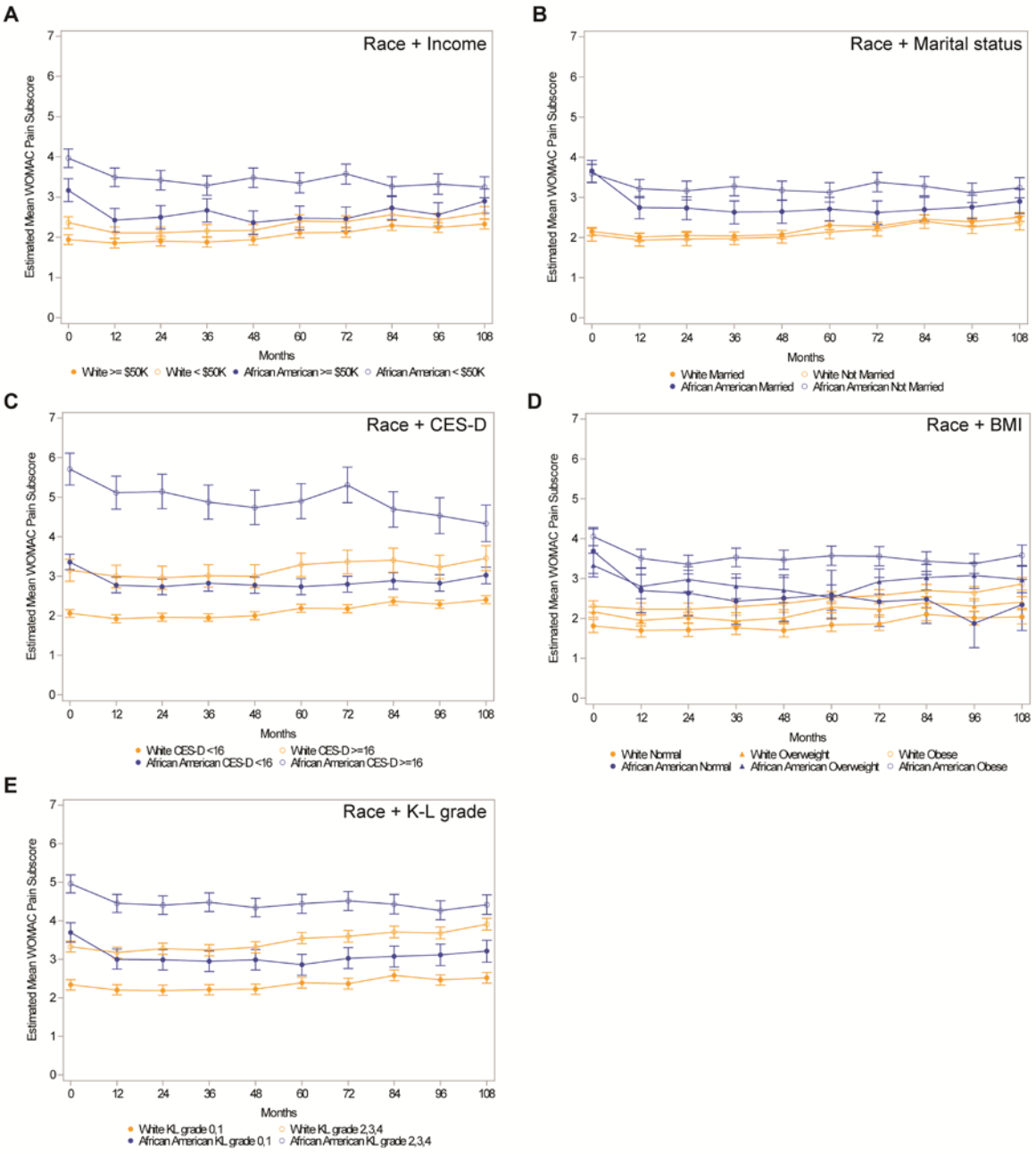
