Prevalence of Knee Osteoarthritis in the United States: Arthritis Data from the Third National Health and Nutrition Examination Survey 1991-94

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ABSTRACT. Objective. To estimate the US national prevalence of tibiofemoral radiographic knee osteoarthritis (RKOA) with and without symptoms, and its influence on functional tasks.

Methods. Radiographic and interview data from the National Health and Nutrition Examination Survey (NHANES III), a nationally representative cross-sectional health examination survey, were used to estimate lifetime RKOA prevalence in adults age 60 years and older. Demographic trends, self-reported activity limitations, physical performance test results, and patterns of recent analgesic use were analyzed.

Results. Among US adults, the prevalence of RKOA and symptomatic RKOA was 37.4% and 12.1%, respectively. RKOA prevalence was greater among women than men (42.1% vs 31.2%). Women had significantly more Kellgren-Lawrence Grade 3–4 changes (12.9% vs 6.5% in men). However, symptomatic RKOA prevalence did not differ by sex. Additionally, some 1.6% of US adults had knee joint replacement. Multivariable analysis showed significantly higher odds of both RKOA and symptomatic RKOA with greater body mass index (BMI ≥ 30), greater age, non-Hispanic Black race/ethnicity, and among men with manual labor occupations. Only symptomatic RKOA was significantly associated with self-reported activity limitations: difficulty walking, stooping, standing from a seated position, and stair climbing. Adults with symptomatic RKOA used significantly more assistive walking devices, had slower measured gait velocities, and used significantly more prescription nonsteroidal antiinflammatory drugs and prescription narcotics, and nonprescription acetaminophen.

Conclusion. NHANES III data provide an overall national assessment of the prevalence, demographic distributions, and functional impact of symptomatic knee OA, which affects more than 1 in 10, or 4.3 million older US adults. (First Release Oct 1 2006; J Rheumatol 2006;33:2271–9)

Key Indexing Terms:
ACTIVITIES OF DAILY LIVING ANALGESICS KNEE PREVALENCE
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Arthritis is the leading cause of disability among older adults in the US, and osteoarthritis (OA) is the most common form of arthritis[1]. Knee OA is a leading cause of OA-related impairments in the general US population. Many epidemiologic surveys of knee OA have examined the prevalence of radiographic knee OA (RKOA), although there is increasing emphasis on symptomatic RKOA, since this is the group most likely to experience impairments and to require medical care. Case definitions for symptomatic knee OA have been developed — the most widely recognized are those recommended by the American College of Rheumatology (ACR)[2-4].

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Previous large-scale surveys of radiographic and symptomatic radiographic knee OA in the US include the Framingham community study (1983-85)[5] and the first National Health and Nutrition Examination Survey (NHANES) conducted 1971–75[6-8]. The Framingham study sampled adults age 63 years and above, while NHANES I studied adults age 35–74 years. No US national-level estimates for knee OA prevalence have been available since those times, and there are none for race/ethnicity population subgroups.

During 1991–94, NHANES III, a nationally representative health examination survey conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention, collected knee radiographs and medical examination and interview data for a sample of US adults aged 60 years and older. The interview data for knee pain have been reported[9]. Radiographic data, however, has only more recently been publicly released (October 2001). This report presents US prevalence estimates for both radiographic and symptomatic radiographic knee OA along with associated indicators of and activity limitations, physical performance test results, and analgesic use.

MATERIALS AND METHODS

Data source. NHANES III was a cross-sectional health examination survey conducted between 1988 and 1994. It used a multistage, stratified probability cluster design to select a representative sample of the civilian noninstitutionalized population. NHANES III oversampled adults aged 60+ years, African-Americans, and Mexican-Americans to improve subgroup estimate precision. The NHANES III operational plan, design, and analytic guidelines have been described[10,11]. Household interviewers collected the demographic and symptom data; physicians and health technicians performed examinations and knee radiographs at Mobile Examination Centers (MEC). The NHANES III survey protocol was approved by the National Center for Health Statistics Institutional Review Board, and written informed consent for data collection was obtained from all subjects.

Subjects. We analyzed data for adults aged 60 and above in Phase II of NHANES III (1991-94) because radiographic readings were only available for this subgroup[12]. In NHANES Phase II, 3128 adults ages 60+ years were interviewed. Of these, 221 were examined in their homes, where radiographs were not performed. The reference population for the knee radiograph study therefore excluded the homebound elderly. Some 2589 participants attended the MEC for examination; however, 174 participants had incomplete radiograph tests: 160 were due either to hardware malfunction, insufficient time, or room unavailability, inability of the examinee to cooperate, or unreadable films. Fourteen participants had bilateral knee joint replacements. Hence, knee radiographs suitable for radiographic OA prevalence estimates were obtained for 2415 persons. For the analysis of symptomatic knee OA, the analytic sample available was 2394 (due to questionnaire item nonresponse). The NHANES sample weights used in data analysis are adjusted for interview and examination nonresponse.

