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Annual Incidence of Knee Symptoms and Four Knee Osteoarthritis Outcomes in the Johnston County Osteoarthritis Project

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Abstract

Objective—To estimate annual incidence rates (IR) of knee symptoms and four knee OA outcomes (radiographic, symptomatic, severe radiographic and severe symptomatic) overall and stratified by socio-demographic characteristics and knee OA risk factors.

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Ethics
The study was approved by the Institutional Review Boards of the University of North Carolina Schools of Medicine and Public Health, and the Centers for Disease Control and Prevention. All participants gave written informed consent at recruitment.

Methods—We analyzed baseline [1991–1997] and first follow-up [1999–2003] data (n=1,518) from Johnston County Osteoarthritis Project. Participants are black and white adults ≥ 45 years living in Johnston County, North Carolina, US. Knee symptoms were pain, aching, or stiffness on most days in a knee. Radiographic OA was K-L grade ≥ 2 (severe radiographic ≥3) in at least one knee. Symptomatic OA was symptoms in a radiographically affected knee; severe symptomatic OA was severe symptoms and severe radiographic OA.

Results—The median follow-up time was 5.5 years. Average annual IRs were: symptoms=6%, radiographic OA=3%, symptomatic OA=2%, severe radiographic OA=2%, and severe symptomatic OA=0.8%. Across outcomes, IRs were highest among those with the following baseline characteristics: age ≥ 75 years; obese; a history of knee injury; or an annual household income ≤ $15,000.

Conclusion—The annual onset of knee symptoms and four OA outcomes in Johnston County was high. This may preview the future of knee OA in the US and underscores the urgency of clinical and public health collaborations that reduce risk factors for, and manage the impact of, these outcomes. Inexpensive, convenient and proven strategies (e.g., physical activity, self-management education courses) complement clinical care, and can reduce pain and improve quality of life for people with arthritis.

Keywords

knee osteoarthritis; knee pain; knee symptoms; population studies; socio-economic factors; epidemiology; osteoarthritis incidence

Introduction

Knee osteoarthritis (OA) is the most common type of lower extremity OA. OA incidence studies indicate that women, older adults, and those who are obese or have a history of a knee injury have a moderate to strongly increased risk of knee symptoms, and radiographic and symptomatic OA (1–3). Most knee OA incidence studies have estimated associations between risk factors and knee OA outcomes; fewer provide descriptive occurrence measures (e.g., incidence rates [IR]). Knowing the rate of new cases entering a population potentially indicates the current and future impact of a health condition. This is especially relevant for knee OA because it is the primary indication for knee joint replacements, a costly medical procedure which is one of the most common reasons for hospitalization in the United States (4).

Previous knee descriptive studies have examined specific population subgroups (e.g., older women, whites) (5–13). Several reported cumulative prevalence proportions which may not account for varying follow-up time across cohort members (8). Cohort attrition is endemic to longitudinal studies but its potential impact on estimates is largely unexamined. Some studies occurred several decades ago and may have limited contemporary generalizability given the current global obesity epidemic (14). Additionally, there has been little quantification of incidence among blacks, who represent 14% of the US population and are among the most rapidly increasing race/ethnic groups in the US (15).

Recognizing these gaps, we estimated annual IR of knee symptoms and four knee OA outcomes (radiographic, symptomatic, severe radiographic, and severe symptomatic knee OA) in a more racially diverse and contemporary sample, the Johnston County Osteoarthritis (JoCo OA) Project cohort.

Methods

Study sample

The JoCo OA Project is a longitudinal population-based investigation of hip and knee OA occurrence and natural history. It was designed to provide data representing the population of civilian, non-institutionalized, white and black adults age ≥ 45 years who were permanent residents of one of six selected townships in Johnston County, North Carolina, and were physically and mentally capable of study completion. The institutional review boards of the Centers for Disease Control and Prevention and the University of North Carolina School of Medicine approved the study's protocol. The project's methods are described in detail elsewhere (16).

We analyzed baseline (1991–1997) and first follow-up (1999–2003) data. At both baseline and follow-up, participants completed an in-home interview, clinical examination, and another in-home interview approximately two weeks following the initial interview. Bilateral anteroposterior knee radiographs with weight bearing and foot map positioning were obtained during the clinic examination. A single bone and joint radiologist (JBR) -- with high reliability (interrater and intrarater weighted kappa = 0.86 and 0.89, respectively) -- read the radiographs using Kellgren-Lawrence (K–L) grades (17, 18).

Anticipated attrition ("reduction in number of participants as study progresses"(19)) was minimized using various strategies (e.g., annual newsletters, personal networks of participants and JoCo OA Project staff, local advertising, medical providers, and community inquiries). Participants' deaths were identified through the National Death Index (NDI) which is the most complete source of US mortality data (estimated completeness=99%) (20).

Outcome definitions

We estimated IRs for five knee outcomes: symptoms and four types of OA (radiographic, symptomatic, severe radiographic and severe symptomatic). People rather than knee joints were the analytic unit because people are the focus of clinical and public health systems. For each outcome, an incident case was someone who did not have the outcome in either knee at baseline but did, in at least one knee, at first follow-up.

Knee symptoms were defined as "yes" to "On **most** days, do you have pain, aching, or stiffness in your (*right, left*) knee?" Those responding "yes" were asked "Is the pain in your (*right, left*) knee mild, moderate, or severe?" Radiographic and severe radiographic OA were defined as Kellgren-Lawrence (K–L) grade ≥2 and ≥3, respectively. Symptomatic knee OA was defined as both radiographic OA (K-L grade ≥2) and symptoms in the same knee; severe symptomatic was defined similarly except radiographically affected knee pain was severe. Those with a radiographically identified total knee replacement (TKR) (<1% of JoCo OA Project participants at baseline) were classified as having all five outcomes. (21)

Our study's purpose was to estimate incidence; therefore, those with the outcomes of interest at baseline (either knee symptoms and radiographic OA combined, or TKRs [n=150]) were ineligible and excluded from all analyses (Table 1). Of the remaining eligible 2,918 participants, approximately half (1,518) had complete baseline and follow-up data (Table 1; Appendix). For each outcome, we analyzed a specific subset that excluded those who had the outcome of interest at baseline (e.g., respondents with baseline symptoms and KL grade < 2 were ineligible for the symptom analysis). Throughout this report, we use '*baseline only*' (n=1,400) and '*analytic*' (n=1,518) to refer to those present at baseline only and both baseline and first follow-up, respectively.

Statistical analyses

We described the analytic population (weighted sample) by examining the baseline distribution of: self-reported socio-demographic characteristics (age, sex, race, marital status, highest education, annual household income); three knee OA risk factors (body mass index [BMI] at age 18, baseline BMI , and knee injury history); and presence and severity of symptoms. Age was examined in four categories: 45–54, 55–64, 65–74, ≥ 75 years, and baseline BMI (kilograms/meter^2) was examined in three (under/normal weight [<25]; overweight [25-<30]; obese [≥30]) and four (under/normal weight [<25]; overweight [25-<30]; obese class I [30-<35] and ≥ II [≥35]) categories. History of knee injury was ascertained during clinic examination with: "Have you ever injured your (*right, left*) knee?"