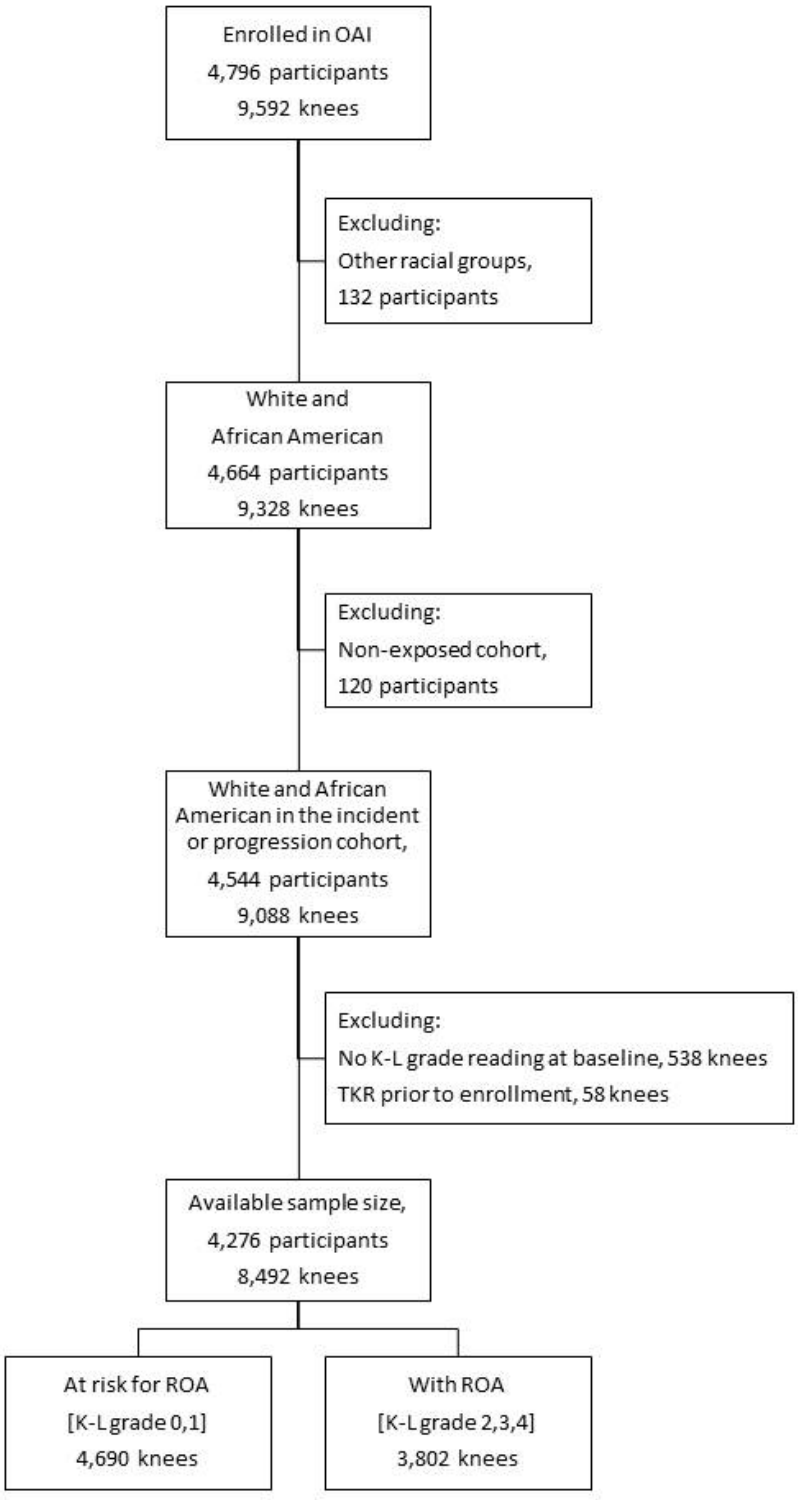