Interview and demographic variables. Data were collected on self-reported age; self-reported race/ethnicity recoded to non-Hispanic (NH) White, NH Black, and Mexican-American (MA); and self-reported education and income. Income was scaled as the Poverty Income Ratio (PIR), with poor = family income < 100% of the federal poverty level (PIR < 1.0), near-poor = 100% to 199% of the poverty level (PIR 1.0–1.99), and non-poor ≥ 200% of the poverty level (PIR ≥ 2.00). Sex was as observed by interviewers. Manual labor occupation was defined as the respondent's longest reported occupation (HAS17R) equal to codes 8 and 19-40; the nonmanual labor group included all other codes. Lifetime history of knee pain for each knee was also obtained during the household interview. Respondents were asked, "Have you ever had pain in your knees on most days for at least six weeks? This also includes aching and stiffness." A followup question identified the affected knee(s).

Knee radiographs and case definitions. Only a single non-weight-bearing anterior-posterior knee radiograph was performed in NHANES III. Less than 2% of radiographs were unreadable for any feature. Individual radiographic features (IRF) for knee OA are used for the descriptive data presented in Figure 1 and also for the descriptive Kellgren-Lawrence (KL) grade distribution shown in Table 1. These were based on the Osteoarthritis Research Society atlas of individual radiographic features of OA[13]. Evidence of disease for IRF (osteophytes and sclerosis) was defined as scores ≥ 1, where a score of 1 represents at least mild (1–33%) abnormality.

All other OA scores (Tables 2 and 3) were based on readings using the KL atlas for knee OA[14]. Here, the presence of knee OA globally was defined as a KL score ≥ 2, where grade 2 equals the definite presence of osteophytes. The current KL classification was based only on tibiofemoral osteophytes and joint sclerosis scores: joint space narrowing and subchondral bone cysts also used in the KL classification system were not determined in this study. It should be noted that in the Kellgren-Lawrence classification system, "severity" is primarily a radiographic term used to denote an increasing percentage of the joint affected by the disease process. It does not necessarily imply the presence of symptoms or functional impairments. Finally, the presence of knee joint replacement in radiographs was also noted.

Details of the NHANES III knee radiograph reading and quality control protocols have been published[12]. Briefly, a trained radiologist read all study radiographs. All radiographs with any evidence of disease, plus a 10% random sample of radiographs, were read by a second trained radiologist. Also, 3 sets of quality control radiographs with equal numbers of normal and advanced disease were used to measure intra- and inter-reader reliability. Kappa measures for inter-rater agreement were > 0.71 for the KL scores, > 0.70 for the IRF osteophyte scores, and > 0.50 for sclerosis scores. Kappas for intra-rater agreement for the primary reader were > 0.84 for the KL scores, > 0.80 for the IRF osteophyte scores, and > 0.68 for sclerosis scores. Kappas for intra-rater agreement for the secondary reader were > 0.82 for the KL scores, > 0.71 for the IRF osteophyte scores, and > 0.58 for sclerosis scores.

Consensus readings were conducted on all radiographs leading to disagreement between the 2 qualified readers by at least 2 grades for KL global scores, IRF osteophyte, or sclerosis scores; or for the presence or absence of minimal disease. Consensus readings were performed on 35.6% of the radiographs for disagreements in at least one radiographic feature. For all other reading differences, reader 1 scores were taken as final.

Symptomatic radiographic knee OA was defined as the presence of radiographic knee OA plus a history of persistent pain in that specific joint. This definition meets ACR criteria for symptomatic knee OA[2-4]. Discordant cases (radiographic changes of knee OA but pain only in the opposite knee joint, n = 14), cases with persistent knee pain but no radiographic findings (n = 201), and respondents (n = 14) meeting ACR criteria for rheumatoid arthritis[15] were excluded from the analysis. The category "No knee OA" was defined as all persons without radiographic evidence of OA and no history of persistent knee pain.

Activity limitation indicators. The NHANES III household interview contained questions about physical limitations based on everyday activities derived from previously validated instruments[16]. Respondents were asked about difficulties due to a health or physical condition (including but not necessarily knee disorders). They were instructed not to include difficulties relating to temporary impairments. The following questions were analyzed:

"Do you have difficulty...

Lifting or carrying something as heavy as 10 lbs (like a sack of potatoes or rice)?

Stooping, crouching, or kneeling?

Walking for a quarter of a mile (that is, about 2 or 3 blocks)?

Standing up from an armless straight chair?"

For the physical limitations questions, respondents chose from 4 ordinal response categories: no difficulty; some difficulty; much difficulty; or unable to do. Any respondent stating that they had no difficulty with an activity, but also reporting the use of assistive devices to perform the activity, was classified as having much difficulty with the activity.

MEC examination tests. Body mass index (BMI) was calculated from measured height and weight determined by standard NHANES protocols[10]. Measured performance tests were as follows: for each of the 2 trials for the timed 8-foot walk test, performance time was measured by stopwatch in seconds, beginning from the subject's first step until they crossed the finish line. The 2 subject trials were highly correlated, and we analyzed the average completion time. The repeated chair-stand test timed the participant's ability to get up from an armless chair. Performance was measured as time required to complete 5 trials. For both the timed walk and the chair-stand tests, eligible persons unable to perform the examination (those unable to walk, stand, or those physically unable to complete the required number of trials) were assigned the maximum observed score in seconds.