IRs—We estimated IRs and 95% confidence intervals (CI) overall and by each of five socio-demographic characteristics (age, sex, race, highest education, annual household income) and the three knee OA risk factors described above. Then, we repeated this stratified analysis, further stratified by race. For each outcome, we estimated overall crude, age-, and age- and sex- standardized IRs. We generated crude estimates to indicate the true or actual annual number of new cases which may be most useful for public health practice, and standardized estimates (age groups 45–54, 55–64, 65–74, ≥ 75 years in 2000 projected US population) to facilitate comparison with other studies (22, 23).

We computed IRs using estimated regression parameters (i.e., intercepts and slopes) from log-linear count models. These methods are described in detail elsewhere (24). Our method yields values close to manual calculation of IRs (number of new cases/number of person-years) which we believe previous studies used to calculate IRs. We used a log-linear count model -- a generalized form of the Poisson regression model -- because the former accommodates clustering from the complex sampling design and also allows for overdispersion (i.e., log-linear count model allows for greater variability in data distribution than a Poisson model). Models included an offset of the log of each participant's observation time to account for participants' variable observation time. For each outcome, we ran 17 models: one model for the overall estimate, eight separate models for each independent variable [five socio-demographic variables and three knee OA risk factors described in previous paragraph], and eight separate models for the race-specific analysis of the four socio-demographic variables [excluding race] and three knee OA risk factors. Race-specific models included an additional race parameter but did not include an interaction term because, for most variables, we lacked sufficient sample size (and corresponding statistical power). We used a model-based approach to facilitate CI estimation that fully accounted for the complex survey design (described below) and significance testing.

Attrition sensitivity analysis—To identify the potential impact of cohort attrition on results, we compared the distributions (weighted) of characteristics in the *analytic* and *baseline only* populations and tested for statistically significant differences (α= 0.05) in the distribution of these populations using a χ^2 test for complex survey data (25). We interpreted any statistically significant difference as a potential source of selection bias. We did not adjust this test for multiple comparisons to detect all potential sources of attrition. Upon identifying characteristics that were significantly different, we estimated IRs that were adjusted using the distribution of these characteristics (i.e., adjusted marginal estimates (26)) for the entire baseline population; i.e., we calculated an overall IR by generating a stratified model, weighting model coefficients with the corresponding proportions from the weighted distributions of these characteristics in the entire baseline sample.

Income imputation—Of all baseline characteristics studied, income had the highest proportion of missing values. Therefore, we conducted multiple imputation using R version 3.0 to assess the impact of missing income values using the following baseline variables in the model: socio-demographics (age [categorical], sex, race, marital status, education), knee OA risk factors and outcomes (BMI at age 18 and study baseline, history of knee injury, K-L grade, knee symptom severity), characteristics potentially associated with income (home ownership, home dwelling type (single family, apartment), employment status (employed, unemployed, retired, disabled), health insurance type (private, public, none/other)), personal health characteristics (alcohol use [none, <3, ≥3 drinks per week], smoking (never, former, current), physical activity <10, ≥10 minutes/week), and chronic conditions [history of stroke, cancer, lung disease, or heart disease]), and sample design information (stratum and median income per primary sampling unit). Primary sampling units (PSUs) were clusters of households along streets where a street was defined as the full length of a named thoroughfare. Within townships, PSUs were stratified by street characteristics (urban/rural and racial/ethnic composition)(16). We estimated average annual IRs using five multiply-imputed datasets; results were combined and adjusted to account for nonresponse and imputation (27).

Sample weighting—JoCo OA Project data are based on a complex sampling design involving varying selection probabilities, sample stratification, and cluster sampling. We accounted for the complex survey design as follows. We applied sampling weights in all analyses so that estimates fully accommodate the varying selection probabilities and differential response rates among members of the chosen sample and are thus representative of the population in the six Johnston County townships. The final weighted sample of respondents was calibrated to 2000 census population counts for the target area. The study's sampling and weighting methods are described in detail elsewhere (16).

Statistical analyses were performed using SUDAAN version 10.0 (28), SAS version 9.2 (29), and R software version 2.14 (30). We tested for statistically significant differences in IRs using a Wald test; variances were estimated using jackknifing to account for the sampling design (31). 95% CIs were estimated using jackknifing, a replication method that accounts for the stratification and clustering of the survey's complex design(30, 31). Furthermore, a finite correction was applied to adjust for sampling without replacement (31). Unadjusted p-values are presented, but we adopted a Bonferroni correction to adjust for multiple comparisons: α=0.00125 as the significance level (α=0.05/40 [5 OA outcomes * 8 independent variables]). For race-specific analyses we used the same significance level (α=0.00125) which is slightly more conservative than using a specific Bonferroni correction for the race-specific models (α=0.05/35=0.0014 [5 OA outcomes * 7 independent variables).

Results

Population characterization

Median follow-up for the *analytic* population (n=1,518) was 5.5 years (range 3–13 years). At baseline, the population was predominantly women (58%), white (79%) and < 65 years (80%)(Table 2). Most were married (72%) and had completed at least high school (89%). A quarter (24%) had an annual household income of < $15,000, and 29% > $35,000; income was unknown for 17%. Whereas only 10% were overweight or obese at age 18, most were overweight (43%) or obese (27%) at baseline. Among those who were obese, a third were Class ≥ II (BMI ≥ 35). One in six respondents reported an injury in at least one knee. Of the 36% who reported knee symptoms on most days, 17% (6% of entire analytic population) reported severe symptoms.

Annual IRs

We have reported annual IRs as percentages, which is equivalent to number of cases per 100 person-years. Statistical significance level was α=0.00125.

Overall—Across the five outcomes, IRs were highest for symptoms (5.6%; 95% CI=5.1–6.1) followed by radiographic OA (2.8%; 95% CI=2.5–3.2), symptomatic OA (2.1%; 95% CI=1.9–2.4), severe radiographic OA (1.7%; 95% CI=1.5–1.9), and severe symptomatic OA (0.8%; 95% CI=0.7–0.9) (Table 3). For each outcome, crude and age-standardized IRs were nearly identical (Table 3). Age- and sex- standardized estimates were similar to crude IRs for symptoms, symptomatic, and severe symptomatic OA, but slightly higher for radiographic (3.6% and 2.8%) and severe radiographic OA (2.2% and 1.7%) (Table 3).

Socio-demographic characteristics

Age—For all outcomes, age-specific IRs were highest among those age ≥ 75 years compared with the youngest age group (45–54) (Table 3). IRs for radiographic, symptomatic, and severe radiographic OA rose with increasing age; IR differences for radiographic and severe radiographic OA were statistically significant.