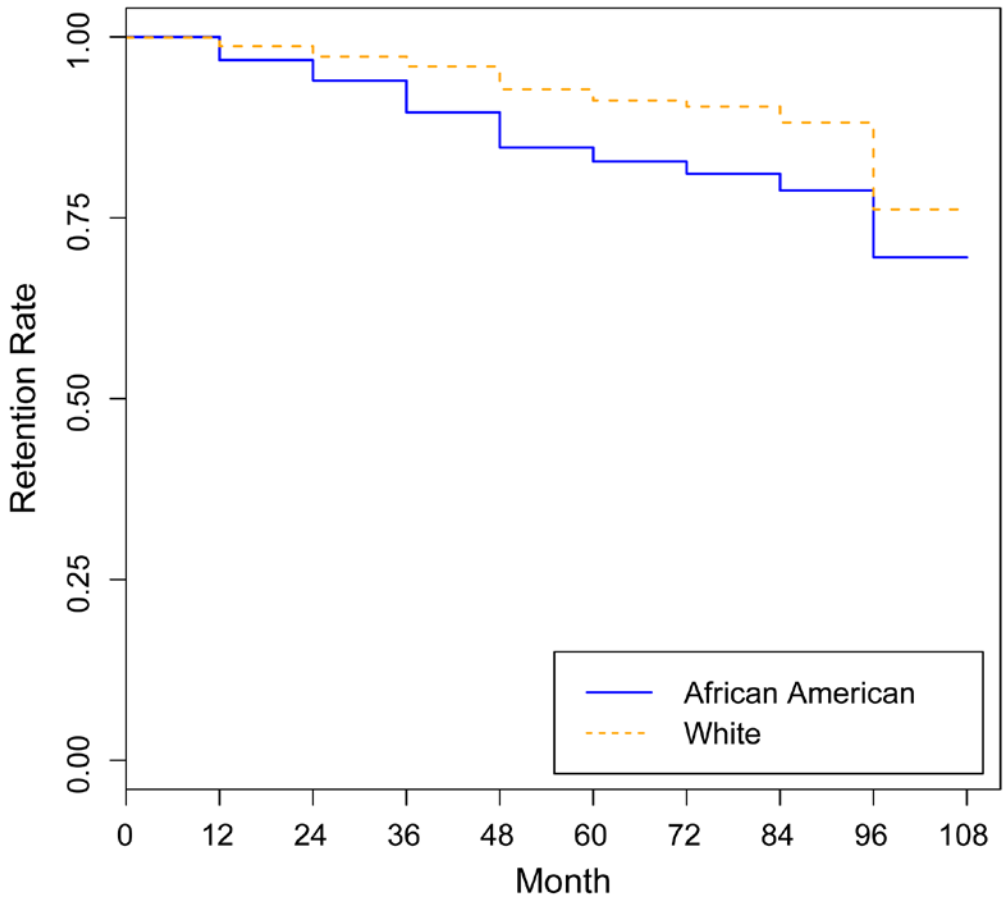



