Title page

Title

Quantifying the association of radiographic osteoarthritis in knee or hip joints with other knees or hips: the Johnston County Osteoarthritis Project

Authors

Eric C. Sayre, Joanne M. Jordan, Jolanda Cibere, Louise Murphy, Todd A. Schwartz, Charles G. Helmick, Jordan B. Renner, M. Mushfiqur Rahman, Jaafar Aghajanian, Weiqun Kang, Elizabeth M. Badley, Jacek A. Kopec

Abstract

Objective

To quantify the association of radiographic osteoarthritis in one knee or hip joint with other knee or hip joints.

Methods

We analyzed baseline data from the Johnston County Osteoarthritis Project (n=3,068). We fit four models for left/right knee/hip. Kellgren Lawrence (KL) radiographic grade severity was based on: KL=0/1 (no/questionable radiographic OA (ROA)); 2 (mild ROA); or 3/4
(moderate/severe ROA). We estimated associations between KL grade in contralateral joints and other joint sites (e.g., worst hip in knee models), adjusting for gender, race/ethnicity (African American/Caucasian), age and measured body mass index, using cumulative odds logistic regression models. Interactions were investigated: race/ethnicity by gender; race/ethnicity and gender by the two explanatory variables.

**Results**

Contralateral joint KL grade was strongly associated with KL grade, with odds ratios (ORs) and 95% confidence intervals (CIs) ranging from 9.2 (95% CI=7.1, 11.9) to 225.0 (95% CI=83.6, 605.7). In the left knee model, the contralateral joint association was stronger among African Americans than Caucasians, but for the other models the associations by race/ethnicity were identical. Models examining other joint sites showed weaker but mostly statistically significant associations (ORs from 1.4 to 1.8).

**Conclusion**

We find a strong multivariable adjusted association between KL grades in contralateral knees and hips, and a modest association with the other joint site (e.g., knees vs. hips). These results suggest that diagnosis of ROA in one large joint may be a marker for risk of multi-joint ROA, and warrant interventions to reduce the incidence or severity of ROA at these other joints.

**Key indexing terms**

polyarthritis, Kellgren Lawrence grade, osteoarthritis, contralateral, knee, hip

**Departments and institutions**

Arthritis Research Centre of Canada, Vancouver, BC, Canada
School of Population and Public Health, University of British Columbia, Vancouver, BC, Canada
Department of Medicine, University of British Columbia, Vancouver, BC, Canada
Thurston Arthritis Research Center, Chapel Hill, NC
University of North Carolina at Chapel Hill, Chapel Hill, NC
Centers for Disease Control & Prevention, Atlanta, GA
Department of Radiology, University of North Carolina at Chapel Hill, Chapel Hill, NC
Arthritis Community Research & Evaluation Unit, University of Toronto, ON, Canada

**Source of support**

The analyses were supported in part by a grant from the Canadian Institutes of Health Research. Funding was made possible (in part) by Association of Schools of Public Health S043 and S3486 from the Centers for Disease Control and Prevention (CDC). The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

**Initials, surnames, appointments and highest academic degrees of all authors**

EC Sayre (Postdoctoral Fellow), PhD1-3, JM Jordan (Adjunct Associate Professor), MD, MPH4,5, J Cibere (Assistant Professor), MD, PhD1,3, L Murphy (Epidemiologist), PhD6, TA Schwartz (Analyst), DrPH5, CG Helmick (Senior Medical Epidemiologist), MD6, JB Renner (Professor), MD, FACR7, MM Rahman (PhD Candidate), MSc1, J Aghajanian (Analyst), BSc1, W Kang (Student), MD, PhD1, EM Badley (Senior Scientist), PhD5, JA Kopec (Associate Professor), MD, PhD1,2

1 Arthritis Research Centre of Canada, Vancouver, BC, Canada
2 School of Population and Public Health, University of British Columbia, Vancouver, BC, Canada
Corresponding author and reprint requests

