

Job-Related Osteoarthritis of the Knee, Foot, Hand, and Cervical Spine

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Objectives: To assess the influence of occupational exposures on risk of site-specific radiographic osteoarthritis (OA) of the knee, hand, foot, and cervical spine. **Methods:** Using a cross-sectional design, data collected from men and women aged 40 years and older participating in the Clearwater Osteoarthritis Study were analyzed ($n = 3436$). Subjects' occupational exposures were queried using the study intake form, including stair climbing, standing on a rigid surface, squatting, and jolting. Physical examinations including radiographs of the knee, hand, foot, and cervical spine were conducted. The Kellgren and Lawrence ordinal scale was used to determine evidence of radiographic OA. **Results:** Both the unadjusted and adjusted odds ratios (ORs) for men and women indicated that age and body mass index were associated with OA. There were no other significant odds ratios for the cervical spine. Among men, there were significant associations with knee OA for stair climbing and jolting of the legs and with foot OA with stair climbing. Among women, there was a significant association between standing on a rigid surface and knee OA. For hand OA in women, there was a significant association for jolting of the hands. **Conclusions:** Although the association with stair climbing was found in other investigations for knee OA, it was also associated with foot OA in this study. In addition, the jolting feature was seen in only one other study for men (knees) and novel for women (hands).

Osteoarthritis (OA) is a degenerative joint disease that affects the ability of men and women to work effectively and pain free. Although personal risk factors for OA are difficult to manage or control, job risk factors may amplify the risk and these suggest opportunities for control. Some occupations have been recognized as having greater risk. These include shipyard workers, carpenters, miners, construction workers, cleaners, agricultural workers, and rock workers.¹⁻⁸ Generally, occupations with heavy physical demands may be at greater risk for OA for the knee^{4,6,7,9} but perhaps not the hand.^{10,11}

Reported job risk factors for knee OA are summarized in Table 1. Six studies have identified squatting and/or kneeling (substantial knee flexion) as a job risk factor with odds ratios (ORs) from 2 to 7.^{6,9,12-15} Jensen⁷ reported this finding in a more comprehensive review of the epidemiological literature. Stair climbing (or climbing) comprises knee flexion with added load during the return to neutral that was identified as contributing to knee OA in three studies with ORs in the 2.5 to 5 range, but Jensen⁷ was more tentative about the association. Five studies identified lifting as job risk factor with ORs from 2 to 5,^{6,12,14-16} which may also involve knee flexion under load. Seidler et al⁶ demonstrated an interaction

between squatting/kneeling and manual materials handling and this was supported by Amin et al¹⁷ for men based on magnetic resonance images. One study reported that jumping was a risk factor with an OR of 2.7 for men.¹⁵ This probably represents an impact load to the knees. Walking more than 3.3 km was significant for women and a mixed population (OR = 2.1 and 1.9).¹² For women, standing from a sitting position more than 25 times per day (OR = 2.3) was a risk factor for OA.¹⁴ There were two reports that occupation may not play a role in OA of the hand.^{10,11} There were no reports of job risk factors for the foot or cervical spine.

Occupational loading of the knee was a common theme for OA of the knee in the studies reported above. Felson¹⁸ recommended that risk factors be separated into two groups, one of which is joint loading, and this was consistent with the literature reported above. Our review of the literature did not find job risk factors for the hand, foot, and cervical spine. The principal purpose of this article was to examine an existing database for radiologically defined OA of the knee, hand, foot, and cervical spine for evidence of job-related risk factors for OA. An expected outcome of this study was to confirm that the contributions of rotational and axial loading and flexion of the knee were associated with OA.

MATERIALS AND METHODS

Database

The Clearwater Osteoarthritis Study (COS), which was initiated in 1988 by the Arthritis Research Institute of America, is an ongoing, community-based, longitudinal cohort study designed to identify the major risk factors for the development and progression of radiographic OA. The longitudinal study collected demographic, historical, clinical, and radiological data in individuals who are older than 40 years.

After eligibility was determined and an institutional review board approved written informed consent was obtained, participants completed the COS History Questionnaire. Also at the intake, a physical examination with an emphasis on clinical and functional joint evaluation was conducted including radiographs. No radiographs of hips were taken. The following potential study participants were excluded from enrolment: individuals with self-reported rheumatoid arthritis or variants (lupus erythematosus, ankylosing spondylitis, etc), gout, disabling neuralgic disease, those confined to a wheelchair, and those not able to give consent.