Figure 3. WOMAC pain means (with 95% CI) plot over 108 months estimated with mixed effects models, adjusted for age, sex, education, marital status, BMI, CES-D, and baseline K-L grade, stratified by: A. Income; B. Marital status; C. CES-D score (<16: without depression, ≥16: with depression); D. BMI category; E. K-L grade.

**SUPPLEMENT**




**Supplement 1.** Flow Chart




| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| African American | 778 | 778 | 753 | 731 | 697 | 659 | 644 | 631 | 613 | 541 |
| White | 3498 | 3495 | 3453 | 3403 | 3355 | 3245 | 3191 | 3162 | 3084 | 2664 |

**Supplement 2.** Retention in the OAI study by race based on time to final drop-out

**Supplement 3.** Means (with 95% CI) of KOA-related measures by race and group differences (with 95% CI) estimated with mixed effects models, adjusted for age, sex, education, marital status, BMI, CES-D, and baseline K-L grade.

| Month | n | AA | 95% CI | n | WH | 95% CI | Difference | 95% CI |
|---|---|---|---|---|---|---|---|---|
| | **WOMAC Pain** | | | | | | | |
| Baseline | 778 | 3.62 | (3.44, 3.80) | 3498 | 2.15 | (2.06, 2.25) | 1.46 | (1.26, 1.67) |
| 12 | 743 | 3.04 | (2.86, 3.22) | 3427 | 2.01 | (1.91, 2.10) | 1.03 | (0.83, 1.24) |
| 24 | 685 | 3.02 | (2.83, 3.20) | 3336 | 2.05 | (1.95, 2.14) | 0.97 | (0.77, 1.18) |
| 36 | 672 | 3.01 | (2.83, 3.20) | 3282 | 2.04 | (1.95, 2.14) | 0.97 | (0.76, 1.18) |
| 48 | 666 | 2.99 | (2.81, 3.18) | 3256 | 2.08 | (1.99, 2.18) | 0.91 | (0.71, 1.12) |
| 60 | 625 | 2.97 | (2.78, 3.16) | 3027 | 2.28 | (2.18, 2.38) | 0.69 | (0.48, 0.90) |
| 72 | 607 | 3.09 | (2.90, 3.28) | 2926 | 2.28 | (2.18, 2.38) | 0.81 | (0.59, 1.02) |
| 84 | 596 | 3.03 | (2.83, 3.22) | 2894 | 2.45 | (2.36, 2.55) | 0.57 | (0.36, 0.79) |
| 96 | 590 | 2.99 | (2.80, 3.19) | 2957 | 2.38 | (2.28, 2.48) | 0.61 | (0.40, 0.83) |
| 108 | 533 | 3.10 | (2.90, 3.30) | 2585 | 2.49 | (2.39, 2.59) | 0.61 | (0.39, 0.83) |
| | **Pain Severity in Past 30 Days** | | | | | | | |
| Baseline | 778 | 3.45 | (3.30, 3.61) | 3493 | 2.47 | (2.38, 2.55) | 0.99 | (0.81, 1.16) |
| 12 | 738 | 2.78 | (2.62, 2.94) | 3421 | 2.33 | (2.25, 2.42) | 0.45 | (0.27, 0.62) |
| 24 | 684 | 2.80 | (2.64, 2.96) | 3328 | 2.38 | (2.30, 2.47) | 0.42 | (0.24, 0.60) |
| 36 | 668 | 2.81 | (2.65, 2.97) | 3278 | 2.46 | (2.38, 2.54) | 0.35 | (0.17, 0.53) |
| 48 | 667 | 2.89 | (2.73, 3.06) | 3248 | 2.52 | (2.43, 2.60) | 0.38 | (0.19, 0.56) |
| 60 | 624 | 2.99 | (2.82, 3.16) | 3026 | 2.59 | (2.50, 2.67) | 0.41 | (0.22, 0.59) |
| 72 | 608 | 3.00 | (2.83, 3.17) | 2927 | 2.64 | (2.56, 2.73) | 0.36 | (0.17, 0.55) |
| 84 | 596 | 3.21 | (3.04, 3.38) | 2895 | 2.65 | (2.57, 2.74) | 0.56 | (0.37, 0.74) |
| 96 | 590 | 3.10 | (2.93, 3.27) | 2959 | 2.67 | (2.59, 2.76) | 0.42 | (0.24, 0.61) |
| 108 | 534 | 3.12 | (2.95, 3.30) | 2585 | 2.75 | (2.67, 2.84) | 0.37 | (0.18, 0.56) |
| | **WOMAC Disability** | | | | | | | |
| Baseline | 777 | 12.19 | (11.58, 12.80) | 3487 | 7.04 | (6.72, 7.36) | 5.15 | (4.46, 5.84) |
| 12 | 740 | 10.59 | (9.98, 11.21) | 3419 | 6.31 | (5.98, 6.63) | 4.29 | (3.59, 4.98) |
| 24 | 679 | 10.67 | (10.04, 11.29) | 3316 | 6.31 | (5.99, 6.64) | 4.35 | (3.65, 5.06) |
| 36 | 666 | 10.20 | (9.56, 10.83) | 3261 | 6.52 | (6.19, 6.84) | 3.68 | (2.97, 4.38) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 48 | 661 | 9.93 | (9.30, 10.57) | 3240 | 6.63 | (6.30, 6.95) | 3.31 | (2.60, 4.03) |
| 60 | 619 | 9.70 | (9.06, 10.35) | 3009 | 7.43 | (7.10, 7.76) | 2.27 | (1.55, 2.99) |
| 72 | 600 | 10.66 | (10.01, 11.31) | 2904 | 7.47 | (7.13, 7.80) | 3.19 | (2.47, 3.91) |
| 84 | 580 | 9.79 | (9.14, 10.44) | 2869 | 8.44 | (8.10, 8.77) | 1.35 | (0.62, 2.08) |
| 96 | 565 | 10.30 | (9.64, 10.96) | 2759 | 7.78 | (7.44, 8.11) | 2.52 | (1.79, 3.26) |
| 108 | 522 | 10.67 | (10.01, 11.34) | 2549 | 8.34 | (8.00, 8.68) | 2.33 | (1.59, 3.08) |