Eric C. Sayre
Arthritis Research Centre of Canada
895 West 10th Avenue, Vancouver, BC, V5Z 1L7, Canada
Tel: (604) 871-4568, Fax: (604) 879-3791
Email: esayre@arthritisresearch.ca

Short running footline

Multi-joint associations in radiographic OA
Introduction

Among US adults, nearly 27 million had clinical osteoarthritis in 2008 (up from 21 million in 1995).\textsuperscript{1} Being strongly related to age and body mass index (BMI), osteoarthritis (OA) presents an increasing burden in North America and the rest of the world as the population ages and grows heavier.\textsuperscript{2-5} Kellgren-Lawrence (KL) grade, an integer index ranging from 0 to 4, is a standard radiographic measurement of joint degradation used in diagnosing OA.\textsuperscript{6} Radiographic OA (ROA) can be defined simply as a KL grade of 2 or higher.

There is a large body of literature suggesting that the occurrence of OA in different joints within an individual is associated, and suggesting some biological basis (e.g., genetic factors).\textsuperscript{7-15} Several previous studies have examined left vs. right side prevalence of osteoarthritis in knees and hips,\textsuperscript{16-21} primarily measuring differences between the univariate distributions of left vs. right side ROA in knees and/or hips. For example, Newton et al (1993)\textsuperscript{19} suggested that the observed difference in left vs. right side distributions was attributable to a difference in impulse loading in right-footed people. Conversely, Stea et al (2008)\textsuperscript{16} observed a higher prevalence of right-hip OA in left-footed Italians, and concluded that in left-footed patients, the right side was subjected to greater stress. Few studies have sought to study between-joint associations in knees or hips, but one, Vossinakis et al (2008)\textsuperscript{22} found that pre-existing hip OA on one side significantly predicted future development of OA on the other side. Spector et al (1994)\textsuperscript{23} also studied the incidence of future development of OA in contralateral joints (knees) among those with pre-existing unilateral disease, however their study did not include a control (disease free) group. They found that obesity was a strong predictor of OA incidence in the contralateral knee.
In this paper, we approach this subject from a new angle, and study the cross-sectional between-joint distribution of ROA in the knees and hips simultaneously (four large joints). We aim to answer the question: how is ROA in one joint associated with ROA in the other three large joints in the body? Odds ratios are estimated in log odds regression models to describe the cross-sectional association of hip (or knee) ROA with contralateral joint, and with the other joint site (hips for knee models, or knees for hip models).

**Materials and Methods**

*Ethics approval*

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 the time of recruitment.

*Data collection*

We conducted a cross-sectional analysis using population-based data from the baseline Johnston County Osteoarthritis Project in rural North Carolina (n=3,068). At the time this study was designed in 1990, Johnston County, North Carolina had a population of about 81,000 and a rural area of about 800 square miles. A majority of residents (66%) lived in completely rural areas, with the remainder in small towns. African-American residents and residents 60 years of age or older constituted 20% and 17% of the population, respectively. The baseline sampling occurred from May 1991 through December 1997 and involved two stages of stratified random sampling. For more details about the Johnston County Osteoarthritis Project, refer to Jordan et al (2007).
Race/ethnicity was self-reported. All participants had radiographic examination of the knees with the anterior-posterior (AP) view with weight-bearing and foot map positioning, and of the hips with an AP pelvis view. Knee and hip radiographs were read without knowledge of participant clinical status, by a single bone and joint radiologist (Jordan B. Renner, MD) using the KL radiographic atlas for overall knee radiographic grades. This scale defines radiographic OA in 5 categories. Radiographs scored as KL grade 0 (normal) showed no radiographic features of OA; KL grade 1 (questionable) included a minute radiographic osteophyte of doubtful pathologic significance; KL grade 2 (mild) showed an osteophyte but no joint space narrowing; KL grade 3 (moderate) showed moderate diminution of joint space; and KL grade 4 (severe) was defined by severe joint space narrowing with subchondral bone sclerosis. Inter-rater reliability assessed with another trained radiologist and intra-rater reliability for the radiologist were high (weighted kappa for inter-rater reliability was 0.86; kappa for intra-rater reliability was 0.89), as described previously.