Medication data. The NHANES III analgesic data collection protocol was as described[17]. In the household interview, respondents reported their use during the previous month of all prescriptions and of specific nonprescription analgesics. We analyzed 4 analgesic subgroups: nonprescription acetaminophen use; nonprescription over the counter (OTC) ibuprofen use; prescription nonsteroidal antiinflammatory drug (NSAID) use (including prescription aspirin compounds); and narcotic analgesics. Frequent monthly OTC use was defined as acetaminophen or nonprescription ibuprofen use 30 or more times per month; chronic prescription analgesic use was a respondent having taken either a prescription NSAID or a prescription narcotic analgesic for 1 year or longer. The category "all types" of analgesics is the sum of each of the 4 anal-

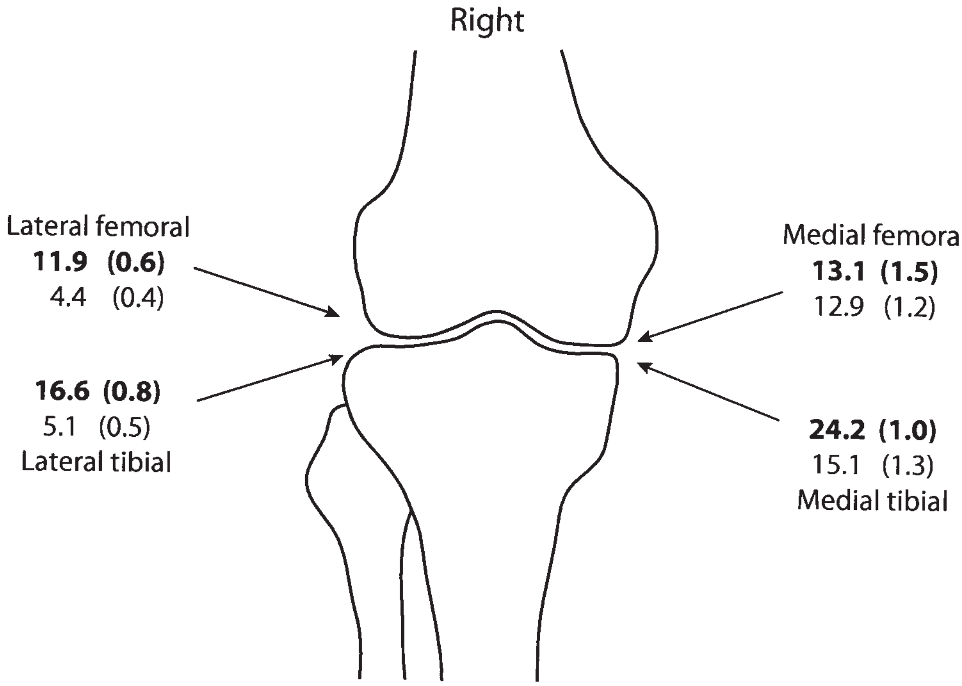

Figure 1. The prevalence distribution for radiographic osteophytosis and sclerosis by knee joint compartment, US adults ages 60 years and older, NHANES III. Data shown are for right knee. Values for osteophytosis shown in bold type; other values for sclerosis. Standard errors in parentheses. Osteophytosis is defined as an Individual Radiographic Features score ≥ 1; sclerosis defined as any disease rated mild or greater.

Table 1. Distribution of Kellgren-Lawrence radiographic knee OA grades in US adults ages 60+ years, NHANES III (phase 2; 1991–94). Estimates represent tibiofemoral OA in at least one knee, based on the presence of osteophytes or joint sclerosis.

	No. of Participants	Prevalence, %	95% CI
All participants			
Grade			
0 (normal)	1133	52.7	50.0–55.4
1	260	9.9	8.5–11.4
2	725	27.2	25.0–29.4
3–4	297	10.2	8.9–11.5
Men			
Grade			
0 (normal)	604	56.9	50.8–63.1
1	139	11.9	9.5–14.3
2	314	24.6	20.4–28.8
3–4	87	6.5	4.2–8.8
Women			
Grade			
0 (normal)	529	49.5	46.0–52.9
1	121	8.4	6.6–10.3
2	411	29.2	26.3–32.0
3–4	210	12.9	10.7–15.1

gesic subgroups when applied in the situation of any analgesic used in the previous month; when applied in the setting of frequent monthly OTC use, it is the sum of frequent monthly acetaminophen and OTC ibuprofen use.

Statistical analysis. Statistical analyses were conducted using SAS[18] and SUDAAN[19]. Survey sample weights adjusted for differential selection probabilities, nonresponse, and noncoverage were used to produce prevalence estimates. Estimates for the numbers of affected persons were then calculated based on data for the US noninstitutionalized civilian population for 1980 according to HNANES III Analytic Guidelines[11]. Variances were calculated with SUDAAN statistical software, which incorporates the sample weights and adjusts for the complex survey design. We applied the NHANES III analytic guidelines[11] to set criteria for minimum acceptable sample sizes and to assess statistical reliability of computed estimates.