Sex—Sex-specific IRs were slightly higher for women for symptoms, symptomatic OA and severe symptomatic OA, but differences were not statistically significant.

Race—Race-specific IRs were slightly higher for blacks for symptoms, symptomatic OA, and severe radiographic OA; differences were not statistically significant.

Highest educational attainment—IRs for radiographic and severe radiographic OA IRs declined with rising levels of education, but were only significantly different for severe radiographic OA.

Annual household income—Among those with known income, IRs decreased with increasing household income (Table 3) for most outcomes, but this was statistically significant only for knee symptoms. The magnitude and pattern of IRs were the same in the primary and income imputed analysis (data not shown).

Knee OA risk factors

Self-reported BMI at age 18—IRs for severe radiographic OA were twice as high among those who were overweight/obese compared with those who were under/normal weight at age 18 (IRs=3.0 [95% CI=2.2–4.1] and 1.5 [95% CI=1.3–1.8], respectively) (statistically significant difference). They were similar for each of the other outcomes.

Clinically measured BMI at baseline—Across all five outcomes, IRs rose consistently with increasing BMI level; for four OA outcomes (radiographic, symptomatic, severe radiographic, severe symptomatic), IRs for the three major BMI categories (under/normal weight, overweight, and obese) were statistically significant different. Findings were similar when BMI was examined in four categories (under/normal weight, overweight, obese class I, and obese class ≥ II), except that radiographic OA were not statistically significant different.

History of knee injury—Whereas IRs for symptoms did not differ, IRs were significantly higher among those with a history of knee injury across each of the four OA outcomes (Table 3).

Race-stratified analyses

With few exceptions, IRs were slightly higher in magnitude for blacks than whites (Table 4)]. The largest difference in the magnitude of race-specific IRs across the five outcomes was for symptoms, where IRs were approximately 1 to 1.5 percentage points higher among blacks than whites in all analyses. Across all socio-demographic and risk factors, patterns in race-specific IRs and significant differences (at Bonferroni adjusted α=0.00125) were similar to the overall sample (Tables 3 and 4).

Attrition sensitivity analysis—Characteristics of the *baseline only* and *analytic* populations overall and for each of the five outcomes are presented in Appendix Table. Comparison of the overall *baseline only* and *analytic* populations indicated a statistically significant difference (α=0.05) in seven characteristics (age[categorical], sex, race, marital status, education, annual household income, baseline BMI, and symptom presence); symptom severity also differed but was not included because it is a component of three of the outcomes. None of the overall IRs (adjusted marginal estimates for the entire baseline population) differed significantly from the crude IRs from the primary analyses; the magnitudes of IRs for three of the five outcomes (knee symptoms and radiographic and symptomatic OA) were nearly identical (Table 3).

Discussion

Average annual IRs of knee symptoms and radiographic, symptomatic, severe radiographic and severe symptomatic knee OA were 6, 3, 2, 2, and 1%, respectively (median follow-up = 5.5 years). (Table 3). Across all outcomes, IRs were highest among the eldest and those who were obese, had less than a high school education, and had a knee injury history. Among those reporting income, IRs were generally highest among those with the lowest income. This is among the first study to systematically generate race-specific estimates for multiple knee OA outcomes: IRs for knee symptoms among blacks were typically 1–1.5 percentage points higher than whites (Tables 3 and 4).

Patterns in IRs for age, BMI (baseline) and knee injury history were consistent with previous incidence studies (1, 32). Women in our study had slightly higher, but not statistically significantly different, IRs. Similar to one of the only studies of socio-economic status (SES) and incident OA, lower SES predicted increased incidence (33). Whereas lower education was a risk factor for two radiographic outcomes, low income was a risk factor for all outcomes except severe symptomatic OA.

Across previous studies, IRs= 6–8% for knee symptoms, 2–4% for radiographic OA, 0.1–1.0% for symptomatic OA, and 2.5–4% for severe radiographic OA (3, 5–9, 13, 33–36); we did not find estimates in the literature for severe symptomatic OA. Overall, our IRs for symptoms and radiographic OA are within CIs of estimates from previous studies (3, 6, 33, 34, 36) but our IRs for symptomatic knee OA are 10-fold higher than previous US studies (5, 9, 34). Although previous studies have defined symptomatic OA based on pain only (rather than pain, aching, or stiffness in this study), the comparable IRs for knee symptoms across studies suggests that our higher IRs for symptomatic OA is not attributable to this difference in definition. Three differences in our populations may account for this. The JoCo OA population: 1) included blacks, who had slightly higher IRs than whites; 2) had lower income (1989 median income was almost $5,000 lower than the US population (37)), which is associated with higher IRs, and 3) was more obese (at baseline, 27% of the JoCo population was obese, which is higher than the prevalence in previous generations of middle-age and older US adults (38)), which is also associated with higher IRs. Our average annual IRs were lower than those from another recent analysis of radiographic OA incidence in the JoCo OA Project, but that study reported cumulative incidence for joints rather than at the person level (11).

We used a log-linear count model -- a generalized form of the Poisson model -- because the former accommodates the clustering from the complex sampling design and also allows for overdispersion (i.e., the log-linear count model allows for greater variability in distribution of data than a Poisson model allows). Similar to the IRs estimated in previous studies of knee incidence, our use of the log-linear model assumes that estimates are not underestimated because of interval censoring (i.e., unknown date of condition onset) and that IRs are constant over follow-up time.

Potential limitations of our study include the following. First, in longitudinal studies, cohort attrition is inevitable and may result in attrition bias. Our sensitivity analyses, which assumed that data were missing at random, accounted for differential attrition from baseline and first follow-up across age, race, sex, BMI, marital status, and income. The IRs in the primary and sensitivity analyses were the same indicating no evidence of bias. To our knowledge, this is the most in depth analysis of potential attrition in knee OA IRs to date. Second, self-reported measures (e.g., injury) may lead to recall bias; however, we observed patterns consistent with previous studies suggesting reasonable construct validity (1, 39). Third, we had sufficient sample size to detect statistically significant differences in IRs for some known risk factors (e.g., age, BMI) but the precision of some subgroup estimates was low because of small sample sizes (e.g. obesity class ≥ II IRs). Also, we did not examine differences in patterns of association (i.e., interactions) by race because small sample sizes. Fourth, the JoCo OA Project does not conduct magnetic resonance imaging, which is used increasingly in clinical studies for examining clinical features and results in earlier detection of structural changes. The effect of this cost prohibitive method is unclear as more incident cases would likely be detected along with a corresponding increase in exclusion of prevalent baseline cases. Fifth, radiographs of patello-femoral joints were obtained for a subsample only and therefore estimates are based on tibio-femoral knee OA only. Omission of this assessment likely resulted in underestimation of all OA outcomes, especially among blacks who, in a previous Project study, were more likely to have patello-femoral knee OA than whites (40).