Due to a skewed and sparse distribution, we analyzed categorized KL grade grouped as follows: KL=0/1 means no/questionable ROA; KL=2 means mild ROA; and KL=3/4 means moderate/severe ROA. ROA as used in this analysis refers to KL grade ≥ 2. Other variables included in our models were age, gender, race/ethnicity (African American or Caucasian) and measured BMI.

Data analysis

All analyses used weighted data to represent the population of Johnston County. The models were fit as "partial proportional odds" cumulative logistic regression models, fit using
generalized estimating equations (GEE) methods.\textsuperscript{27} When analyzing data with an ordinal outcome, a proportional odds model assumes that the cumulative odds of each level of an ordinal outcome is in constant proportion with the explanatory variable. When the odds ratio for a particular explanatory variable varies across the level of outcome KL grade being considered (in this analysis, varied between outcomes of KL grade $\geq 2$ and KL grade $\geq 3$) a model allowing non-proportional odds (NPO) is required. Non-proportional odds terms were formally tested and allowed into the models (when statistically significant) on a per-variable basis (hence, "partial" proportional odds model). A practical example of non-proportional odds can be found in a study by Campbell et al (2009),\textsuperscript{28} looking at racial and ethnic disparities in breast cancer. They found that women in high-poverty areas are at substantially greater risk for late-stage diagnosis of breast cancer, but the disparity was less for early stage diagnoses (non-proportional odds).

We fit four separate models, one each for the left and right knees and hips. The two main explanatory variables of interest were contralateral joint KL grade and maximum KL grade in the other joint site (that is, maximum KL grade in hips for left and right knee models, and vice versa). Thus, what we label as a left knee ROA outcome model has the main explanatory variables of right knee ROA and maximum KL grade for the hips. All models were adjusted for age, gender, race/ethnicity (African American or Caucasian) and measured BMI. According to standard model development, several two-way statistical interactions were investigated: race/ethnicity by gender; race/ethnicity by each of the two main explanatory variables; and gender by each of the two main explanatory variables. From herein interactions refer to statistical interactions. Non-proportionality terms for all main effects were tested in unadjusted models based on the generalized score test for GEE models\textsuperscript{29} at a significance level (i.e., alpha) of 0.10.
From the multivariable model that resulted (non-significant non-proportional odds terms were excluded), interactions and any remaining non-proportionality terms were then selected out with backwards elimination at a significance level of 0.05. The two main explanatory variables and the main effects for age, gender, race/ethnicity and BMI were included in the model regardless of significance. Bootstrap replication was used to accommodate design effects associated with the complex survey design. All statistical analyses were done using SAS version 9.1.3.

**Results**

Table 1 shows the sample weighted baseline distribution of age group, gender, race/ethnicity and grouped BMI. Weights were scaled in order to reflect sample weighted percentages (for example, the distribution of gender by race/ethnicity is quite different when weighted), while maintaining an accurate sense of sample size. Scaled weights were used to represent population-based percentages while maintaining the scale of our sample size. The sample was between 45 and 93 years old, with two thirds of the sample 55 and older. More than half the subjects were female, and close to one fifth were African American. Thirty-four percent were obese (BMI ≥ 30).

