Occupational Physical Loading Tasks and Knee Osteoarthritis: A Review of the Evidence

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ABSTRACT

Purpose: To perform a systematic review with best evidence synthesis examining the literature on the relationship between occupational loading tasks and knee osteoarthritis (OA). **Methods:** Two databases were searched to identify articles published between 1946 and April, 2011. Eligible studies were those that (1) included adults reporting on their employment history; (2) measured individuals' exposure to work-related activities with heavy loading in the knee joint; and (3) identified presence of knee OA (determined by X-ray), cartilage defects associated with knee OA (identified by magnetic resonance imaging), or joint replacement surgery. **Results:** A total of 32 articles from 31 studies met the inclusion criteria. We found moderate evidence that combined heavy lifting and kneeling is a risk factor for knee OA, with odds ratios (OR) varying from 1.8 to 7.9, and limited evidence for heavy lifting (OR = 1.4–7.3), kneeling (OR = 1.5–6.9), stair climbing (OR = 1.6–5.1), and occupational groups (OR = 1.4–4.7) as risk factors. When examined by sex, moderate level evidence of knee OA was found in men; however, the evidence in women was limited. **Conclusions:** Further high-quality prospective studies are warranted to provide further evidence on the role of occupational loading tasks in knee OA, particularly in women.

Key Words: knee joint; occupational diseases; occupations; osteoarthritis.

RÉSUMÉ

Objectif : Critiquer de façon systématique en fonction d'une synthèse des meilleures données probantes les publications sur le lien entre les tâches professionnelles imposant une charge et l'arthrose du genou (AG). **Méthode :** On a effectué des recherches dans deux bases de données pour trouver des articles publiés entre 1946 et avril 2011. Les études admissibles étaient celles qui 1) incluaient des adultes présentant leur historique d'emploi; 2) mesuraient l'exposition des personnes en cause à des activités du travail imposant une lourde charge sur l'articulation du genou; 3) révélaient la présence d'une arthrose du genou (déterminée par radiographie), de défauts des cartilages associés à l'arthrose du genou (déterminés par imagerie par résonance magnétique) ou d'une arthroplastie. **Résultats :** Au total, 32 articles provenant de 31 études ont satisfait aux critères d'inclusion. Nous avons trouvé des données probantes modérées indiquant que le fait de lever des objets lourds et combiné à l'obligation de s'agenouiller constitue un facteur de risque d'arthrose du genou, les rapports de cote (RC) variant de 1,8 à 7,9 et des données probantes limitées indiquant que le fait de lever des objets lourds (RC = 1,4 à 7,3), de s'agenouiller (RC = 1,5 à 6,9), de monter des escaliers (RC = 1,6 à 5,1) et les groupes professionnels (RC = 1,4 à 4,7) constituaient les facteurs de risque. Lorsqu'on les a analysées en fonction du sexe, on a constaté l'existence de données probantes de niveau modéré pour l'arthrose du genou chez les hommes, mais les données probantes étaient limitées dans le cas des femmes. **Conclusion :** D'autres études prospectives de grande qualité s'imposent pour produire d'autres données probantes sur le rôle que des tâches professionnelles qui imposent une charge jouent dans l'arthrose du genou, en particulier chez les femmes.

Osteoarthritis (OA) is the most common joint disease in the world, affecting 10%–15% of adults, and is a leading cause of chronic pain and disability.^{1–3} The knee is one of the most commonly affected joints.³ It has been suggested that biomechanically overloading a joint through excessive body weight,⁴ elite sports participation,⁵ or high-intensity occupational physical loading^{6,7} may contribute to knee OA. Evidence from in vitro and epidemiological studies suggests that some cyclical mechanical loading is beneficial and necessary for cartilage homeostasis, but excessive intensity or duration of dynamic

loading may stimulate catabolic processes that contribute to the development of OA.⁸ Physiotherapists are considered experts in movement and physical activity, during which joint loading occurs. As a profession, physiotherapy promotes bone and joint health in the community; knowledge of the relationship between occupational joint loading and OA will thus contribute to therapists' ability to provide comprehensive public education.

In the health literature, the term *occupation* usually refers to paid employment outside the home.^{7,9} Some occupations that involve repetitive performance of tasks

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Contributors: All authors designed the study; collected, analyzed, and interpreted the data; drafted or critically revised the article; and approved the final draft.

Competing interests: None declared.

Physiotherapy Canada 2014; 66(1):91–107; doi:10.3138/ptc.2012-45BC

such as heavy lifting, kneeling, and stair climbing have been hypothesized to play a role in knee OA.^{6,10} Denmark and Germany have accepted knee OA as an occupational disease, although a clear dose-response relationship has not been quantified.¹¹ In British Columbia, Canada, WorkSafeBC currently defines occupational disease as one “peculiar to or characteristic of a particular process, trade, or occupation”;¹² at present, however, only one type of osteoarthritis—that affecting the first carpometacarpal joint of both thumbs, which can affect physiotherapists who perform deep friction massage—is recognized as an occupational disease.