A major study strength is that we systematically examined five knee outcomes among middle-age and older adults in a more contemporary and relatively large population-based sample using statistically rigorous methods with clinically confirmed radiographic measures. We believe that this is the first report to: 1) describe incidence of severe symptomatic OA, a potential indication for knee replacements, and 2) systematically examine impact of cohort attrition in knee OA incidence. We generated estimates across multiple socio-demographic characteristics and risk factors. In particular, we addressed a major gap in the literature by providing race-specific IRs.

The generalizability of our JoCo OA Project study findings to the contemporary US population is unclear. Although there are some similarities in distributions of socio-demographic characteristics, there are substantial differences in income and BMI. Distributions of age, sex and race in the entire eligible baseline sample (1991–1997) were close to the US population in 2010; however, after attrition, there was a slightly higher proportion of middle-aged adults, women, and whites in the analytic population (41). The proportion of the analytic population below the poverty line was almost twice that of the 2010 US population (24 and 13%)(42); patterns in IRs across income suggest our overall estimates are potentially higher than would be observed in the US. The baseline (1991–1997) prevalence of overweight (43%) and obesity (27%) in the analytic population was higher (32%) than among US adults age ≥ 20 years (23%) in the same era (1988–94). By 2009–2010, however, US prevalence of overweight was the same and obesity prevalence was even higher (36%) (38, 43, 44) than in our study. The higher IRs for those who were obese in the JoCo OA Project may provide an important glimpse into future burden of knee OA among US adults.

Knee symptoms and knee OA can be highly disabling conditions which reduce quality of life. Self-management strategies, which complement clinical care, are an inexpensive, convenient and evidence-based approach for reducing arthritis symptoms and improving quality of life (http://www.cdc.gov/arthritis/interventions.htm). Engaging in 150 minutes of physical activity each week, in as little as 10 minute increments, reduces pain (effects comparable to NSAIDS(45)) and physical limitations(45, 46), and decreases levels of depression and anxiety (46). Participation in self-management education classes can lead to sustained increased self-efficacy (i.e., confidence in their ability) which can lead to greater adherence to medication and other health recommendations (47, 48).

Our estimates indicate the substantial rate of knee OA outcomes and those who are disproportionately susceptible. We have provided a potential preview of the burden of knee OA in the US resulting from endemic obesity which highlight the urgency for clinical and public health practitioners to work together to decrease the current and future impact of knee OA.

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Appendix

Table

Distribution of baseline characteristics among entire eligible baseline sample and the subset with both baseline and follow-up data, overall and for knee symptoms and four OA outcomes*,†

	Overall		Outcome subpopulation									
			Symptoms		Radiographic		Symptomatic		Severe radiographic		Severe symptomatic‡	
	Baseline Only (n=1,400)	Analytic (n=1,518)	Baseline Only (n =765)	Analytic (n = 887)	Baseline Only (n = 974)	Analytic (n = 1,246)	Baseline Only (n = 1,190)	Analytic (n = 1,342)	Baseline Only (n = 1,306)	Analytic (n = 1,419)	Baseline Only (n = 1,374)	Analytic (n = 1,473)
	%	%	%	%	%	%	%	%	%	%	%	%
Socio-demographic characteristics												
Age (years)												
45–54	31	37	36	41	37	41	35	40	32	39	31	37
55–64	23	31	22	32	25	31	23	31	24	30	23	31
65–74	28	25	28	21	25	23	28	23	28	24	29	24
≥75	17	8	14	7	13	5	15	6	16	7	17	8
Sex												
Men	47	41	51	44	49	42	48	42	47	41	47	41
Women	53	49	49	56	51	58	52	58	53	59	53	59
Race												
Black	22	14	23	12	21	13	22	14	21	14	22	14
White	78	86	77	88	79	87	78	86	79	86	78	86
Marital status												
Never married	3	3	3	3	4	3	4	3	4	3	4	3
Married	62	70	69	73	65	72	64	72	63	71	62	71
Separated/Divorced	12	8	10	7	12	9	12	8	12	8	12	8
Widowed	23	18	19	16	19	16	20	17	21	18	22	18
Annual household income												
$0 – <$15,000	42	27	33	22	38	24	39	25	40	27	41	27
15,000 – <$35,000	24	30	26	31	25	31	25	31	25	31	24	30
$35,000+	13	22	19	27	15	24	14	23	13	23	13	23

	Overall		Outcome subpopulation									
			Symptoms		Radiographic		Symptomatic		Severe radiographic		Severe symptomatic‡	
	Baseline Only (n=1,400)	Analytic (n=1,518)	Baseline Only (n =765)	Analytic (n = 887)	Baseline Only (n = 974)	Analytic (n = 1,246)	Baseline Only (n = 1,190)	Analytic (n = 1,342)	Baseline Only (n = 1,306)	Analytic (n = 1,419)	Baseline Only (n = 1,374)	Analytic (n = 1,473)
	%	%	%	%	%	%	%	%	%	%	%	%
Don't know	9	8	9	7	9	8	9	8	10	8	9	8
Refused	12	12	13	13	14	13	13	13	12	12	12	12
Highest education												
Less than high school	27	14	22	9	24	13	25	13	26	14	27	14
Some/completed high school	48	54	47	53	49	54	49	54	50	54	48	54
Greater than high school	24	32	31	38	26	34	26	33	24	32	25	32
Knee OA risk factors												
Self-reported BMI (kg/m^2) at age 18												
Underweight/Normal(<25)	88	91	88	93	88	92	88	92	89	91	88	92
Overweight/Obese (≥25)	12	9	12	7	12	8	12	8	11	9	12	8
Clinically measured baseline BMI (kg/m^2)												
Underweight/Normal(<25)	37	33	41	39	40	35	39	35	38	33	37	33
Overweight (25-<30)	39	43	39	43	40	43	39	43	40	43	39	44
Obese (≥ 30)	24	24	20	18	20	22	22	22	22	23	24	23
Obese Class I (30-<35)	17	18	16	14	15	17	16	17	16	17	16	17
Obese Class ≥ II (≥35)	7	7	4	4	6	5	6	5	6	6	7	6
History of knee injury												
No	84	84	93	92	86	87	86	87	85	85	85	85
Yes	16	16	7	8	14	13	14	13	15	15	15	15
Knee symptoms (pain, aching and/or stiffness)												
None	56	60	10	10	62	66	66	68	58	63	58	61
Yes	44	40	0	0	38	34	34	32	42	37	42	39
Severity of pain												