Table 2 and Table 3 show the cross-tabulated KL grade levels in knees and hips (left vs. right side). Knees show significantly more ROA on the right side (22.1%) than the left (19.5%) (Table 2); McNemar’s unweighted p-value<0.01. Hips show more ROA on the left side (20.2%) than the right (18.6%) (Table 3), but the difference is not significant at alpha=0.05. Crude (unadjusted) odds ratios for contralateral joint KL grade can also be calculated from these tables, comparing the odds of left vs. right side KL grade in knees and hips, using either KL ≥ 2 or KL=3/4 as the definition of ROA for the calculation. The crude odds ratios for contralateral joint
KL grade are very high. For the outcome KL ≥ 2 knees, the odds ratio for having a contralateral knee with KL ≥ 2 was 20.1 (95% confidence interval (CI)=16.2, 25.1) compared with a knee without ROA; for the outcome KL ≥ 3 knees, the odds ratio for having a contralateral knee with KL ≥ 3 was 62.7 (95% CI=42.3, 93.1). For the outcome KL ≥ 2 hips, the odds ratio for having a contralateral hip with KL ≥ 2 was 11.8 (95% CI=9.4, 14.7); for the outcome KL ≥ 3 hips, the odds ratio for having a contralateral hip with KL ≥ 3 was 150.7 (95% CI=72.7, 312.2).

Table 4 lists the adjusted odds ratios for the main explanatory variables from the models.

Goodness of fit tests for GEE showed adequate fit for these models. Maximum KL grade in the other joint site exhibited proportional odds in all four models. However, contralateral joint KL grade had non-proportional odds in both knee models, and BMI had non-proportional odds in the left hip model. A significant interaction term between race/ethnicity and contralateral joint KL grade remained in the left knee model. To ease the interpretation of these models, non-proportional odds terms are represented in Table 4 as the calculated effect of the explanatory variable for each cut-point of the outcome variable. Similarly, the interaction between race/ethnicity and contralateral joint KL grade is listed as the effect of contralateral joint KL grade by race/ethnicity (and by cut-point level, since the same model had NPO for contralateral joint KL grade). Because of the race/ethnicity interaction and the non-proportional odds in the left knee model, the effect of contralateral joint KL grade in that model requires that one consider race/ethnicity and the outcome level (are we interested in effects on the association with mild/moderate/severe ROA, or with moderate/severe ROA?). Consider a specific example to illustrate how to interpret the ORs in Table 4. In the top left cell, the odds ratio for the association between the explanatory variable contralateral (right) joint KL grade=2 and outcome
left-knee KL grade≥2 among Caucasians is 10.2, meaning that a Caucasian with right-knee KL grade=2 is 10.2 times as likely to have left-knee KL grade≥2 than is a Caucasian with right-knee KL grade=0/1. In the same cell, the odds ratio for the association between the explanatory variable contralateral (right) joint KL grade=3/4 and outcome left-knee KL grade≥2 among Caucasians is 47.3, meaning that a Caucasian with right-knee KL grade=3/4 is 47.3 times as likely to have left-knee KL grade≥2 than a Caucasian with right-knee KL grade=0/1.

The results in Table 4 show that contralateral joint KL grade is strongly associated with KL grade in knees and hips, with all effects highly significant in all models. Contralateral joint KL grade=2 (vs. 0/1) odds ratios for associations with higher KL grade in the outcome joint range from 9.2 (right hip; both races/ethnicities; both cut-points) to 24.0 (left knee; African American; cut-point KL grade≥2 vs. KL grade=0/1). Contralateral joint KL grade=3/4 (vs. 0/1) odds ratios for associations with higher KL grade in the outcome joint range from 36.5 (right knee; both races/ethnicities; cut-point KL grade≥2 vs. KL grade=0/1) to 225.0 (right hip; both races/ethnicities; both cut-points). Maximum KL grade in the other joint site showed a weaker effect in all four models, but six of the eight coefficients were statistically significant and all odds ratios exceeded 1. Odds ratios ranged from 1.4 to 1.5 for other joint site KL grade=2 (vs. 0/1), and from 1.6 to 1.8 for other joint site KL grade=3/4.