For this study, the five exposures from the intake questionnaire associated with occupational activities were stair climbing, standing on a rigid surface, squatting, jolting of the feet and legs, and jolting of the hands and legs. Exposure to climbing stairs was dichotomized to "yes" for daily stair climbing of more than five times and to "no" for daily stair climbing five or less times per day. Exposure to standing on a rigid surface was dichotomized to "yes" for daily exposure of 2 or more hours and to "no" for daily exposure less than 2 hours. The last three exposure factors (squatting, jolting of the feet and legs, and jolting of the hands and legs) were created from the following intake item, "Did the job you had for most of your life involve: Standing most of the time; Sitting most of the time; Sitting and standing about equally; Squatting a lot; Jolting with your feet and legs; or Jolting with your hands and legs." If a

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TABLE 1. Job Risk Factors With Significant ORs for Knee OA as Noted in the Literature

Job Risk Factor	OR	Reference
Squatting >30 min/d	Mixed: 6.9	Cooper et al ¹³
Squatting or kneeling >1 hr/d	Men: 2.0 Women: 2.1 Mixed: 1.9	Coggon et al ¹²
Squatting >500 times for >10 yr	Men: 2.9	Sandmark et al ¹⁵
Kneeling/Squatting \geq 2 hr/d	Women: 1.8	Manninen et al ⁹
Kneeling \geq 14 times/d ^a	Men: 3.1	D'Souza et al ¹⁴
Squatting/kneeling 4,757–10,800 hr ^b	Men: 2.8	Seidler et al ⁶
Squatting/kneeling >10,800 hr ^b	Men: 4.0	Seidler et al ⁶
Stair climbing >10 flights/d	Mixed: 2.7	Cooper et al ¹³
Stair climbing >15 flights/d	Men: 2.5 Women: 5.1	Lau et al ¹⁶
Climbing (high) ^c	Men: 3.1	Manninen et al ⁹
Lifting >25 kg at >10 times/wk	Women: 1.7 Mixed: 1.7	Coggon et al ¹²
Lifting >11,400 times for >10 yr	Men: 3.0	Sandmark et al ¹⁵
Heavy lifting \geq 20 times/d ^d	Men: 2.7	D'Souza et al ¹⁴
Lifting \geq 10 kg at >10 times/wk	Men: 5.4 Women: 2.0	Lau et al ¹⁶
Lifting/carrying 630–5,120 kg \times hr ^b	Men: 2.0	Seidler et al ⁶
Lifting/carrying 5,120–37,000 kg \times hr ^b	Men: 3.6	Seidler et al ⁶
Lifting/carrying >37,000 kg \times hr ^b	Men: 3.5	Seidler et al ⁶
Jumping >500 times for >10 yr	Men: 2.7	Sandmark et al ¹⁵
Walking >3.3 km (2 min)	Women: 2.1 Mixed: 1.9	Coggon et al ¹²
Standing 31–36 times/d ^e	Women: 2.3	D'Souza et al ¹⁴

^aExposure to kneeling was classified as first quartile (<4 times/d) and fourth quartile (\geq 14); reference group is first quartile and OR is for fourth quartile.

^bTotal exposure over lifetime.

^cExposure to climbing was classified as low (not at all or very little), medium (some), or high (much), with low as the reference group and OR is for high.

^dExposure to heavy lifting was assessed as first quartile (<4 times/d) and fourth quartile (>20); reference group is first quartile and OR is for fourth quartile.

^eExposure to standing was classified as first quartile (<26 times/d), third quartile (30 < to \leq 36), and fourth quartile (>36); reference group is first quartile, OR is for third quartile, and fourth not significant.

person reported “Jolting with your feet and legs,” they were not included in the category “Jolting with your hands and legs” to differentiate where the hands were involved in jolting activities. For the exposures to squatting, jolting of the feet and legs, and jolting of the hands and legs, the reference group was those subjects who indicated “Sitting most of the time.” For example, the association between “Jolting of the feet and legs” and radiographic OA was compared the risk of radiographic OA among those who reported “Jolting of the feet and legs” to those who reported “Sitting most of the time.”