	Overall		Outcome subpopulation									
			Symptoms		Radiographic		Symptomatic		Severe radiographic		Severe symptomatic‡	
	Baseline Only (n=1,400)	Analytic (n=1,518)	Baseline Only (n =765)	Analytic (n = 887)	Baseline Only (n = 974)	Analytic (n = 1,246)	Baseline Only (n = 1,190)	Analytic (n = 1,342)	Baseline Only (n = 1,306)	Analytic (n = 1,419)	Baseline Only (n = 1,374)	Analytic (n = 1,473)
	%	%	%	%	%	%	%	%	%	%	%	%
None	57	61	10	10	62	66	67	68	59	63	58	61
Mild	11	16	0	0	9	15	8	14	11	15	12	16
Moderate	21	19	0	0	18	14	16	14	19	17	22	19
Severe	11	5	0	0	11	4	9	4	12	5	8	4
KL grade												
0	46	51	52	59	64	61	54	57	49	54	47	53
1	26	32	26	32	36	39	30	37	27	34	27	33
2	22	12	18	7			13	5	24	12	20	10
3	4	3	3	1			2	1			5	3
4	2	1	1	0			0	0			2	1

* Distributions (percentages) differ from those presented in Table 2 because they were derived using baseline sampling weights which were based on 1990 Population in six townships in Johnston County. First follow-up weights (based on 2000 Population in six townships in Johnston County) were applied when estimating distributions and IRs for the analytic sample (i.e., those with both baseline and first follow-up data) to make estimates representative of the population in six townships in Johnston County.

† Eligible respondents in overall population are those who did not have pre-existing knee symptoms and KL grade ≥ 2 at baseline; eligible respondents in each subpopulation are those who did not have the pre-existing outcome at interest at baseline. Baseline only are those respondents who were eligible at baseline but did not have follow-up data; analytic population are those with both baseline and first follow-up data.

‡ Presence of symptoms (pain, aching, or stiffness) and severe pain

BMI, body mass index; K-L, Kellgren-Lawrence; OA, osteoarthritis

Innovation and Significance

- Each year 6% developed knee symptoms and 2% developed symptomatic knee osteoarthritis. Elderly adults (age ≥ 75 years), and those who were obese or had a history of knee injury or a low annual household income (≤ $15,000) were at an even higher risk.
- We estimated the annual incidence of severe symptomatic knee osteoarthritis, a potential indication for knee joint replacements. Each year 0.8% developed this highly disabling outcome.
- The racial diversity of the Johnston County Osteoarthritis Project provided the opportunity to generate race-specific incidence rates for knee symptoms and four knee osteoarthritis outcomes. Our study addresses a substantial gap in the knee OA descriptive literature: the absence of estimates for blacks who, in the US, are among the fastest growing demographic groups. The largest difference in estimates was for symptoms, where incidence rates were approximately 1 to 1.5 percentage points higher among blacks than whites in all analyses.

Table 1

Entire baseline, eligible baseline, and analytic* samples: overall and for incidence analyses of knee symptoms and four OA outcomes

	Overall	Knee symptoms	Knee osteoarthritis			
			Radiographic	Symptomatic	Severe radiographic	Severe symptomatic
Entire baseline sample ‡	3,068	3,068	3,068	3,068	3,068	3,068
Exclusion: Pre-existing outcome at baseline†	150	1,416	848	536	343	221
Eligible baseline sample ‡	2,918	1,652	2,220	2,532	2,725	2,847
Participant exclusions:						
Ineligible						
Moved	228	127	163	198	209	222
Deceased	352	169	214	276	305	338
Refused	396	262	301	358	378	387
Mentally/physically unable	198	87	119	155	182	188
Lost to follow-up						
Unable to locate	76	41	55	67	70	73
No clinic visit (household interview only)	143	79	103	119	132	136
Missing data for first follow-up visit	7	0	19	17	30	30
Analytic sample ‡	1,518	887	1,246	1,342	1,419	1,473

*Response and completion rates, respectively: entire baseline sample (n=3,068) =60% and 83%; analytic sample (n=1,590)=71% and 91%.

†Overall group excludes those with either presence of both knee symptoms and radiographic OA grade ≥ 2 in at least one knee or radiographic evidence of total knee replacement (because both symptoms and radiographic evidence are indications for knee replacement). For specific outcomes, those with pre-existing specific outcome of interest at baseline were excluded.

‡Entire baseline sample comprised all respondents at baseline, regardless of whether they have pre-existing outcome of interest. Eligible baseline sample comprised all respondents eligible for analysis at baseline (i.e., those who do not have pre-existing outcome of interest at baseline) and comprised those with baseline only data and those with both baseline and first follow-up data (analytic sample). Characteristics of each of these groups is in Appendix Table.

Table 2

Distribution (weighted)* of baseline socio-demographic characteristics, knee OA risk factors, and presence and severity of knee symptoms in the overall *analytic population* (n=1,518)†

	%
Socio-demographic characteristics	
Age (years)	
45–<55	58
55–<65	22
65–<75	15
≥75	5
Sex	
Men	42
Women	58
Race	
Black	21
White	79
Marital status	
Never married	5
Married	72
Separated/Divorced	11
Widowed	13
Highest education ‡	
< High school	11
Some/completed high school	55
> High school	34
Annual household income §	
$0–<$15,000	24
$15,000–<$35,000	29
≥$35,000	29
Don't know	6
Refused	11
Knee osteoarthritis risk factors	
Self-reported BMI at age 18 (kg/m²) ‖	
Under or healthy weight (<25)	90
Overweight/obese (≥25)	10
Clinically measured BMI at baseline (kg/m²) ‖	
Under/healthy weight (< 25)	30
Overweight (25 -<30)	43
Obese (≥30)	27
Obese Class I (30 – < 35)	*18*
Obese Class ≥ II (≥35)	*9*

	%
History of knee injury	
No	84
Yes	16
Presence and severity of knee symptoms	
Symptoms (pain, aching and/or stiffness)	
None	64
Yes	36
Severity of pain	
No symptoms	64
Mild	14
Moderate	17
Severe	6

Percentages may not sum to 100% because of rounding

*Weighted to 2000 population of six townships in Johnston County

†Missing values for the *analytic* sample were: marital status (n=2); highest education (n=3); annual household income (n=1); BMI at age 18 (n=51); baseline BMI (n=51); history of knee injury (n=43); presence of symptoms (n=20); and severity of symptoms (n=25).

‡Education was categorized based on total years of schooling: < high school (0-<9); some or completed high school (9–13/GED [general equivalency high school diploma]); and > high school (≥ 14).