To simplify Table 4, we present the non-proportional odds terms and race/ethnicity interactions for contralateral joint KL grade here in the following text only. In the right knee model, the odds ratios for the association between contralateral joint KL grade=2 and mild/moderate/severe ROA (KL grade≥2) was 1.4 (95% CI=0.8, 2.3) times stronger than the association between
contralateral joint KL grade=2 and moderate/severe ROA (KL grade≥3). Conversely, the association between contralateral joint KL grade=3/4 and KL grade≥2 was only 0.4 (95% CI=0.2, 0.7) times the association between contralateral joint KL grade=3/4 and KL grade≥3. Similar to the right knee model, in the left knee model, the association between contralateral joint KL grade=2 and outcome KL grade≥2 was 1.9 (95% CI=1.0, 3.6) times the association between contralateral joint KL grade=2 and the outcome of KL grade≥3. Also similar to the right knee model, the association between contralateral joint KL grade=3/4 and an outcome of KL grade≥2 was less (0.6 times, 95% CI=0.3, 1.1) the association between contralateral joint KL grade=3/4 and an outcome of KL grade≥3. The non-proportional odds terms in these models suggest that the effects of contralateral joint KL grade are stronger when associated with ROA of a similar level in the outcome joint than ROA of a dissimilar level.

We found the contralateral associations to vary across race/ethnicity: in the left knee model, the association for KL grade=2 was 2.4 (95% CI=1.3, 4.4) times stronger among African Americans than Caucasians, and the association for KL grade=3/4 was 1.4 (95% CI=0.6, 2.9) times stronger. Statistically significant interactions were not observed in the right knee models.

**Discussion**

The association between moderate/severe ROA in the contralateral knee and moderate/severe ROA was stronger than the association between moderate/severe ROA and mild/moderate/severe ROA. We also found that the association between mild ROA in the contralateral knee and mild/moderate/severe ROA was stronger than the association between mild ROA and moderate/severe ROA. We found evidence of only one interaction, race/ethnicity and right-knee
KL grade in the left knee model. The interaction suggests that African Americans experienced a stronger association than Caucasians between outcome and contralateral joint KL grades. We found no other interactions between gender or race/ethnicity, and contralateral joint KL grade or maximum KL grade in the other joint site.

In this study we did not explicitly compare ROA prevalence according to left or right side beyond the basic comparison of marginal distributions made earlier from Table 2 and Table 3. However, this topic has been studied on large joints previously, with somewhat inconsistent results.16-21 For example, Neame et al (2004)17: found that OA in the tibiofemoral (knee) joint was more prevalent on the right side, and that the minimum joint space in hips was smaller on the left side (consistent with our data). On the other hand, Chitnavis et al (2000)18 reported that patients undergoing total joint replacement surgeries had more right-side replacements than left-side, in both knees and hips.

Of all the studies cited previously, Neame et al (2004)17 and Vossinakis et al (2008)22 have reported on associations somewhat similar to a contralateral joint odds ratio (in terms of “right vs. left side” OA). Neame et al reported unadjusted odds ratios for left vs. right side OA of 0.89 (95% CI=0.62, 1.28) in hips, 1.24 (95% CI=1.01, 1.52) in tibiofemoral knee radiographs and 1.02 (95% CI=0.84, 1.24) in patellofemoral knee radiographs. These results differ completely from ours. However, the odds ratios reported by Neame et al actually related to the ratio of left vs. right side univariate distributions, and therefore do not represent the effect of contralateral joint OA on the odds of OA in a joint. In a study more similar to ours, Vossinakis et al found that pre-existing hip OA on one side significantly predicted future development of OA on the other side.
They reported an odds ratio of 3.99 (95% CI=1.28, 12.39), adjusted for age and gender. This result is substantially different (lower) than ours, which is likely attributable to the differences in study design: for example, at study inception, Vossinakis et al examined unilateral hip OA only (excluding bilateral hip disease), with follow-up of 2 to 31 years when/if symptoms developed in the contralateral joint, or between 10 and 35 years among those who remained symptom-free. Our study design differs substantially from these two studies, which prevents direct comparisons of the quantitative results. Nevertheless, the Vossinakis et al study does provide some support for the notion that OA in the contralateral joint is associated with OA in the outcome joint. While the odds ratios for contralateral joint KL grade in our study are relatively very high, comparisons with raw ORs calculated from Table 2 and Table 3 suggest a biologically consistent relationship. It may also be noted that large odds ratios are not uncommon when the reference category has a very small probability. Table 2 and Table 3 show that the marginal probabilities of KL grade 3/4 in left/right knees/hips are all very low.