**Supplement 4.** Baseline to 12 month change in WOMAC pain subscore, by socioeconomic status, clinical indicators, and depression at baseline

| | | | White | | African American |
|---|---|---|---|---|---|
| | month | n | mean (95% CI) | n | mean (95% CI) |
| Household Income | | | | | |
| ≥ $50,000 | 0 | 2248 | 2.00 (1.87, 2.13) | 276 | 3.26 (2.97, 3.55) |
| | 12 | 2205 | 1.91 (1.78, 2.03) | 263 | 2.51 (2.22, 2.80) |
| | Δ | | -0.09 (-0.17, -0.01) | | -0.74 (-0.98, -0.51) |
| < $50,000 | 0 | 1126 | 2.41 (2.26, 2.56) | 446 | 4.03 (3.80, 4.27) |
| | 12 | 1095 | 2.18 (2.03, 2.32) | 421 | 3.56 (3.32, 3.80) |
| | Δ | | -0.24 (-0.35, -0.12) | | -0.47 (-0.66, -0.29) |
| Marital Status | | | | | |
| Married | 0 | 2546 | 2.33 (2.22, 2.44) | 293 | 3.78 (3.50, 4.07) |
| | 12 | 2487 | 2.18 (2.07, 2.29) | 278 | 2.91 (2.62, 3.19) |
| | Δ | | -0.15 (-0.23, -0.07) | | -0.88 (-1.11, -0.64) |
| Not married | 0 | 939 | 2.06 (1.90, 2.23) | 467 | 3.58 (3.35, 3.82) |
| | 12 | 920 | 1.95 (1.78, 2.11) | 443 | 3.19 (2.95, 3.43) |
| | Δ | | -0.12 (-0.24, 0.01) | | -0.39 (-0.58, -0.21) |
| Depression | | | | | |
| No depression (CES-D<16) | 0 | 3202 | 2.11 (2.01, 2.21) | 614 | 3.46 (3.26, 3.66) |
| | 12 | 3134 | 1.97 (1.87, 2.08) | 585 | 2.90 (2.70, 3.10) |
| | Δ | | -0.14 (-0.21, -0.07) | | -0.56 (-0.72, -0.40) |
| Mild to Severe (CES-D≥16) | 0 | 276 | 3.23 (2.93, 3.52) | 136 | 5.75 (5.32, 6.18) |
| | 12 | 266 | 3.05 (2.76, 3.34) | 126 | 5.07 (4.64, 5.51) |
| | Δ | | -0.18 (-0.41, 0.07) | | -0.68 (-1.03, -0.33) |
| Body Mass Index | | | | | |
| Normal | 0 | 912 | 1.89 (1.72, 2.06) | 74 | 3.62 (3.04, 4.19) |
| | 12 | 894 | 1.79 (1.62, 1.96) | 72 | 2.80 (2.22, 3.38) |
| | Δ | | -0.10 (-0.23, 0.03) | | -0.82 (-1.29, -0.35) |
| Overweight | 0 | 1427 | 2.24 (2.10, 2.38) | 248 | 3.32 (3.01, 3.63) |
| | 12 | 1389 | 2.01 (1.87, 2.15) | 234 | 2.79 (2.48, 3.11) |
| | Δ | | -0.23 (-0.33, -0.12) | | -0.53 (-0.78, -0.27) |
| Obese | 0 | 1158 | 2.38 (2.23, 2.52) | 452 | 4.14 (3.90, 4.37) |
| | 12 | 1134 | 2.31 (2.16, 2.46) | 429 | 3.57 (3.33, 3.81) |
| | Δ | | -0.07 (-0.18, 0.05) | | -0.57 (-0.76, -0.38) |
| K-L Grade | | | | | |
| 0,1 | 0 | 1987 | 2.34 (2.19, 2.48) | 318 | 3.66 (3.39, 3.93) |
| | 12 | 1949 | 2.20 (2.05, 2.35) | 304 | 3.01 (2.73, 3.28) |
| | Δ | | -0.13 (-0.22, -0.05) | | -0.65 (-0.87, -0.43) |
| 2,3,4 | 0 | 1510 | 3.44 (3.28, 3.60) | 460 | 5.12 (4.87, 5.36) |
| | 12 | 1468 | 3.29 (3.13, 3.44) | 435 | 4.60 (4.34, 4.85) |
| | Δ | | -0.15 (-0.25, -0.05) | | -0.52 (-0.72, -0.33) |