§In 1990, $15,000 was the US poverty threshold for a family of five

//BMI at age 18 was calculated from self-reported weight at age 18 and height measured by Project staff at baseline; BMI at baseline was calculated from weight and height measured by Project staff at baseline clinic examination

Table 3

Annual incidence rates (per 100 people*) and 95% confidence intervals of knee symptoms and OA outcomes, overall and by socio-demographic characteristics and knee osteoarthritis risk factors

	Symptoms		Osteoarthritis							
			Radiographic		Symptomatic		Severe Radiographic		Severe Symptomatic††	
	%	**(95% CI)**	**%**	**(95% CI)**	**%**	**(95% CI)**	**%**	**(95% CI)**	**%**	**(95% CI)**
Overall†	5.6	(5.1 – 6.1)	2.8	(2.5 – 3.2)	2.1	(1.9 – 2.4)	1.7	(1.5 – 1.9)	0.8	(0.7 – 0.9)
Age-standardized§	5.6	(5.1 – 6.1)	2.7	(2.4 −3.1)	2.1	(1.8 – 2.4)	1.5	(1.3 – 1.8)	0.9	(0.7 – 0.9)
Age- and sex- standardized§	5.8	(5.3 – 6.3)	3.6	(3.2 – 4.0)	2.4	(2.1 – 2.8)	2.2	(1.9 – 2.5)	0.8	(0.7 – 1.0)
Socio-demographic characteristics										
Age (years)										
45–54	5.3	(4.6 – 6.1)	2.1	(1.7 – 2.6) ‡	1.8	(1.4 – 2.3)	1.2	(1.0 – 1.6) ‡	0.6	(0.4 – 0.8)
55–64	6.1	(5.4 – 6.8)	3.2	(2.8 – 3.7)	2.4	(2.0 – 2.8)	1.5	(1.2 – 1.9)	1.1	(0.8 – 1.4)
65–74	5.7	(4.8 – 6.8)	4.5	(3.9 – 5.1)	2.6	(2.2 – 3.1)	2.8	(2.4 – 3.3)	1.0	(0.7 – 1.4)
≥75	6.6	(5.1 – 8.6)	5.7	(4.2 – 7.7)	3.4	(2.2 – 5.2)	4.1	(3.1 – 5.5)	0.9	(0.5 – 1.8)
Sex										
Men	5.0	(4.3 – 5.9)	2.8	(2.4 – 3.3)	1.9	(1.6 – 2.4)	1.7	(1.3 – 2.1)	0.6	(0.4 – 0.9)
Women	6.0	(5.5 – 6.6)	2.8	(2.5 – 3.3)	2.3	(1.9 – 2.7)	1.7	(1.4 – 1.9)	0.9	(0.7 – 1.1)
Race										
Black	6.6	(5.4 – 7.9)	2.8	(2.1 – 3.7)	2.5	(1.8 – 3.4)	1.9	(1.5 – 2.4)	0.9	(0.6 – 1.1)
White	5.3	(4.8 – 5.9)	2.8	(2.5 – 3.2)	2.0	(1.8 – 2.3)	1.6	(1.4 – 1.9)	0.8	(0.6 – 0.9)
Highest education //										
Less than high school	5.9	(4.8 – 7.2)	3.5	(2.8 – 4.5)	1.9	(1.4 – 2.5)	2.8	(2.3 – 3.4) ‡	0.8	(0.5 – 1.3)
Some/completed high school	6.3	(5.6 – 7.1)	2.9	(2.5 – 3.3)	2.3	(1.9 – 2.8)	1.7	(1.4 – 2.0)	0.7	(0.6 – 0.9)
Greater than high school	4.5	(3.8 – 5.3)	2.5	(2.0 – 3.1)	1.9	(1.5 – 2.4)	1.2	(0.9 – 1.7)	0.9	(0.6 – 1.3)
Annual household income¶										
$0 – <$15,000	7.4	(6.3 – 8.7) ‡	3.3	(2.8 – 3.9)	2.8	(2.3 – 3.3)	2.4	(2.0 – 2.9)	0.6	(0.4 – 0.9)
15,000 – <$35,000	5.4	(4.6 – 6.3)	2.6	(2.2 – 3.2)	2.2	(1.7 – 2.7)	1.5	(1.2 – 1.9)	1.1	(0.8 – 1.5)

	Symptoms		Osteoarthritis							
			Radiographic		Symptomatic		Severe Radiographic		Severe Symptomatic††	
	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)
$35,000+	4.3	(3.4 – 5.5)	2.3	(1.6 – 3.1)	1.4	(0.9 – 2.3)	1.1	(0.6 – 1.7)	0.6	(0.4 – 1.0)
Don't know	7.7	(6.4 – 9.4)	3.4	(2.5 – 4.7)	2.3	(1.5 – 3.5)	1.7	(0.9 – 3.1)	1.0	(0.6 – 1.6)
Refused	5.1	(3.9 – 6.6)	3.4	(2.6 – 4.4)	2.3	(1.6 – 3.3)	1.9	(1.3 – 2.9)	0.7	(0.4 – 1.2)
Knee OA risk factors										
Self-reported BMI (kg/m^2) at age 18**										
Underweight/Normal(<25)	5.5	(5.0 – 6.1)	2.9	(2.6 – 3.2)	2.1	(1.8 – 2.4)	1.5	(1.3 – 1.8) ‡	0.7	(0.6 – 0.9)
Overweight/Obese (≥25)	5.3	(3.3 – 8.7)	1.9	(1.3 – 2.9)	2.0	(1.3 – 3.1)	3.0	(2.2 – 4.1)	1.0	(0.6 – 1.9)
Clinically measured baseline BMI (kg/m^2)**										
Underweight/Normal(<25)	4.9	(4.1 – 5.7)	2.0	(1.6 – 2.5) ‡	1.2	(0.9 – 1.5) ‡	0.7	(0.5 – 1.0) ‡	0.4	(0.3 – 0.5) ‡
Overweight (25-<30)	5.3	(4.6 – 6.1)	2.7	(2.2 – 3.2)	1.9	(1.6 – 2.3)	1.5	(1.2 – 2.0)	0.7	(0.5 – 1.0)
Obese (≥ 30)	7.0	(5.6 – 8.7)	3.7	(2.9 – 4.6)	3.1	(2.4 – 3.9)	2.7	(2.3 – 3.3)	1.2	(0.9 – 1.6)
Obese Class I (30-<35)	7.7	(6.1 – 9.7)	3.7	(2.8 – 4.9)	3.4	(2.6 – 4.6)	2.1	(1.7 – 2.7)	1.3	(0.9 – 1.7)
Obese Class ≥ II (≥35)	5.1	(3.4 – 7.6)	3.5	(2.3 – 5.1)	2.2	(1.5 – 3.2)	4.1	(3.1 – 5.3)	1.1	(0.6 – 2.0)
History of knee injury										
No	5.6	(5.1 – 6.1)	2.6	(2.3 – 2.9) ‡	1.9	(1.6 – 2.2) ‡	1.5	(1.3 – 1.7) ‡	0.7	(0.5 – 0.8) ‡
Yes	5.5	(4.1 – 7.3)	4.6	(3.7 – 5.8)	3.5	(2.8 – 4.5)	2.7	(2.1 – 3.4)	1.5	(1.1 – 2.0)

* Annual percent is equivalent to number of new cases per 100 person-years

† IRs in attrition sensitivity analysis were: symptoms (5.6; 95% CI=5.1–6.1); radiographic OA (3.1; 95% CI=2.8–3.4); symptomatic OA (2.2; 95% CI=1.9–2.4); severe radiographic OA (1.8; 95% CI=1.6–2.1); and severe symptomatic OA (0.8; 95% CI=0.6–1.0)

‡ Statistically significant based on overall Wald test at $\alpha = 0.00125$ (Bonferroni-adjusted significance level). Clinically measured BMI: three level (underweight/normal; overweight; obese) was statistically significant for all four OA outcomes (radiographic, symptomatic, severe radiographic, and severe symptomatic); four level (underweight/normal; overweight; obese Class I; obese Class ≥ II) was statistically significant for three OA outcomes (symptomatic, severe radiographic, and severe symptomatic OA.