Before our systematic review began, two reviews had been published examining occupational physical loading and knee OA; the most recent, by Jensen and colleagues, included publications up to 2004.^{6,7} Both reviews reported evidence that heavy lifting, kneeling, and combined heavy lifting and kneeling are associated with knee OA in men but not in women. The authors explained that this might be because (1) very few women work in physically demanding jobs or (2) most studies did not recognize homemaking as an occupation.^{6,7} More recently, some authors have recognized that homemakers should be considered when exploring occupational physical loading, since kneeling and lifting are central components of performing household chores.^{13,14} This conclusion accords with a broader definition of *occupation*, such as that suggested by the Canadian Occupational Therapy Association: occupation is what people do to occupy themselves with some regularity or consistency by contributing to the productivity of their communities through engagement in the workforce or at home.¹⁵ As several studies have been published since the last review, it is appropriate to update the literature on occupational exposure as a risk factor for knee OA.

The purpose of this review, therefore, is to synthesize the epidemiological evidence on the role of occupational physical loading in knee OA in men and women, focusing on studies that addressed occupational exposure to (1) heavy lifting, (2) kneeling, (3) combined heavy lifting and kneeling, and (4) climbing stairs, as well as studies examining risks associated with certain occupations.

METHODS

Search strategy and study selection

We conducted a systematic literature search using MEDLINE (1946–April 2011) and EMBASE (1982–April 2011). Appendix 1 outlines the MEDLINE search strategy, which was adapted for EMBASE. A study was eligible if it (1) included adults who reported their employment history; (2) measured individuals’ exposure to heavy lifting, kneeling, knee bending, and/or stair climbing in their occupations; and (3) measured the presence of knee OA by radiography or magnetic resonance imaging (MRI) and/or included individuals with knee-replacements.

Owing to the cost of translation, only English articles were included. All titles and abstracts were screened by one reviewer (AE). Reference lists of all included articles were reviewed to identify additional studies. The same reviewer performed data extraction, quality assessment, and data synthesis, and the results were checked by the second author (LL).

Evaluation of study quality

Methodological quality was rated using a protocol developed by Jensen and colleagues⁶ in a previous review on occupational physical load and knee OA (see Appendix 2). This protocol assesses five categories: (1) design and materials, (2) measurement of exposure, (3) measurement of outcome, (4) adjustment for confounders, and (5) data presentation and statistical analysis; each item is scored from 0 to 3 for a maximum total of 15 points. According to Jensen and colleagues, a study should be considered poor quality if it scores 0–5, medium quality if it scores 6–10, and high quality if it scores 11–15. We chose to use this quality-assessment method so that our findings could be directly compared with those of the previous review.⁶

Data synthesis

We conducted a best evidence synthesis¹⁶ of studies that examined the association between knee OA and occupational exposure to (1) heavy lifting, (2) kneeling or knee bending, (3) combined heavy lifting and kneeling, and (4) stair climbing. In addition, we examined the risk of knee OA by occupation and by sex. Finally, we determined the level of evidence for each type of occupational exposure (see Appendix 3) based on the design of eligible studies and their methodological quality as measured by the Jensen criteria.⁶ A prospective cohort design was considered the best design because of its lower risk of bias and confounders, followed by case-control and cross-sectional designs.

RESULTS

Identification of literature and study quality

The electronic search found 635 articles from MEDLINE and 987 from EMBASE. After ineligible and duplicate papers were removed via title and abstract screening, 25 articles met the inclusion criteria, and we located a further seven studies by screening reference lists. After a full-text review, a total of 32 articles^{9,11,13,14,17–44} from 31 studies were included (see Figure 1). Since the most recent published review,⁶ 14 new studies have been published that meet eligibility criteria for our review.^{11,14,31,33–43} The quality of the studies varied greatly (see Appendix 4); 16 studies scored ≥ 11 points, indicating high methodological quality, and 10 of these (58.8%) were published after 2004, the cut-off point for studies included in Jensen’s review.⁶ The majority of studies controlled for risk factors such as age and body mass index (BMI) that

Figure 1 Literature Search Result.

* A single study may measure more than one type of occupational exposure.

have been strongly implicated in knee OA in previous literature.^{4,45} Further characteristics of all included studies are summarized in Table 1; Table 2 summarizes the results.

Occupational physical loading tasks

Heavy lifting

Seventeen eligible studies produced 18 articles examining the relationship between heavy lifting and knee OA. The study design included three cohort studies,^{9,21,22} 12 case-control publications from 11 studies,^{11,13,14,20,24–26,29–32,36} and three cross-sectional studies.^{19,38,41} Of these, 11 articles^{11,13,14,19,21,26,29–31,36,38} showed a significantly positive association between heavy lifting and knee OA, with odds ratios (ORs) between 1.4 and 7.3. Ten studies^{9,13,14,19,25,26,29,31,41} were deemed to be of high quality based on the Jensen criteria; four of these were published since the 2004 review,^{14,31,41,46} and three reported a statistically significant positive result.^{14,31,38} All three cohort studies in this area are more than 20 years old; one is of high quality,⁹ while another reported statistically significant results.²¹ Based on the results of the cohort studies, as well as the overall methodological quality of the remaining studies in this area, we conclude that there is limited evidence that occupations consisting of heavy lifting are associated with knee OA.