The four study outcomes were radiographic OA of the knee, hand, foot, and cervical spine. A licensed radiograph technician using standard exposure techniques took hand, lateral cervical spine, anteroposterior weight-bearing knee, and weight-bearing foot radiographs. A board-certified radiologist, blinded to participant's information, interpreted all of the radiographs. Each radiograph was graded 0 to 4 for OA by the ordinal criteria of Kellgren and Lawrence: 0, absent; 1, questionable osteophytes and no joint space narrowing; 2, definite osteophytes with possible joint space narrowing; 3, definite joint space narrowing with moderate multiple osteophytes and some sclerosis; and 4, severe joint space narrowing with cysts, osteophytes, and sclerosis present.¹⁹ Subjects whose radio-

graphs were interpreted as grades 2, 3, or 4 were classified as OA cases. Subjects whose radiographs were interpreted as grades 0 or 1 were classified as OA controls (free of disease). The six bilateral hand joints assessed were the second distal interphalangeal joint, third proximal interphalangeal joints, and first carpometacarpal joints. Foot OA status was based on radiological evidence of disease in the first metatarsophalangeal joint.

Confounding variables used in the adjusted analyses were selected by reviewing the relevant literature and considerations regarding the limitations of the data set. While assessing the relationship between occupational exposures and radiographic OA, the authors examined the potential influence of several factors. Although cigarette smoking has sometimes been found related to the incidence of OA, the association was weak and it was not included.²⁰ Leisure time activities and exercise status were considered, but these factors did not significantly influence the risk estimates. Age and body mass index (BMI) were the most consistent and well-known confounders, and these factors were retained in the final adjusted models.

A further confounding variable is genetics. It is clear that genetic markers are related to OA, but the relationships are complex and differ by joint.^{21–23} Information on family links and specific joint OA was not available and thus cannot be accounted for. Because of the genetic link, if family members decided to participate in the COS study, this could bias our findings by overestimating the incidence of disease.

Statistical Analyses

Descriptive baseline data were generated through the calculation of frequencies and means. Logistic regression analyses were used to test the hypotheses of the relationship between the exposure factors and radiographic OA.²⁴ The exponentiated beta coefficient produced ORs for the associations under investigation. Site-specific radiographic OA was the dependent variable. The reference group for each of the analyses was the absence of OA. The dichotomous predictor variables for each of the analyses were the occupational exposures (eg, squatting). Separate analyses for gender were performed. The adjusted analyses retained age and BMI as continuous variables. Statistical Analyses Software (SAS, Cary NC), version 9.13, was used (PROC LOGISTIC) for the analyses of these data. The ORs with accompanying 95% CIs were calculated. Results were deemed statistically significant at $\alpha = 0.05$. Observations with missing values were omitted from analyses rather than imputing and assigning undetermined values.

RESULTS

Volunteer participants in the study were recruited by a variety of methods. These included invitational letters; television and radio announcements; newspaper articles publicizing the study; information posted in community organizations' bulletins; and seminars given at community clubs and organizations. Special recruitment efforts were used to encourage participation in the study by employees of the Pinellas County school system, the City of Clearwater, and Pinellas County to include subjects who were more likely to be free of disease and/or younger subjects at risk for OA. A comparison between the COS study sample and the source population (during the time period of initial recruitment) shows an overrepresentation of subjects 45 to 54 years of age and a deficit of participants among those 75 years and older. In addition, the majority of COS participants are White (99%). Recruitment strategies for the community-based study limited our ability to calculate response rates.

The study sample ($n = 3548$) consisted of 1098 men and 2450 women. The mean (\pm SD) age was 63.4 (\pm 10.9) years for men and 61.4 (\pm 10.7) for women; and BMI was 27.6 (\pm 4.4) kg/m² for men and 26.2 (\pm 5.3) for women. The percentage of all subjects

TABLE 2. Survey Response Categories and OA Status^a for Knee, Hand, Foot and Cervical Spine (C-Spine) by Gender and Includes Mean ± Standard Deviation of Age and BMI