Although our study used cross-sectional data, results suggest that diagnosis of OA in one large joint may be a marker for risk of multi-joint ROA. This information could prove beneficial to people with newly diagnosed unilateral ROA. Knowing the increased risk of OA in other joints, they could be counseled to avoid high risk activities (e.g., occupational or recreational heavy weight-lifting involving the at-risk joints) and offered interventions (e.g., weight loss, or exercises designed to strengthen joints such as targeted physiotherapy) designed to avoid or delay the onset of symptomatic OA (if not ROA) in the at-risk joint(s).
Our study has a number of strengths. First, the sample is large and population-based (sample weighted), providing precise results that are generalizable to six townships of Johnston County, and possibly to a wider population because the socio-demographic characteristics of the US population are comparable (e.g., BMI) to the Johnston County population at baseline. Second, we have obtained radiographs of both knees and both hips simultaneously for all subjects, giving us the relatively rare opportunity to study associations between ROA occurring in different large joints within the body. Third, having recorded race/ethnicity (African American vs. Caucasian), gender and BMI allowed us to investigate possible effect modification (interactions) with contralateral joint and other joint site, as well as control for potentially confounding factors. This study also has a number of limitations. First, the sample was collected in a rural part of North Carolina that had a relatively high proportion of African Americans and a relatively high prevalence of obesity at baseline. As such, study results may be less generalizable to people in urban centers, though controlling for BMI and investigating interactions with gender and race/ethnicity would most likely have mitigated this problem. In addition, as mentioned before, BMI in the US today is heavier than previously, further mitigating this problem. Second, the baseline data analyzed in this study were collected over a relatively long period of time (1991 to 1997) for a cross-sectional sample. While it is possible that some drift in the population distribution of ROA could have occurred during that time, it is unlikely that this would be substantial enough to affect our results, particularly since the four joints within each person were collected simultaneously. Finally, results are based on cross-sectional data and therefore we do not know the temporal sequence of the associations we have studied.
In summary, we find a very strong cross-sectional association between KL grade in a knee or hip joint and KL grade in the contralateral knee or hip, even after controlling for age, gender, BMI, race/ethnicity and maximum KL grade in the other joint site. The odds ratio for contralateral joint KL grade can be in the tens or even hundreds depending on which cut-point and joint are being considered. The biggest effect was found in African Americans and associations with knee ROA. Maximum KL grade in the other joint site showed a weaker but mostly significant effect on the odds of higher KL grade in the outcome joint, after controlling for age, gender, BMI, race/ethnicity and contralateral joint KL grade. The strength of the association between ROA in the outcome and contralateral joints far exceeds the strength of any other known risk factor. These results magnify the critical importance of the multi-joint OA phenotype in studies of OA etiology, and also illustrate the need for etiologic studies of contralateral associations.