§ Adjusted to 2000 projected US population

// Education was categorized based on total years of schooling: < high school (0-<9); some or completed high school (9–13/GED [general equivalency high school diploma]); and > high school (≥ 14).

¶In 1990, $15,000 was the US poverty threshold for a family of five

**BMI at age 18 was calculated from self-reported weight at age 18 and height measured by Project staff at baseline; BMI at baseline was calculated from weight and height measured by Project staff at baseline clinic examination

††Presence of symptoms (pain, aching, or stiffness) and severe pain

BMI, body mass index; kg, kilograms; m, meters

Table 4

Annual race-specific incidence rates (per 100 people*) and 95% confidence intervals of knee symptoms and OA outcomes, overall and by socio-demographic characteristics and knee osteoarthritis risk factors†

	Symptoms		Radiographic		Symptomatic		Severe Radiographic		Severe Symptomatic**	
	%	**(95% CI)**	**%**	**(95% CI)**	**%**	**(95% CI)**	**%**	**(95% CI)**	**%**	**(95% CI)**
Overall										
Black										
Crude	6.6	(5.4 – 7.9)	2.8	(2.1 – 3.7)	2.5	(1.8 – 3.4)	1.9	(1.5 – 2.4)	0.9	(0.6 – 1.1)
Age-standardized	6.7	(5.5 – 8.0)	2.8	(2.1 – 3.8)	2.5	(1.8 – 3.4)	1.8	(1.4 – 2.3)	0.9	(0.6 – 1.1)
Age- and sex-standardized‡	6.8	(5.7 – 8.2)	3.7	(2.9 – 4.8)	2.8	(2.2 – 3.7)	2.6	(2.0 – 3.3)	1.0	(0.7 – 1.3)
White										
Crude	5.3	(4.8 – 5.9)	2.8	(2.5 – 3.2)	2.0	(1.8 – 2.3)	1.6	(1.4 – 1.9)	0.8	(0.6 – 0.9)
Age-standardized	5.3	(4.8–5.9)	2.7	(2.4–3.1)	2.0	(1.7–2.3)	1.5	(1.2–1.8)	0.7	(0.6–0.9)
Age- and sex-standardized‡	5.5	(4.9 – 6.1)	3.5	(3.1 – 4.0)	2.3	(1.9 – 2.7)	2.1	(1.7 – 2.5)	0.8	(0.6 – 1.0)
Socio-demographic characteristics										
Age (years)										
Black										
45–54	6.3	(5.1 – 7.7)	2.2	(1.6 – 3.2)	2.1	(1.5 – 3.1)	1.4	(1.1 – 1.9)	0.7	(0.5 – 0.9)
55–64	7.4	(6.0– 9.1)	3.3	(2.5– 4.5)	2.9	(2.1– 4.0)	1.8	(1.3– 2.5)	1.3	(0.9– 1.9)
65–74	6.8	(5.3– 8.6)	4.7	(3.6– 6.2)	3.2	(2.3– 4.3)	3.3	(2.4– 4.5)	1.2	(0.8– 1.7)
≥75	8.0	(5.8– 10.9)	5.9	(4.0– 8.8)	4.1	(2.5– 6.7)	4.9	(3.3– 7.1)	1.1	(0.5– 2.2)
White										
45–54	5.0	(4.3– 5.9)	2.1	(1.7– 2.6)	1.7	(1.3– 2.1)	1.2	(0.9– 1.6)	0.6	(0.4– 0.8)
55–64	5.9	(5.2– 6.7)	3.2	(2.7– 3.7)	2.3	(1.9– 2.7)	1.5	(1.2– 1.8)	1.1	(0.8– 1.4)
65–74	5.4	(4.5– 6.5)	4.4	(3.8– 5.2)	2.5	(2.1– 3.0)	2.7	(2.3– 3.2)	1.0	(0.7– 1.4)
≥75	6.4	(4.9– 8.3)	5.6	(4.1– 7.7)	3.2	(2.1– 5.0)	4.0	(2.9– 5.3)	0.9	(0.5– 1.8)
Sex										
Black										
Men	5.9	(4.7– 7.5)	2.8	(2.1– 3.7)	2.2	(1.6– 3.1)	1.9	(1.4– 2.6)	0.7	(0.4– 1.0)
Women	7.1	(5.9– 8.5)	2.8	(2.1– 3.9)	2.6	(1.9– 3.7)	1.9	(1.4– 2.4)	1.0	(0.7– 1.3)