Men (n = 1,098)	Age = 63.1 ± 10.9 yr				BMI = 27.6 ± 4.4 kg/m ²			
	Knee OA ^a		Hand OA ^a		Foot OA ^a		C-Spine OA ^a	
Yes	No	Yes	No	Yes	No	Yes	No	
Stair climbing more than 5 times/d								
Yes	55	159	96	118	67	147	80	133
No	146	697	346	497	200	643	230	577
Stand on rigid surface for ≥2 hr								
Yes	116	473	249	340	146	443	185	398
No	84	375	196	263	116	343	153	304
Squat a lot								
Yes	28	89	52	65	29	88	52	63
No	46	223	119	150	69	200	99	168
Jolt feet/legs								
Yes	32	70	43	59	25	77	37	64
No	45	227	118	154	69	203	101	169
Jolt feet/hands w/o Jolt feet/legs								
Yes	24	84	44	64	29	79	41	65
No	45	226	118	153	69	202	99	170
Age = 61.4 ± 10.7 yr BMI = 26.2 ± 5.3 kg/m ²								
Women (n = 2,450)	Knee OA ^a		Hand OA ^a		Foot OA ^a		C-Spine OA ^a	
Yes	No	Yes	No	Yes	No	Yes	No	
Stair climbing more than 5 times/d								
Yes	102	441	259	284	100	443	170	368
No	265	1,485	699	1,051	313	1,437	477	1,261
Stand on rigid surface for ≥2 hr								
Yes	201	969	491	679	207	963	308	853
No	155	894	436	613	183	886	311	731
Squat a lot								
Yes	16	142	63	95	25	133	36	119
No	107	592	301	398	129	570	210	488
Jolt feet/legs								
Yes	20	88	55	53	21	87	35	71
No	106	598	300	404	127	577	208	495
Jolt feet/hands w/o Jolt feet/legs								
Yes	21	101	67	55	22	100	42	78
No	105	596	298	403	127	574	207	493

^aThe Kellgren and Lawrence scale was used with osteoarthritis disease defined as grade 2+ [Kellgren and Lawrence¹⁹].

with radiographic OA for knee was 17%, for foot was 20%, for hand was 42%, and for cervical spine was 30%. Table 2 presents the two-by-two tables of OA disease and reports of job risk factors by gender. More than 20% of all the participants reported standing on rigid surfaces (50%) and climbing stairs (21%). Less than 10% of the total reported squatting (8%), jolting of the feet and legs (6%), and jolting of the hands and legs (without jolting of the feet and legs) (6%).

The crude ORs by gender for age, BMI, and five job risk factors are reported in Table 3. As expected, age was a significant factor for both men and women across all four body regions. BMI was significant across the four joints for women and significant for men for the knee and foot. Among the job risk factors, there were four statistically significant factors. Stair climbing was a significant risk factor for knee OA for both men and women. In addition, jolting of the feet and legs contributed to the risk for knee OA for

men. For the foot, only stair climbing contributed to risk and for men only. For the hand, only jolting of hands and legs contributed for women only. There were no significant job-related ORs for cervical spine.

Table 4 lists the adjusted ORs (adjusted for age and BMI) by gender for age, BMI, and the job risk factors. Age (adjusted for BMI) remained significant for men and women for all joints. BMI (adjusted for age) remained significant for women across all joints and for men for knee and foot. Among men, after adjusting for age and BMI, significant ORs for knee OA emerged for stair climbing (OR = 1.61; 1.11 to 2.32) and jolting the feet and legs (OR = 2.39; 1.38 to 4.15). In addition, men demonstrated a relationship between stair climbing and foot OA (OR = 1.41; 1.01 to 1.97). Among women, jolting of the hands and legs (without jolting of the feet and legs) was associated with hand OA (OR = 1.82; 1.19 to 2.76). Women also demonstrated a relationship between standing on a rigid surface and knee OA

TABLE 3. Gender-Stratified Unadjusted ORs, by Body Site for Selected Job Risk Factors