Multivariable adjusted odds ratios and prevalences were calculated with the SUDAAN Proc RLogist and Multilog procedures, employing the Condmarg subroutine. The set of variables in the analyses included radiographic and symptomatic radiographic knee OA, age, sex, race/ethnicity, PIR, BMI, education, and occupation. In the multivariable analyses of risks for activity limitations, separate, individual models were run for each type of limitation acting as the dependent variable. Each was classified ordinally as no difficulty, some difficulty, or much difficulty/unable to do. Initially all control variables and their interactions were entered into the modeling; however, estimates reported are for the final parsimonious models for each limitation. Multivariable adjusted means for the timed 8-foot walk and chair-stand tests were calculated with log-transformed values using the Condmarg procedure in SUDAAN Proc Regress. Group differences were tested using the Proc Regress Effects routine (t test statistic). Trend tests for demographic variables (age group, BMI, education, PIR) were performed using the Cond Effects routine in SUDAAN Proc RLogist, adjusting for all other demographic variables. For unadjusted prevalence estimates, Student t tests were used to compare group differences, which were tested at $\alpha = 0.01$ (chosen to account for multiple comparisons). P values for multivariable adjusted odds ratios were calculated using the Satterthwaite adjusted chi-square statistic.

RESULTS

Table 1 gives KL grades for radiographic knee OA among US

Table 2. Prevalence estimates for radiographic knee OA in US adults 60+ years by selected demographic subgroups, NHANES III (phase 2; 1991–94).

	Radiographic OA*				Symptomatic Radiographic OA†			
Group*	N	n	%	95% CI	N	n	%	95% CI
Total	2415	1022	37.4	35.0–39.8	2394	353	12.1	10.6–13.5
Male	1144	401	31.2	26.4–35.9	1133	137	10.0	7.0–13.0
60–69	564	167	27.4	21.6–33.2	559	56	7.5	3.6–11.5
70–79	328	126	33.5	26.5–40.5	327	45	12.9	7.4–18.4
≥ 80	252	108	40.7	35.0–46.3	247	36	12.7	6.9–18.4
Female	1271	621	42.1	38.2–46.0	1261	216	13.6	11.3–15.9
60–69	528	214	35.2	29.4–40.9	524	74	10.6	7.5–13.7
70–79	473	249	44.6	38.1–51.1	467	88	15.3	11.0–19.6
≥ 80	270	158	55.6	46.7–64.5	270	54	18.2	9.7–26.8
Race-Ethnicity								
NH White	1356	545	36.2	33.4–39.1	1340	179	11.9	10.2–13.6
NH Black	457	240	52.4	47.1–57.8	452	80	17.7	13.6–21.9
Mexican-American	497	198	39.7	32.5–46.9	497	83	14.8	8.0–21.5
Poverty income ratio (PIR)								
≤ 1.00	489	236	42.6	35.3–49.9	486	91	14.3	9.4–19.2
1.01–1.99	702	290	36.8	31.7–41.9	695	104	12.8	9.2–16.4
≥ 2.00	987	398	37.3	34.3–40.2	977	117	11.1	8.9–13.3
Occupation								
Manual workers	1369	604	40.5	36.8–44.2	1359	222	14.2	11.9–16.4
All others	884	336	33.6	30.0–37.3	875	104	10.3	8.2–12.5
Education								
Less than high school	1330	611	42.9	39.4–46.4	1322	226	13.8	11.3–16.3
High school	583	240	35.6	30.5–40.8	577	69	10.3	6.9–13.7
Some college	488	165	31.6	26.7–36.5	481	55	11.4	7.5–15.3
Smoking								
Current	350	114	27.1	17.2–36.9	348	36	9.2	3.6–14.9
Former	901	338	34.1	29.4–38.8	893	133	12.0	9.6–14.5
Never	1164	570	43.3	39.7–46.9	1153	184	12.9	10.2–15.5
Body mass index								
< 25	803	227	23.8	18.6–28.9	797	63	6.5	3.9–9.1
25–29	988	416	36.9	31.7–42.0	979	125	9.9	7.4–12.5
≥ 30	619	377	57.4	52.0–62.7	613	164	23.2	18.8–27.6

* Radiographic OA group includes K-L grade ≥ 2 changes for both symptomatic and asymptomatic cases. † Symptomatic radiographic knee OA as defined[2]. ** For PIR, education, and BMI, sample sizes are reduced due to item nonresponse. For race/ethnicities, data presented only for the major race-ethnicity groups in NHANES III survey design. For occupation, results for the group " Never worked" are not presented. N: total sample; n: number of cases; %: percentage prevalence.

adults ages 60+ years for the 1991–94 survey period. These estimates are based on the presence of tibiofemoral osteophytosis and sclerosis, and are produced without reference to the presence of knee joint symptoms. Overall, 47.3% of participants had radiographic KL grade ≥ 1 in at least one knee. For men, this figure was 43.1% and for women 50.5%; however, the percentage difference was not statistically significant. For mild to moderate radiographic OA (KL grade 2), men and women had similar prevalence (24.6% and 29.2%, respectively); however, women had significantly greater prevalence of severe KL grade 3–4 knee OA compared to men (12.9% vs 6.5%, respectively; $p < 0.01$). Figure 1 shows the anatomical prevalence distribution for radiographic osteophytosis and sclerosis by knee joint compartment (IRF score ≥ 1). Anatomically, the medial tibio/femoral compartment has greater prevalences than the lateral compartments, and tibial surface osteophytic changes are much more prevalent than femoral surface changes.