Acknowledgements

We wish to thank Erik Myers of the University of North Carolina at Chapel Hill for his quick and thorough responses to numerous data preparation requests, without which these analyses would not have been possible.
References


17. Neame R, Zhang W, Deighton C, Doherty M, Doherty S, Lanyon P, Wright G. Distribution of radiographic osteoarthritis between the right and left hands, hips, and

18. Chitnavis J, Sinsheimer JS, Suchard MA, Clipsham K, Carr AJ. End-stage
coxarthrosis and gonarthrosis. Aetiology, clinical patterns and radiological features of

19. Newton J, Seagroatt V. Why is osteoarthritis of the hip more common on the right?
Lancet 1993;341:179.

Epidemiology of osteoarthritis: Zoetermeer survey. Comparison of radiological
osteoarthritis in a Dutch population with that in 10 other populations. Ann Rheum Dis

21. Lederman R. An epidemiological and therapeutic multicenter study involving 3,309

22. Vossinakis IC, Georgiades G, Kafidas D, Hartofilakidis G. Unilateral hip
osteoarthritis: can we predict the outcome of the other hip? Skeletal Radiol

23. Spector TD, Hart DJ, Doyle DV. Incidence and progression of osteoarthritis in
women with unilateral knee disease in the general population: the effect of obesity.

Schwartz TA, Abbate LM, Callahan LF, Kalsbeek WD, Hochberg MC. Prevalence of
knee symptoms and radiographic and symptomatic knee osteoarthritis in African
Americans and Caucasians: the Johnston County Osteoarthritis Project. J Rheumatol
2007;34:172-80.


Table 1. Weighted* distribution of age, gender, race/ethnicity and BMI (n=3,068)

<table>
<thead>
<tr>
<th>Variable</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age group</strong></td>
<td></td>
</tr>
<tr>
<td>45-54</td>
<td>1030 (33.6)</td>
</tr>
<tr>
<td>55-64</td>
<td>826 (26.9)</td>
</tr>
<tr>
<td>65-74</td>
<td>816 (26.6)</td>
</tr>
<tr>
<td>75+</td>
<td>395 (12.9)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1308 (42.6)</td>
</tr>
<tr>
<td>Female</td>
<td>1760 (57.4)</td>
</tr>
<tr>
<td><strong>Race/ethnicity</strong></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>566 (18.4)</td>
</tr>
<tr>
<td>Caucasian</td>
<td>2502 (81.6)</td>
</tr>
<tr>
<td><strong>BMI group</strong></td>
<td></td>
</tr>
<tr>
<td>&lt;25</td>
<td>799 (26.0)</td>
</tr>
<tr>
<td>25-29.9</td>
<td>1208 (39.4)</td>
</tr>
<tr>
<td>30+</td>
<td>1051 (34.2)</td>
</tr>
<tr>
<td>Missing</td>
<td>10 (0.3)</td>
</tr>
</tbody>
</table>

* Scaled weighted counts are rounded to the nearest integer
Table 2. Weighted* distribution of left vs. right side KL grade in knees

| Left knee KL grade (Row %) | Right knee KL grade |  
|---------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
|                           | No/questionable (0/1) | Mild (2) | Moderate/severe (3/4) | †Total (column %) |
| No/questionable (0/1)     | 2158 | 223 | 28 | 2409 (80.5) |
| Mild (2)                  | 155  | 219 | 53 | 427 (14.3) |
| Moderate/severe (3)       | 20   | 36  | 102 | 157 (5.2) |
| †Total (row %)            | 2333 (77.9) | 479 (16.0) | 182 (6.1) | 2994 (100.0) |

* Scaled weighted counts are rounded to the nearest integer

† Total less than 3,068 due to missing data and total joint replacement
Table 3. Weighted* distribution of left vs. right side KL grade in hips

<table>
<thead>
<tr>
<th>Left hip KL grade</th>
<th>No/questionable (0/1)</th>
<th>Mild (2)</th>
<th>Moderate/severe (3/4)</th>
<th>†Total (column %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No/questionable (0/1)</td>
<td>1961</td>
<td>188</td>
<td>15</td>
<td>2164 (79.9)</td>
</tr>
<tr>
<td>Mild (2)</td>
<td>239</td>
<td>251</td>
<td>14</td>
<td>504 (18.6)</td>
</tr>
<tr>
<td>Moderate/severe (3)</td>
<td>7</td>
<td>9</td>
<td>26</td>
<td>41 (1.5)</td>
</tr>
<tr>
<td>†Total (row %)</td>
<td>2207</td>
<td>448</td>
<td>55</td>
<td>2709 (100.0)</td>
</tr>
</tbody>
</table>