	Men	Women
Knee		
Age	1.04 (1.03–1.06)	1.06 (1.05–1.08)
BMI	1.10 (1.07–1.14)	1.11 (1.09–1.14)
Stair climbing (>5 times/d)	1.65 (1.16–2.36)	1.30 (1.01–1.67)
Standing on a rigid surface (≥2 hr/d)	1.10 (0.80–1.50)	1.20 (0.95–1.50)
Squatting	1.53 (0.90–2.59)	0.62 (0.36–1.09)
Jolting of the feet and legs	2.31 (1.36–3.90)	1.28 (0.76–2.17)
Jolting of the hands and legs	1.44 (0.82–2.50)	1.18 (0.71–1.97)
Foot		
Age	1.03 (1.02–1.05)	1.06 (1.05–1.07)
BMI	1.04 (1.01–1.08)	1.03 (1.01–1.05)
Stair climbing (>5 times/d)	1.47 (1.05–2.04)	1.04 (0.81–1.33)
Standing on a rigid surface (≥2 hr/d)	0.97 (0.74–1.29)	1.02 (0.82–1.27)
Squatting	0.96 (0.58–1.58)	0.83 (0.52–1.33)
Jolting of the feet and legs	0.96 (0.56–1.62)	1.10 (0.66–1.83)
Hand		
Age	1.07 (1.05–1.08)	1.09 (1.08–1.10)
BMI	0.99 (0.97–1.02)	1.03 (1.02–1.05)
Jolting of the hands and legs	0.89 (0.57–1.40)	1.65 (1.12–2.43)
Cervical spine		
Age	1.09 (1.07–1.10)	1.08 (1.07–1.09)
BMI	1.00 (0.98–1.03)	1.02 (1.00–1.04)
Stair climbing (>5x/d)	1.34 (0.98–1.83)	1.22 (0.99–1.51)
Standing on a rigid surface (≥2 hr/d)	0.92 (0.71–1.20)	0.85 (0.71–1.02)
Jolting of the feet and legs	0.97 (0.60–1.55)	1.17 (0.76–1.81)
Jolting of the hands and legs	1.08 (0.68–1.72)	1.28 (0.85–1.93)

95% CIs are shown; shaded cells are significant at $\alpha = 0.05$.

(OR = 1.36; 1.06 to 1.73). The cervical spine did not demonstrate strong relationships, for either gender, with the occupational risk factors explored in the COS database.

DISCUSSION

Because the study population was a nonrandom community-based cohort around Clearwater, Florida, these data may represent an over-sampling of those persons interested in OA, thus having a higher prevalence in the cohort. The potential bias introduced into the data would be of concern if estimating disease prevalence; however, the population is appropriate for estimating associations or disease risk. As with any study using volunteers, there is the potential for the healthy worker bias. Naturally, only those feeling well-enough to participate are in the volunteer population. The results need to be interpreted with this limitation in mind. Generalizability may be limited based on study recruitment design.

The primary null hypothesis was that there was no association between occupational exposure and risk of radiographic OA. A cross-sectional design was used to assess the association between occupational exposure and site-specific radiographic OA. Cross-sectional analysis studies the relationship between different variables at a given point in time. This study design was efficient for exploratory research and was valuable for generating hypotheses for future research.

The associations of age and BMI to OA are well established.^{25,26} The fact that these factors contributed significantly

TABLE 4. Gender-Stratified Adjusted ORs, by Body Site for Selected Job Risk Factors

	Men	Women
Knee		
Age	1.05 (1.03–1.07)	1.07 (1.06–1.08)
BMI	1.12 (1.08–1.16)	1.12 (1.10–1.15)
Stair climbing (>5 times/d)	1.61 (1.11–2.32)	1.14 (0.87–1.49)
Standing on a rigid surface (≥2 hr/d)	1.12 (0.81–1.55)	1.36 (1.06–1.73)
Squatting	1.56 (0.89–2.75)	0.89 (0.50–1.61)
Jolting of the feet and legs	2.39 (1.38–4.15)	1.39 (0.78–2.45)
Jolting of the hands and legs	1.54 (0.86–2.75)	1.32 (0.76–2.29)
Foot		
Age	1.04 (1.02–1.05)	1.06 (1.04–1.07)
BMI	1.05 (1.02–1.09)	1.03 (1.01–1.05)
Stair climbing (>5 times/d)	1.41 (1.01–1.97)	0.88 (0.68–1.13)
Standing on a rigid surface (≥2 hr/d)	1.00 (0.75–1.34)	1.14 (0.91–1.43)
Squatting	1.00 (0.59–1.68)	1.05 (0.65–1.70)
Jolting of the feet and legs	0.97 (0.56–1.69)	1.14 (0.68–1.94)
Hand		
Age	1.07 (1.05–1.08)	1.09 (1.08–1.10)
BMI	1.01 (0.98–1.04)	1.03 (1.01–1.04)
Jolting of the hands and legs	0.93 (0.57–1.51)	1.82 (1.19–2.76)
Cervical spine		
Age	1.09 (1.07–1.10)	1.08 (1.07–1.09)
BMI	1.03 (0.99–1.06)	1.02 (1.00–1.03)
Stair climbing (>5 times/d)	1.22 (0.87–1.72)	0.98 (0.79–1.23)
Standing on a rigid surface (≥2 hr/d)	1.04 (0.79–1.39)	0.99 (0.81–1.21)
Jolting of the feet and legs	0.97 (0.58–1.61)	1.27 (0.81–2.01)
Jolting of the hands and legs	1.18 (0.71–1.96)	1.34 (0.88–2.06)