CES-D: Center for Epidemiologic Studies Depression Scale; K-L grade: Kellgren–Lawrence grading scale

All means and differences were estimated with mixed effects models and adjusted for age, sex, BMI, education level, marital status, CES-D, and baseline K-L grade.

**Supplement 5.** Association between race and clinically important differences in pain and disability over consecutive annual visits*

| | | Worsening | | | Improvement | | |
|---|---|---|---|---|---|---|---|
| | | White | African American | | White | African American | |
| | Interval (Months) | n (%) | n (%) | $OR_W$ (95% CI) | n (%) | n (%) | $OR_I$ (95% CI) |
| WOMAC Pain Subscore | 0-12 | 613 (9.0) | 208 (14.2) | 2.10 (1.74, 2.54) | 1231 (18.1) | 467 (31.8) | 2.37 (2.06, 2.74) |
| | 12-24 | 630 (9.8) | 231 (17.8) | 2.28 (1.90, 2.74) | 949 (14.7) | 293 (22.5) | 1.93 (1.64, 2.29) |
| | 24-36 | 574 (9.1) | 201 (16.3) | 2.25 (1.85, 2.73) | 952 (15.1) | 292 (23.6) | 1.97 (1.66, 2.33) |
| | 36-48 | 591 (9.5) | 209 (17.3) | 2.33 (1.92, 2.82) | 910 (14.6) | 285 (23.5) | 2.08 (1.74, 2.47) |
| | 48-60 | 699 (12.0) | 191 (16.0) | 1.63 (1.34, 1.98) | 831 (14.3) | 284 (23.8) | 2.06 (1.72, 2.45) |
| | 60-72 | 572 (10.2) | 219 (19.0) | 2.37 (1.96, 2.88) | 933 (16.6) | 276 (23.9) | 1.85 (1.55, 2.20) |
| | 72-84 | 662 (12.0) | 197 (17.4) | 1.80 (1.47, 2.19) | 745 (13.5) | 260 (22.9) | 2.12 (1.76, 2.54) |
| | 84-96 | 546 (10.3) | 183 (16.8) | 2.05 (1.67, 2.52) | 921 (17.3) | 278 (25.5) | 1.86 (1.56, 2.23) |
| | 96-108 | 558 (11.4) | 188 (18.7) | 2.04 (1.65, 2.51) | 740 (15.1) | 226 (22.5) | 1.87 (1.54, 2.27) |
| Pain Severity in Past 30 Days | 0-12 | 1332 (19.8) | 263 (18.2) | 1.10 (0.93, 1.31) | 1529 (22.7) | 493 (34.1) | 1.84 (1.58, 2.13) |
| | 12-24 | 1340 (20.9) | 276 (21.4) | 1.08 (0.91, 1.28) | 1242 (19.4) | 284 (22.1) | 1.20 (1.01, 1.43) |
| | 24-36 | 1286 (20.6) | 284 (23.2) | 1.25 (1.05, 1.48) | 1123 (18.0) | 255 (20.9) | 1.28 (1.07, 1.52) |
| | 36-48 | 1248 (20.2) | 289 (24.1) | 1.36 (1.14, 1.62) | 1159 (18.7) | 263 (22.0) | 1.33 (1.11, 1.59) |