	Symptoms		Radiographic		Symptomatic		Severe Radiographic		Severe Symptomatic**	
	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)
White										
Men	4.8	(4.0– 5.7)	2.8	(2.4– 3.4)	1.8	(1.5– 2.3)	1.6	(1.3– 2.0)	0.6	(0.4– 0.9)
Women	5.8	(5.2– 6.4)	2.9	(2.5– 3.3)	2.2	(1.8– 2.5)	1.6	(1.3– 1.9)	0.9	(0.7– 1.1)
Highest education§										
Black										
Less than high school	6.7	(5.3– 8.4)	3.4	(2.5– 4.7)	2.2	(1.5– 3.0)	2.9	(2.2– 3.9)	0.9	(0.6– 1.4)
Some/completed HS	7.3	(6.0– 9.0)	2.8	(2.0– 3.9)	2.7	(1.9– 3.8)	1.8	(1.3– 2.3)	0.8	(0.6– 1.1)
Greater than high school	5.2	(4.1– 6.7)	2.4	(1.7– 3.4)	2.2	(1.5– 3.1)	1.3	(0.9– 1.8)	1.0	(0.6– 1.5)
White										
Less than high school	5.6	(4.5– 6.9)	3.6	(2.7– 4.6)	1.8	(1.3– 2.4)	2.7	(2.2– 3.4)	0.8	(0.5– 1.3)
Some/completed HS	6.1	(5.3– 6.9)	2.9	(2.5– 3.3)	2.2	(1.9– 2.6)	1.7	(1.4– 2.0)	0.7	(0.6– 0.9)
Greater than high school	4.3	(3.7– 5.1)	2.5	(2.0– 3.1)	1.8	(1.4– 2.3)	1.2	(0.9– 1.7)	0.9	(0.6– 1.3)
Annual household income //										
Black										
$0 – <$15,000	7.8	(6.2– 9.7)	3.2	(2.4– 4.1)	2.9	(2.2– 3.9)	2.4	(1.8– 3.2)	0.7	(0.5– 1.0)
15,000 – <$35,000	5.7	(4.6– 7.1)	2.5	(1.7– 3.6)	2.3	(1.6– 3.4)	1.5	(1.1– 2.1)	1.2	(0.8– 1.8)
≥ $35,000	4.6	(3.4– 6.2)	2.1	(1.2– 3.7)	1.5	(0.7– 3.1)	1.1	(0.6– 1.8)	0.7	(0.4– 1.2)
Don't know	8.1	(6.4– 10.3)	3.3	(2.2– 4.8)	2.5	(1.5– 3.9)	1.7	(0.9– 3.2)	1.1	(0.7– 1.9)
Refused	5.4	(4.0– 7.5)	3.2	(2.1– 4.7)	2.5	(1.5– 4.0)	1.9	(1.2– 3.0)	0.8	(0.4– 1.5)
White										
$0 – <$15,000	7.2	(6.1– 8.5)	3.4	(2.8– 4.2)	2.7	(2.1– 3.3)	2.4	(2.0– 2.9)	0.6	(0.4– 0.9)
15,000 – <$35,000	5.3	(4.5– 6.3)	2.7	(2.2– 3.3)	2.1	(1.7– 2.7)	1.5	(1.1– 2.0)	1.0	(0.7– 1.4)
≥ $35,000	4.3	(3.4– 5.4)	2.3	(1.7– 3.1)	1.4	(0.9– 2.2)	1.1	(0.6– 1.8)	0.6	(0.4– 0.9)
Don't know	7.5	(6.1– 9.3)	3.5	(2.6– 4.9)	2.2	(1.4– 3.5)	1.7	(0.9– 3.2)	1.0	(0.6– 1.6)
Refused	5.0	(3.9– 6.6)	3.4	(2.6– 4.5)	2.2	(1.6– 3.2)	1.9	(1.3– 2.9)	0.7	(0.4– 1.2)
Knee OA risk factors										
Self-reported BMI (kg/m^2) at age 18¶										
Black										
Underweight/Normal(<25)	6.3	(5.2– 7.7)	3.0	(2.2– 4.1)	2.5	(1.8– 3.5)	1.6	(1.3– 2.1)	0.7	(0.5– 1.0)

	Symptoms		Radiographic		Symptomatic		Severe Radiographic		Severe Symptomatic**	
	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)
Overweight/Obese (≥25)	6.1	(3.7– 10.1)	2.0	(1.3– 3.2)	2.3	(1.4– 3.8)	3.3	(2.2– 4.7)	1.0	(0.5– 1.8)
White										
Underweight/Normal(<25)	5.3	(4.8– 6.0)	2.9	(2.5– 3.2)	2.0	(1.7– 2.3)	1.5	(1.2– 1.8)	0.7	(0.6– 0.9)
Overweight/Obese (≥25)	5.2	(3.2– 8.5)	1.9	(1.2– 2.9)	1.9	(1.2– 2.9)	2.9	(2.1– 4.0)	1.0	(0.5– 1.9)
Clinically measured BMI (kg/m^2) at baseline¶										
Black										
Underweight/Normal(<25)	5.9	(4.6– 7.6)	1.9	(1.3– 2.8)	1.3	(0.9– 1.9)	0.7	(0.5– 1.1)	0.3	(0.2– 0.6)
Overweight (25-<30)	6.2	(4.9– 7.7)	2.6	(2.0– 3.4)	2.1	(1.6– 2.9)	1.6	(1.2– 2.2)	0.6	(0.4– 0.9)
Obese (≥30)	8.1	(6.3– 10.3)	3.5	(2.4– 5.1)	3.4	(2.3– 5.0)	2.8	(2.1– 3.8)	1.1	(0.8– 1.6)
Obese Class I (30-<35)	9.0	(7.0– 11.6)	3.6	(2.3– 5.6)	3.8	(2.5– 5.9)	2.2	(1.5– 3.1)	1.1	(0.8– 1.7)
Obese Class ≥ II (≥35)	5.9	(3.9– 8.9)	3.3	(2.2– 5.2)	2.4	(1.6– 3.7)	4.2	(3.0– 5.9)	1.0	(0.5– 2.0)
White										
Underweight/Normal(<25)	4.8	(4.0– 5.6)	2.1	(1.6– 2.6)	1.2	(0.9– 1.5)	0.7	(0.5– 1.1)	0.4	(0.3– 0.5)
Overweight (25-<30)	5.0	(4.3– 5.8)	2.7	(2.2– 3.3)	1.9	(1.5– 2.3)	1.6	(1.2– 2.2)	0.7	(0.5– 1.1)
Obese (≥30)	6.5	(5.1– 8.4)	3.7	(3.0– 4.6)	3.0	(2.4– 3.7)	2.8	(2.1– 3.8)	1.3	(0.9– 1.7)
Obese Class I (30-<35)	7.2	(5.6– 9.4)	3.8	(2.9– 4.9)	3.3	(2.6– 4.3)	2.2	(1.5– 3.1)	1.3	(0.9– 1.8)
Obese Class ≥ II (≥35)	4.7	(3.2– 7.0)	3.5	(2.3– 5.3)	2.1	(1.4– 3.2)	4.2	(3.0– 5.9)	1.2	(0.6– 2.2)
History of knee injury										
Black										
No	6.6	(5.4– 7.9)	2.6	(1.9– 3.6)	2.3	(1.7– 3.2)	1.7	(1.3– 2.3)	0.8	(0.6– 1.0)
Yes	6.6	(4.8– 9.0)	4.8	(3.4– 6.7)	4.4	(3.1– 6.3)	3.2	(2.3– 4.5)	1.7	(1.1– 2.6)
White										
No	5.3	(4.8– 5.9)	2.6	(2.2– 2.9)	1.8	(1.5– 2.1)	1.4	(1.2– 1.7)	0.6	(0.5– 0.8)
Yes	5.3	(4.0– 7.1)	4.6	(3.7– 5.8)	3.3	(2.6– 4.3)	2.6	(2.0– 3.3)	1.4	(1.0– 1.9)

*Annual percent is equivalent to number of new cases per 100 person-years

†There were no statistically significant differences based on an overall Wald test at α = 0.00125

‡Adjusted to 2000 projected US population

§Education was categorized based on total years of schooling: < high school (0-<9); some or completed high school (9–13/GED [general equivalency high school diploma]); and > high school (≥ 14).

[//] In 1990, $15,000 was the US poverty threshold for a family of five

[¶] BMI at age 18 was calculated from self-reported weight at age 18 and height measured by Project staff at baseline; BMI at baseline was calculated from weight and height measured by Project staff at baseline clinic examination

[**] Presence of symptoms (pain, aching, or stiffness) and severe pain

BMI, body mass index; kg, kilograms; m, meters