95% CIs are shown; shaded cells are significant at $\alpha = 0.05$.

individually (crude ORs) and jointly (adjusted ORs) was not surprising. In fact, age and BMI represented the only risk factors associated with OA for the cervical spine in the context of this study. Although there are genetic risk factors,^{21–23} it was not possible to control for these within the study design.

As mentioned in the introduction section, there was ample evidence of a relationship between job risk factors and OA of the knee. For men, a significant risk factor was stair climbing. The adjusted OR in this study was 1.61 (1.11 to 2.32) for climbing more than five times per day (referenced to none to five times per day). Cooper et al¹³ reported an OR = 2.7 when there were more than 10 flights per day, and Lau et al¹⁶ reported an OR = 2.5 for men for 15 flights/d, a number of stairs that was likely more than reported in the current population. Although five times per day lacks the precision of number of flights in 1 day, a reasonable assumption for the response was each time represented a flight. The lower threshold for stair climbing in the current study can explain the somewhat lower OR and provided support for a dose-response relationship, which has not been demonstrated.⁷ To further explore the possibility of a dose response, the stair climbing data were stratified into four levels (none [reference level], <2 times/d, 2 to 5 times/d, and >5 times/d). The unadjusted knee OA OR for the highest level remained significant, but there were not significant findings for the other levels or for any level in the adjusted ORs. It would not be surprising that there were no significant findings to support a dose response if five times per day was near the threshold effect level.

Also for men, jolting of the feet and legs referenced to sitting most of the time carried a significant risk for knee OA (OR = 2.39; 1.38 to 4.15). The population size for this effect was 374 men because of the restricted reference group. "Jolting," as used in the standard questionnaire, was neither elaborated on nor quantified. Rather, it was taken as the respondents perceived it. This was somewhat similar to jumping reported by Sandmark et al¹⁵ with a similar OR of 2.7. The common exposure seemed to be an impact loading of the knee versus rotational loading associated with climbing stairs. When both jolting and stair climbing were included in the model for this study, only jolting was significant. That is, the contribution of impact for the current population was stronger than the stair climbing. Although the risk due to stair climbing might be relatively small due to a low demand of five times per day, impacts (through the jolting descriptor) may point to a job risk factor that has not been well described in the past literature.

Kneeling and squatting have been associated with knee OA in previous studies as reported in Table 1. The stress can be described more as an extreme flexion of the knee rather than rotational loading or impact. To help focus the association with squatting, the reference group was narrowly defined as those who sat most of the time. Given all the evidence from previous studies for squatting and kneeling and the intentional focusing of the sample to maximize contrast, the lack of significance in this study was somewhat surprising. Of the 1098 men, the sample size was 386, composed of the 117 who reported squatting a lot and the 269 who reported sitting most of the time. Although the smaller sample size would have reduced the power, this probably does not fully account for the lack of significance. The sample size was similar to other studies. There was some vagueness in that the question asked if there was a lot of squatting on the job, and this may have contributed to the inability to find significance. For the NHANES III database, D'Souza et al¹⁴ found a prevalence of kneeling, which they defined as a composite descriptor of extreme knee flexion, was ~8% of the overall population. This prevalence is about the same as that for squatting in this study for both men and women of 7.4%. The remaining explanation was that jolting was preferred as an alternative descriptor as thus biased some of the data away from squatting. The magnitude of the OR (1.56; 0.89 to 2.75) was similar to one previous study¹² but much smaller than the others reported in Table 1.