* Scaled weighted counts are rounded to the nearest integer
† Total less than 3,068 due to missing data and total joint replacement
<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Four Models (by outcome variable)</th>
<th>OR (95% CI)</th>
<th>OR (95% CI)</th>
<th>OR (95% CI)</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left knee model</td>
<td>Right knee model</td>
<td>Left hip model</td>
<td>Right hip model</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
<td></td>
</tr>
<tr>
<td><strong>Among Caucasians</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contralateral KL grade (for <strong>outcome KL grade≥2</strong>†)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 vs. 0/1</td>
<td>10.2 (7.4, 14.0)</td>
<td>12.9 (9.8, 17.1)</td>
<td>9.4 (7.3, 12.2)</td>
<td>9.2 (7.1, 11.9)</td>
<td></td>
</tr>
<tr>
<td>3/4 vs. 0/1</td>
<td>47.3 (27.0, 82.8)</td>
<td>36.5 (19.9, 67.2)</td>
<td>89.7 (33.6, 239.3)</td>
<td>225.0 (83.6, 605.7)</td>
<td></td>
</tr>
<tr>
<td>Contralateral KL grade (for <strong>outcome KL grade≥3</strong>‡)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 vs. 0/1</td>
<td>5.3 (2.7, 10.6)</td>
<td>9.6 (5.7, 16.1)</td>
<td>(odds were proportional)</td>
<td>(odds were proportional)</td>
<td></td>
</tr>
<tr>
<td>3/4 vs. 0/1</td>
<td>83.3 (40.7, 170.5)</td>
<td>104.2 (57.5, 188.7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Among African Americans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contralateral KL grade (for <strong>outcome KL grade≥2</strong>†)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 vs. 0/1</td>
<td>24.0 (14.0, 41.1)</td>
<td>(no race/ethnicity interaction)</td>
<td>(no race/ethnicity interaction)</td>
<td>(no race/ethnicity interaction)</td>
<td></td>
</tr>
<tr>
<td>3/4 vs. 0/1</td>
<td>64.1 (32.0, 128.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contralateral KL grade (for <strong>outcome KL grade≥3</strong>‡)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 vs. 0/1</td>
<td>12.5 (5.7, 27.2)</td>
<td>(no race/ethnicity interaction)</td>
<td>(no race/ethnicity interaction)</td>
<td>(no race/ethnicity interaction)</td>
<td></td>
</tr>
<tr>
<td>3/4 vs. 0/1</td>
<td>112.8 (52.0, 244.8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>Same as Caucasian outcome KL grade≥2</td>
<td>Same as Caucasian outcome KL grade≥2</td>
<td>Same as Caucasian outcome KL grade≥2</td>
<td>Same as Caucasian outcome KL grade≥2</td>
<td></td>
</tr>
<tr>
<td>Other joint site max. KL grade †</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 vs. 0/1</td>
<td>1.5 (1.2, 2.0)</td>
<td>1.4 (1.0, 1.8)</td>
<td>1.5 (1.2, 2.0)</td>
<td>1.5 (1.1, 2.0)</td>
<td></td>
</tr>
<tr>
<td>3/4 vs. 0/1</td>
<td>1.7 (0.9, 3.0)</td>
<td>1.8 (1.0, 3.3)</td>
<td>1.8 (1.2, 2.7)</td>
<td>1.6 (1.0, 2.4)</td>
<td></td>
</tr>
</tbody>
</table>

* ORs are multivariable adjusted and derived from models that included all the variables in a column: age, gender, race/ethnicity, BMI, contralateral KL grade, and other joint site maximum KL grade

† Referent is KL grade 0/1

‡ Referent is KL grade 0/1/2
Odds were proportional for other joint site max KL grade