| | 48-60 | 1199 (20.7) | 288 (24.3) | 1.32 (1.11, 1.57) | 1096 (18.9) | 258 (21.7) | 1.29 (1.08, 1.55) |
| | 60-72 | 1172 (20.8) | 256 (22.2) | 1.16 (0.97, 1.39) | 1081 (19.2) | 258 (22.4) | 1.27 (1.06, 1.51) |
| | 72-84 | 1080 (19.6) | 276 (24.3) | 1.38 (1.15, 1.65) | 1028 (18.7) | 226 (19.9) | 1.18 (0.98, 1.42) |
| | 84-96 | 1044 (19.6) | 249 (22.8) | 1.37 (1.14, 1.65) | 995 (18.7) | 269 (24.7) | 1.56 (1.30, 1.87) |
| | 96-108 | 969 (19.8) | 252 (25.1) | 1.52 (1.26, 1.84) | 867 (17.7) | 230 (22.9) | 1.55 (1.27, 1.89) |
| WOMAC Disability Subscore | 0-12 | 1032 (15.3) | 388 (26.7) | 2.37 (2.00, 2.80) | 728 (10.8) | 261 (17.9) | 2.20 (1.83, 2.65) |
| | 12-24 | 680 (10.6) | 249 (19.4) | 2.33 (1.92, 2.83) | 757 (11.8) | 252 (19.6) | 2.10 (1.74, 2.54) |
| | 24-36 | 650 (10.5) | 255 (21.0) | 2.65 (2.17, 3.23) | 753 (12.1) | 244 (20.1) | 2.20 (1.81, 2.66) |
| | 36-48 | 699 (11.4) | 247 (20.8) | 2.40 (1.98, 2.92) | 717 (11.7) | 240 (20.2) | 2.29 (1.88, 2.78) |
| | 48-60 | 594 (10.3) | 248 (21.2) | 2.59 (2.12, 3.18) | 932 (16.1) | 226 (19.3) | 1.49 (1.23, 1.82) |

| | | | | | | |
|---|---|---|---|---|---|---|
| **60-72** | 720 (13.0) | 210 (18.6) | 1.82 (1.48, 2.24) | 722 (13.0) | 262 (23.2) | 2.28 (1.87, 2.78) |
| **72-84** | 511 (9.4) | 231 (21.1) | 2.75 (2.23, 3.39) | 949 (17.5) | 206 (18.8) | 1.32 (1.07, 1.62) |
| **84-96** | 830 (15.9) | 191 (18.1) | 1.40 (1.13, 1.73) | 593 (11.4) | 234 (22.2) | 2.41 (1.96, 2.96) |
| **96-108** | 535 (11.2) | 186 (19.1) | 2.17 (1.73, 2.71) | 740 (15.4) | 221 (22.7) | 1.86 (1.51, 2.29) |

*Multinomial logistic regression was used to compare the odds of reporting worsening ($OR_W$) and the odds of reporting improvement ($OR_I$), for AAs compared to WHs, for each pair of consecutive OAI visits; the referent outcome was reporting no CID
†CID criteria: ≤-1.5 for improvement, ≥2.2 for worsening [27]
‡CID criteria: ≤-1.7 for improvement; ≥1.7 for worsening [28]
§CID criteria: ≤-6.0 for improvement; ≥6.0 for worsening [29]

WOMAC: Western Ontario and McMaster Universities Arthritis Index