Knee OA for women presented a different set of risk factors in this study. Standing for more than 2 hours was a significant risk factor with an OR of 1.36 (1.06 to 1.73). D'Souza et al¹⁴ reported repeated standing (31 to 36 times per day) presumably from a sitting position as a risk factor for women (OR = 2.3), whereas this study looked at sustained standing. Because the presumptive exposure in this study was a steady loading of the knee while the exposure in the D'Souza et al¹⁴ study was a rotational loading similar to stair climbing, the mechanisms were probably different and there is little room for direct comparison. When standing on rigid surface was stratified, only the highest level (>6 hours/d) was significant for knee OA (OR = 1.46).

Because the questionnaire compounded jolting of the hands and legs in one question, the group that answered "yes" to this question and "no" to the question of jolting of the feet and legs was used. In this way, we hoped to segregate those who were reporting predominately hands. In practice, it seems that women had more jobs that represented a mix of both and that the jolting contributed to OA of the knee as it did for men.

From Table 4, there was a significant association among men between stair climbing and foot OA. When the stair climbing data were stratified as described for knee, there were no significant findings. Like knee, the foot OA may have a threshold effect around five times per day, which might be in the vicinity of five flights per

day. There were no other reports of foot OA related to stair climbing to compare the results in this study.

There was one job risk factor that emerged for women that affected the hand and that was jolting of the hands and legs (without a report of jolting of the legs). As mentioned previously, this was to tease out the possible role of impact loading on the hands. For the hands of women, the adjusted OR was 1.82 (1.19 to 2.76). The contribution of impacts (eg, jolts) seemed to have an important association with OA of the hand. This has not been reported elsewhere. Caspi et al¹⁰ reported that there were no occupational risk factors of OA of the hands and wrists, but they used a relatively general description of work load that would not bring out impact loading. With a study population of lumberjacks with high levels of hand-arm vibration, Kivekas et al¹¹ did not observe OA of the hands.

Two weaknesses of the study with regard to occupational factors were the sample population and the limited questions associated with occupational factors. A study strength was the objective measurement of radiographic OA using the Kellgren and Lawrence ordinal scale.¹⁹ Radiographs were read blindly using a carefully controlled method. In addition to the consistency of disease status measurement, the cohort sample size affords an appropriate amount of statistical power for estimating category-specific risk estimates.

In summary, for men's knees, climbing stairs was a clear job risk factor based on previous studies (see Table 1), the review by Jensen,⁷ and this study. This pointed to repeated rotational loading of the knee as an important risk factor. Impact loading of the knees due to jumping¹⁵ or jolting (this study) seemed to be another job risk factor, which deserves more attention. There was ample support for kneeling/squatting (ie, marked flexion) in other studies (see Table 1) and the lack of support in this study was more likely due to sample size for exposure to that risk. In all, job designs should avoid repeated rotational loading of the knee equivalent to body weight, sudden axial loading, and extreme flexion. There was evidence that stair climbing was associated with foot OA, and this deserves more attention. For women, the findings were narrower with an indication that jolting of the hands may be a risk factor for OA of the hand. Our data did not suggest an association between job-related risk factors and OA of the cervical spine.

REFERENCES

1. Lindberg H, Montgomery F. Heavy labor and the occurrence of gonarthrosis. *Clin Orthop Relat Res.* 1987;235-236.
2. O'Reilly SC, Muir KR, Doherty M. Occupation and knee pain: a community study. *Osteoarthritis Cartilage.* 2000;8:78-81.
3. Jensen LK, Mikkelsen S, Loft IP, Eenberg W, Bergmann I, Logager V. Radiographic knee osteoarthritis in floorlayers and carpenters. *Scand J Work Environ Health.* 2000;26:257-262.
4. Rossignol M, Leclere A, Allaert FA, et al. Primary osteoarthritis of hip, knee, and hand in relation to occupational exposure. *Occup Environ Med.* 2005;62:772-777.
5. Jarvholm B, From C, Lewold S, Malchau H, Vingard E. Incidence of surgically treated osteoarthritis in the hip and knee in male construction workers. *Occup Environ Med.* 2008;65:275-278.
6. Seidler A, Bolm-Audorff U, Abolmaali N, Elsner G; the Knee Osteoarthritis Study-Group. The role of cumulative physical work load in symptomatic knee osteoarthritis—a case-control study in Germany. *J Occup Med Toxicol.* 2008;3:14.
7. Jensen LK. Knee osteoarthritis: influence of work involving heavy lifting, kneeling, climbing stairs or ladders, or kneeling/squatting combined with heavy lifting. *Occup Environ Med.* 2008;65:72-89.
8. Felson DT, Lawrence RC, Dieppe PA, et al. Osteoarthritis: new insights, Part I: the disease and its risk factors. *Ann Intern Med.* 2000;133:635-646.
9. Manninen P, Heliovaara M, Riihimaki H, Suoma-Iainin O. Physical workload and the risk of severe knee osteoarthritis. *Scand J Work Environ Health.* 2002;28:25-32.