Table 2 gives unadjusted prevalence estimates for both definite radiographic knee OA (KL grade ≥ 2 irrespective of symptom status) and symptomatic radiographic knee OA (knee pain plus KL grade ≥ 2 changes) for US adults aged 60+, by selected demographic characteristics. Overall, 37.4% of US adults aged 60+ [an estimated 13.3 million persons (95% CI 12.4–14.2 million)] had definite radiographic OA in at least one knee. The corresponding prevalence of symptomatic radiographic OA was 12.1%, representing 4.3 million older adults (95% CI 3.8–4.8 million). Both radiographic and symptomatic radiographic knee OA prevalences appeared to be greater with age, but a t test for the prevalence difference between the age groups ≥ 80 years versus 60–69 years was significant only for radiographic knee OA ($p < 0.01$). Women had significantly more radiographic knee OA changes than men (42.1% vs 31.2%, respectively; $p < 0.01$); however, the differences between men and women with respect to symptomatic radiographic knee OA were not significant. By race/eth-

Table 3. Prevalence estimates for self-reported activity limitations, recent analgesic use, and examination tests by knee OA status, US adults ages 60+ years, NHANES III (phase 2; 1991–94).

	Symptomatic Knee OA			No Radiographic Knee OA*				
	n	%	95% CI	n	%	95% CI	MOR**	95% CI
Activity type								
Pain on ambulation								
Yes	79	23.9	15.7–32.1	56	4.9	3.0–6.8	6.11	3.32–11.26
Assistive device used for walking								
Yes	73	14.8	7.6–21.9	73	4.8	2.1–7.5	3.44	2.22–5.35
Walk 1/4 mile								
No difficulty	124	55.2	46.6–63.8	829	83.0	78.7–87.3	1.00	
Some difficulty	77	21.2	12.8–29.7	122	9.4	6.0–12.9	3.38	2.01–5.69
Difficult/unable	101	23.6	18.5–28.7	100	7.5	5.5–9.6	4.72	3.28–6.81
Kneel, stoop, crouch								
No difficulty	65	25.7	15.6–35.8	635	60.9	54.7–67.1	1.00	
Some difficulty	83	31.5	20.0–42.9	272	29.5	24.6–34.4	2.52	1.24–5.15
Difficult/unable	146	42.8	33.8–51.8	113	9.6	6.6–12.5	10.59	5.94–18.88
Stand from armless chair								
No difficulty	195	70.0	60.7–79.3	1000	88.0	84.9–91.3	1.00	
Some difficulty	100	22.4	13.7–31.1	145	10.1	7.0–13.1	2.80	1.68–4.65
Difficult/unable	55	7.6	3.9–11.4	42	1.9	1.3–2.6	5.04	3.02–8.42
Climb 10 steps								
No difficulty	132	52.9	42.6–63.2	820	82.8	79.6–86.0	1.00	
Some difficulty	67	26.7	14.9–38.6	153	11.8	8.7–15.0	3.53	1.80–6.93
Difficult/unable	101	20.4	14.9–25.8	77	5.4	3.96–7.2	5.92	3.77–9.31
Analgesic use***								
Any analgesic used (previous month)								
All types	208	72.5	62.4–82.5	476	50.0	46.6–53.4	2.63	1.50–4.62
Acetaminophen	110	41.1	33.6–48.5	323	31.6	27.8–35.5	1.51	1.07–2.12
OTC ibuprofen	55	18.0	10.7–25.3	140	17.3	13.7–20.9	1.05	0.57–1.94
Prescription NSAID	81	28.5	17.3–39.8	69	5.4	3.4–7.3	7.02	3.62–13.62
Prescription narcotic	29	11.2	4.9–17.4	32	1.8	0.9–2.7	6.90	2.89–16.46
Frequent monthly OTC use								
All types	51	13.2	8.1–18.3	79	8.7	6.8–10.7	1.59	1.04–2.43
Acetaminophen	30	9.1	5.7–12.5	57	6.1	4.0–8.1	1.54	0.09–2.64
OTC ibuprofen	22	4.4†		26	3.1	1.7–4.4	1.45	
Chronic prescription analgesic use								
NSAID	45	15.3	6.3–24.4	38	3.6	2.2–4.9	4.89	2.57–9.33
Narcotic	21	8.3†		17	1.0†		9.19	
Examination tests‡	n	Mean	95% CI	n	Mean	95% CI	T	p
Timed 8-foot walk	302	3.6	3.5–3.7	1032	3.3	3.3–3.4	3.70	< 0.01
5 chair-stands	288	13.3	12.8–13.9	1039	12.8	12.1–13.6	1.34	0.19

* No history of chronic knee pain and Kellgren-Lawrence radiographic grade 0 or 1. ** MOR is for symptomatic knee OA; no significant MOR seen for No Radiographic Knee OA (see text). *** Frequent monthly use defined as having taken a medication 30 or more times within the previous month. Chronic prescription NSAID use is having taken medication ≥ 1 year. Referent for MOR analysis is the group of participants with no radiographic knee OA. † Estimate not statistically reliable. ‡ Measured in seconds; estimates adjusted for age, sex, race/ethnicity, BMI, and occupation. n: number of cases; %: percentage prevalence adjusted for age, sex, race/ethnicity, PIR, BMI, education, and occupation; MOR: multivariate odds ratio adjusted for age, sex, race/ethnicity, PIR, BMI, education, and occupation (referent for ambulatory pain and assistive devices is the group with no radiographic OA); OA: osteoarthritis; OTC: over the counter analgesic.

nicity, NH-Blacks had a significantly higher prevalence of radiographic knee OA than either NH-Whites or Mexican-Americans (both differences $p < 0.01$). Further analysis (data not shown) indicates that in the NH-Black category, females have the highest prevalence of radiographic knee OA (60.2%; 95% CI 52.8–67.5%).