10. Caspi D, Flusser G, Farber I, et al. Clinical, radiologic, demographic, and occupational aspects of hand osteoarthritis in the elderly. *Semin Arthritis Rheum.* 2001;30:321–331.
11. Kivekas J, Riihimaki H, Husman K, et al. Seven-year follow-up of white-finger symptoms and radiographic wrist findings in lumberjacks and referents. *Scand J Work Environ Health.* 1994;20:101–106.
12. Coggon D, Croft P, Kellingray S, Barrett D, McLaren M, Cooper C. Occupational physical activities and osteoarthritis of the knee. *Arthritis Rheum.* 2000;43:1443–1449.
13. Cooper C, McAlindon T, Coggon D, Egger P, Dieppe P. Occupational activity and osteoarthritis of the knee. *Ann Rheum Dis.* 1994;53:90–93.
14. D'Souza JC, Werner RA, Keyserling WM, et al. Analysis of the Third National Health and Nutrition Examination Survey (NHANES III) using expert ratings of job categories. *Am J Ind Med.* 2008;51:37–46.
15. Sandmark H, Hogstedt C, Vingard E. Primary osteoarthrosis of the knee in men and women as a result of lifelong physical load from work. *Scand J Work Environ Health.* 2000;26:20–25.
16. Lau EC, Cooper C, Lam D, Chan VN, Tsang KK, Sham A. Factors associated with osteoarthritis of the hip and knee in Hong Kong Chinese: obesity, joint injury, and occupational activities. *Am J Epidemiol.* 2000;152:855–862.
17. Amin S, Goggins J, Niu J, et al. Occupation-related squatting, kneeling, and heavy lifting and the knee joint: a magnetic resonance imaging-based study in men. *J Rheumatol.* 2008;35:1645–1649.
18. Felson DT. Risk factors for osteoarthritis: understanding joint vulnerability. *Clin Orthop Relat Res.* 2004;S16–S21.
19. Kellgren J, Lawrence J. *Atlas of Standard Radiographs: The Epidemiology of Chronic Rheumatism.* Oxford, England: Blackwell Scientific; 1963.
20. Wilder FV, Hall BJ, Barrett JP. Smoking and osteoarthritis: is there an association? The Clearwater Osteoarthritis Study. *Osteoarthritis Cartilage.* 2003;11:29–35.
21. MacGregor AJ, Li Q, Spector TD, Williams FM. The genetic influence on radiographic osteoarthritis is site specific at the hand, hip and knee. *Rheumatology (Oxford).* 2009;48:277–280.
22. Valdes AM, Spector TD. The contribution of genes to osteoarthritis. *Med Clin North Am.* 2009;93:45–66, x.
23. Peach CA, Carr AJ, Loughlin J. Recent advances in the genetic investigation of osteoarthritis. *Trends Mol Med.* 2005;11:186–191.
24. SAS. *Logistic Regression Examples Using the SAS System*, Version 6. Cary, NC: SAS Institute Inc; 1995.
25. Lethbridge-Cejku M, Tobin JD, Scott WW Jr, Reichle R, Plato CC, Hochberg MC. The relationship of age and gender to prevalence and pattern of radiographic changes of osteoarthritis of the knee: data from Caucasian participants in the Baltimore Longitudinal Study of Aging. *Aging (Milano).* 1994;6:353–357.
26. Oliveria SA, Felson DT, Cirillo PA, Reed JI, Walker AM. Body weight, body mass index, and incident symptomatic osteoarthritis of the hand, hip, and knee. *Epidemiology.* 1999;10:161–166.