There were not significant prevalence differences for either radiographic or symptomatic radiographic knee OA by income or for manual labor occupations. Lower radiographic and symptomatic radiographic knee OA prevalence was seen with increasing education. However, a t test for prevalence difference was significant only for radiographic knee OA (42.9% among those with less than high school education vs 31.6% among those with some college education; $p < 0.01$). Finally, a lower prevalence of knee OA in both categories was seen in current smokers as compared to lifetime nonsmokers. For radiographic knee OA, the prevalence difference between current smokers and nonsmokers was significant ($p < 0.01$).

Increasing BMI was a powerful predictor of knee OA risk: for radiographic knee OA, there was a 2-fold greater prevalence in obese persons (BMI ≥ 30) as compared to the non-obese (BMI < 25): 57.4% vs 23.8%, respectively (population reference data for BMI in NHANES III is published separately[20]). For symptomatic radiographic knee OA, there was more than a 3-fold prevalence difference between these 2 BMI categories (23.2% vs 6.5%, respectively). Finally, as multivariable-adjusted prevalences were not materially different from the previously described unadjusted ones, only unadjusted estimates are presented in Table 2.

For both radiographic and symptomatic radiographic knee OA, statistical testing was performed to evaluate the presence of trends in relation to age, BMI, education levels, and poverty income ratio. The tests were performed adjusting for the effects of all other demographic variables. Increasing age and BMI were both significantly associated with higher prevalence of radiographic knee OA ($T = 4.63$, $p < 0.01$, and $T = 7.05$, $p < 0.01$, respectively) and symptomatic radiographic knee OA ($T = 3.13$, $p < 0.01$, and $T = 5.51$, $p < 0.01$, respectively). There were no significant trends for either education or poverty income ratio.

A multivariable analysis based on logistic regression (data not shown) was performed for radiographic knee OA and symptomatic knee OA, using the variables for sex, age, race/ethnicity, BMI, occupation, smoking status, education, and income. This analysis indicated that age group was associated with greater knee OA risk. The multivariable adjusted odds ratio (MOR) was 1.97 (95% CI 1.51–2.56) and 2.54 (95% CI 1.64–3.95), respectively, for radiographic knee OA and symptomatic radiographic knee OA, comparing those aged 70+ years to a 60–69-year-old referent. By sex, women had significantly more radiographic knee OA changes than men (MOR 1.58, 95% CI 1.07–2.32), whereas there were no significant gender differences for symptomatic knee OA in multivariable modeling. By race/ethnicity, NH-Blacks had greater risk of both radiographic knee OA (MOR 1.65, 95% CI 1.17–2.34, vs NH-Whites as a referent) and symptomatic radiographic knee OA (MOR 1.52, 95% CI 1.06–2.19).

BMI remained strongly associated with knee OA risk in multivariable modeling. The MOR estimate for a BMI ≥ 30 using a BMI of < 25 as a referent was 3.27 (95% CI 2.14–4.99) for radiographic knee OA and 6.07 (95% CI 3.48–10.61) for symptomatic radiographic knee OA. There was no overall greater risk of knee OA by occupation; however, in a separate analysis by sex, among men there was a significantly increased MOR for manual labor occupations and radiographic knee OA (1.49, 95% CI 1.00–2.23) as well as symptomatic radiographic knee OA (MOR 1.95, 95% CI 1.02–3.73). Multivariable modeling showed no significant associations of knee OA in either category with smoking status, education level, or income.

The prevalence of knee joint replacements is not presented here; however, in the population of US adults aged 60+ years, the prevalence of knee joint replacement was 1.56% (95% CI 0.40–2.71%). A total of 44 participants had a knee joint replacement in at least one knee, and 11 of these had bilateral knee joint replacements. The observed knee joint replacement prevalence was slightly higher in men compared to women, but no conclusions could be drawn because the estimates were not statistically reliable. By age, 25% of participants with joint replacement were 60–69 years, 48% were 70–79 years, and 28% were 80+ years. Some 73% of participants with unilateral knee joint replacements had a radiographic KL score ≥ 2 in the contralateral knee. No participant with a knee joint replacement met study criteria for rheumatoid arthritis[15].

Self-reported activity limitations, analgesic use patterns, and physical performance test data were analyzed with the independent variable knee OA categorized into 3 groups: symptomatic radiographic OA, asymptomatic radiographic OA, and no radiographic OA. As the results for the asymptomatic radiographic OA and no radiographic OA groups were not significantly different, only the latter are reported in Table 3, although both groups were retained in the multivariable modeling process. Both the prevalences and the odds ratios for individual activity limitations variables were calculated, adjusted for age, sex, race/ethnicity, PIR, BMI, and occupation.

Approximately 20% of participants with symptomatic radiographic OA reported pain on ambulation at the time of examination, while 15% used an assistive device to walk. Symptomatic knee OA cases had a 4-fold greater prevalence of pain on ambulation, and a 3-fold greater prevalence for the use of assistive devices for walking as compared to persons without radiographic knee OA. Both findings were statistically significant ($p < 0.01$). For all 4 other self-reported activity limitation indicators, symptomatic radiographic knee OA cases either had difficulty with, or were unable to perform, ordinary tasks significantly more often than participants with no radiographic knee OA. Tasks requiring knee bending (kneeling, stooping, crouching) had the greatest absolute and relative impairments: some 40% had much difficulty with or were unable to do such tasks, and the multivariable OR adjusted for age, sex, race/ethnicity, and BMI (≥ 30 vs < 30) was 10.59 (95% CI 5.94–18.88). Seven percent had much difficulty with, or were unable to stand from an armless chair (MOR 5.04, 95% CI 3.02–8.42) and about 20% of cases reported much difficulty with, or were unable to do stair climbing (MOR 5.92, 95% CI 3.77–9.31).

The NHANES III performance examination results showed that for the 8-foot timed walk, there were significantly greater mean test performance times (i.e., slower gait speed) for symptomatic radiographic knee OA cases compared to those with no radiographic knee OA (Table 3). The mean performance time for the repeated chair-stands test showed a relative increase among symptomatic knee OA cases, but this was not statistically significant.

Symptomatic radiographic knee OA cases had significantly greater prevalence of analgesic and inflammatory medication use (Table 3). Nearly 70% had used a prescription or non-prescription analgesic at some time within the previous month compared to 50% of participants with no radiographic OA. The relative odds of both frequent monthly OTC analgesic use and of chronic prescription NSAID use was significantly elevated among those with symptomatic knee OA compared to those without [MOR 1.59 (95% CI 1.04–2.43) and 4.89 (95% CI 2.57–9.33), respectively].

DISCUSSION

The methodological strength of NHANES is its nationally representative sample of both men and women, its oversampling of older persons and ethnic subgroups, its standardized monitored data collection process, and its quality control protocol for radiograph readings. Also, knee pain and radiographic examinations were conducted independently by household interviewers and MEC radiograph technicians, respectively. By design, NHANES III excluded institutionalized persons from the survey. Also, the group of homebound older persons who otherwise participated in the survey did not undergo radiographs. This may affect prevalence estimates, as either of these groups could possibly have a greater prevalence of either radiographic or symptomatic radiographic knee OA. The NHANES cross-sectional survey design is ideal for prevalence estimation. This does, however, present important study limitations. For the analytic associations derived, the temporal sequence of risk factor exposures and disease cannot be assessed with certainty, and hence needs to be determined by longitudinal studies. Also, we cannot estimate the effects of birth cohort, mortality, or age-specific incidence rates on the observed prevalences.

From a disease classification point of view, we could not identify or exclude some important subsets of secondary OA cases, and in this respect, our estimates represent knee OA generally, and not its specific subgroups. The most important cases to exclude would be posttraumatic knee OA; however, NHANES III did not collect data on this topic. We did, however, exclude cases of secondary OA due to rheumatoid arthritis in our dataset.

It is significant that the radiographic protocol employed for NHANES III knee examination biases our prevalence estimates lower than the true population values. NHANES III obtained only a single anterior/posterior, non-weight-bearing radiograph for each knee. This makes it more difficult to identify osteophytes when they are present. Also, as lateral knee and patellar "sunrise" radiographs were not obtained, it was only possible for us to include tibio-femoral OA and not patello-femoral OA in our overall prevalence estimates. That the NHANES radiographs were non-weight-bearing also meant that joint space narrowing, an early sign of OA and an important feature of the Kellgren-Lawrence OA classification scheme, could not be evaluated. This makes it more difficult for radiograph readers to distinguish possible (KL grade 1) from definite (KL grade ≥ 2) knee OA. Finally, NHANES III knee radiographs were not read for subchondral bone cysts, which are routinely included in the KL classification scheme.

In the literature, there is variability among epidemiologic studies in the questionnaire criteria for knee pain. It is not known for certain how this may affect prevalence estimates for symptomatic OA. The NHANES III question recorded a lifetime history of knee pain, using a 6-week duration of knee pain as a criterion. In contrast, NHANES I and the Framingham study used lifetime knee pain prevalence of 1-month duration. Other studies have used "current knee pain on most days" as an indicator, which was not recorded in NHANES III.

The definition of knee pain pertinent to OA is important and likely deserves additional study, because the radiographic stigmata of OA are widely prevalent in older adults, whereas local knee pain symptoms are much less so. Thus, the epidemiologic criteria for knee pain could be a central factor influencing symptomatic knee OA prevalence estimates in population studies.

Other limitations of our data are that for symptomatic knee OA there are a number of conditions besides OA that could potentially cause either local or referred knee pain. Therefore some proportion of those we classify as symptomatic knee OA may in fact represent "asymptomatic" radiographic knee OA. This specific limitation is shared by similar studies in the literature, and unfortunately the NHANES III protocol lacks the data to properly address this issue. A further limitation of the NHANES III questionnaire data is that they did not capture a full range of comorbidities that could potentially affect functional limitations and performance examination data related to the knee. Since we could not adjust for all potentially relevant confounders, there is some degree of uncertainty about the positive associations currently reported.

Our principal findings are that some 37% of US adults age 60 and older, or an estimated 13.3 million persons in the 1991–94 period, had radiographic evidence of definite tibio-femoral knee OA, whereas 12% (4.3 million) were estimated to have had symptomatic radiographic knee OA. Increasing age, female sex, increasing BMI, and non-Hispanic Black race/ethnicity were most strongly associated with greater prevalence of knee OA, whether radiographic or symptomatic radiographic disease. Symptomatic radiographic OA was positively associated with self-reported activity limitations, especially including tasks that require knee bending (kneeling, standing from a chair, or climbing steps). Also, 15% of those with symptomatic radiographic knee OA used assistive devices for ambulation. In the 8-foot timed walk test, participants with symptomatic knee OA did significantly worse than those with no radiographic OA. Symptomatic radiographic OA cases also had significantly greater overall analgesic use, both frequent monthly OTC analgesic use and chronic prescription NSAID use.

The major prior national-scale study of radiographic knee OA in the US was NHANES I, conducted 1971–75[6-8]. The results of NHANES I, however, are difficult to compare directly to NHANES III because of differences in the design of the 2 surveys. Specifically, NHANES I studied adults 35–74 years of age, and used a 4-week recall period for lifetime history of knee pain, rather than a 6-week period as in NHANES III. Also, in retrospect it is thought, on the basis of the very low prevalence of OA in published NHANES I radiographic data, that the radiographs were under-read[1]. For example, the prevalence of definite radiographic knee OA in those 65–74 years old in NHANES I was only 9% in men and 20.3% in women, as compared to 31.2% and 42.1%, respectively, in the same age group in our NHANES III data. While absolute values for prevalence rates may therefore systematically differ between NHANES I and NHANES III, many of the same associations derived for radiographic OA in the earlier NHANES study were found to apply in NHANES III, specifically the increasing trend with age, BMI, and occupation, and the greater prevalence among NH-Black women[6]. However, a significant association between radiographic knee OA and low educational attainment observed in NHANES I[7,8] was not seen in our analysis of NHANES III data.

A more directly comparable study was the prevalence survey of knee OA in the elderly in Framingham, Massachusetts, 1983–85[5]. Methodologically, this study used the same 4-week recall period lifetime knee pain question as employed in NHANES I (compared to a 6-week recall period for NHANES III), but obtained weight-bearing AP radiographs of White participants aged 63+ years (mean 73 yrs). Thus, the full range of KL criteria could be applied. Both Framingham and the NHANES surveys are alike in excluding institutionalized persons, for example, those in hospitals or nursing homes.

To more accurately compare prevalence estimates from the 2 studies, prevalence estimates for the NH-White age group 63+ years were created from the NHANES III file (data not shown). These estimates show a general, but not precise, correspondence between prevalences estimated from the 2 surveys. For example, among all subjects, the prevalence of KL grade ≥ 2 knee OA was 38.3% (95% CI 36.4–41.2%) for NHANES III compared to 33.0% in the Framingham study. Some 9.6% (95% CI 7.4–11.8%) of NHANES III respondents had KL grade ≥ 3 knee changes, whereas the corresponding prevalence in the Framingham study was 15.7%. Women had a 42.7% (95% CI 38.1–47.3%) prevalence of radiographic knee OA in NHANES III compared to 34.4% in the Framingham study. The comparable estimates in men were 32.4% (95% CI 26.0–38.8%) versus 30.9%, respectively. Both studies showed a consistent trend of increasing prevalence of radiographic knee OA changes with age.

A more recent study was the Johnston County Osteoarthritis Project, which surveyed a rural US population[21]. This study found generally comparable, but slightly higher radiographic knee OA prevalences that increased with age, but not by sex or race/ethnicity. Radiographic knee OA was associated with self-reported functional status, and with performance times for both the 8-foot walk test and a timed chair-stand test. The differences between the Johnston County study and our NHANES III prevalence estimates may result from regional community-based factors that may be obscured by the nationally representative sampling strategy used for NHANES surveys.

Our estimates for US radiographic OA are the most current available. There is uncertainty, however, whether they can be said to accurately represent the current prevalence of radiographic knee OA in the US. There is some reason to suspect that the prevalence of knee OA has increased since the NHANES III data were collected. Current NHANES studies for 1999–2004 indicate that there have been dramatic increases in BMI in the US since the time of NHANES III[22]. Such changes are likely to have resulted in significantly higher prevalence of knee OA among older persons. Also, the aging of the US population means that the absolute numbers of persons with knee OA will increase dramatically, even if the age and sex-specific risks remain the same.

Our findings update previous US community and population-based studies of radiographic and symptomatic radiographic knee OA prevalence. While our prevalence estimates must be interpreted in light of the limitations noted for the NHANES III data set, our analytic associations are less likely to be affected by such methodological factors. Indeed, the NHANES III data confirm and extend many previously known associations. In any case, it is difficult to escape the conclusion that symptomatic radiographic osteoarthritis represents a major cause of lower extremity functional impairment in the population of older US adults. With increasing longevity, these problems may become even more significant. The NHANES III data provide an assessment of the overall prevalence and impact of this important problem in a more recent time period, and will assist in public health planning for persons with this important musculoskeletal disorder.

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