Kneeling or knee bending

Sixteen articles from 15 studies examined the association between kneeling or knee bending and knee OA. These include two cohort studies,^{9,22} nine case-control studies that produced 10 articles,^{11,13,14,24,25,27,29,30,32,36} and four cross-sectional studies.^{19,39,41,43} Of these 16 articles, 11 showed a significant positive association between kneeling/knee bending and knee OA with substantial ORs between 1.5 and 6.9.^{11,13,14,19,24,25,27,29,30,36,43} Nine papers received a quality score > 11,^{9,13,14,19,25,29,39,41,43} four of them published after 2004. Six of these articles reported statistically significant results, yet neither of the two cohort studies,^{9,22} one of which was high quality, found statistically significant results. We concluded that there is limited evidence for a significant relationship between knee-bending or kneeling tasks and knee OA.

Combined heavy lifting and kneeling

Six studies examined the role of combined heavy lifting and kneeling in knee OA, including one cohort study,⁹ three case-control designs,^{11,24,25} and two cross-sectional studies.^{34,41} Five of the six studies showed an increased risk for knee OA (OR = 1.8–7.9)^{9,11,24,25,34}; four of the six were rated as high quality.^{9,25,34,41} Although fewer studies investigated the role of combined heavy lifting and kneeling, the single high-quality cohort study did report significant results.⁹ We concluded that there is

Table 1 Occupational Physical Loading and Knee Osteoarthritis: Study Characteristics

Author (Date) [Country]	Study sample	Study design	Exposure measurement	Adjusted for covariates	Outcome	Results: OR (95% CI)
Kellgren & Lawrence (1952) ¹⁷ [England]	<i>n</i> = 171 M: 171 Age: 40–50 y	CS	Occupational title (miners, manual workers, office workers)	None	Knee OA: KL ≥ 2	Miners vs. office workers: 2.77 (1.2–6.3)* Miners vs. manual workers: 3.03 (1.36–6.79)* Manual workers vs. office workers: 0.91 (0.34–2.48)
Wickstrom et al. (1983) ¹⁸ [Finland]	<i>n</i> = 583 M: 583 Age: mean 42 y (range 20–64 y)	CS	Occupational title (reinforcement workers, painters) and observation	Age	Knee OA: KL ≥ 3	Reinforcement workers vs. painters: 1.1 (0.72–1.74)
Anderson & Felson, (1988) ¹⁹ [United States]	<i>n</i> = 5,193 M: 2,428 W: 2,765 Age: 35–74 y	CS	Current occupation used to compute physical demands from the US Dictionary of Occupational Titles (DOT) by professionals	Ethnicity, BMI, education	Knee OA: KL ≥ 2	<i>Knee bending:</i> M: 45–54 y: OR = 0.82 (0.32–2.11) M: 55–64 y: OR = 2.45 (1.21–4.97)* W: 45–54 y: OR = 2.07 (0.71–6.08) W: 55–64 y: OR = 3.49 (1.22–10.52)* <i>Heavy lifting:</i> M: 45–54 y: OR = 1.05 (0.45–2.4) M: 55–64 y: OR = 1.88 (0.88–4.0) W: 45–54 y: OR = 1.09 (0.31–3.5) W: 55–64 y: OR = 3.13 (1.04–9.4)*
Kohatsu & Schurman, (1990) ²⁰ [United States]	<i>n</i> = 92 (Cases = 46, Controls = 46) M: 36 W: 56 Age: mean 71 y	CC	Questionnaire classifying occupations as light, moderate, or heavy work	None	Knee OA: KL 3–4 or TKR	<i>Moderate/heavy work:</i> 20–29 y: OR = 2.3 (0.9–6.1) 30–39 y: OR = 3.4 (0.9–10.8) 40–49 y: OR = 3.0 (0.9–11.4)
Felson et al. (1991) ⁹ [United States]	<i>n</i> = 1,831 M: 745 W: 1,086 Age: mean 73 y	C	Interview	Age, smoking, BMI, history of knee injury, education	Knee OA: KL ≥ 2	<i>Lifting:</i> M: OR = 0.96 (0.49–1.87) W: OR = 2.53 (0.82–7.85) <i>Knee bending/light demands:</i> M: OR = 1.07 (0.53–2.17) W: OR = 1.43 (0.77–2.63) <i>Knee bending/lifting med, heavy, very heavy:</i> M: OR = 2.22 (1.38–3.58)* W: OR = 0.36 (0.09–1.40)
Vingård et al. (1991) ²¹ [Sweden]	<i>n</i> = 250,217 M: 207,638 W: 42,579 Age: 37–77 y	C	Occupational title scored	Age, residence	Knee OA: Hospitalized in 1981–1983	<i>High vs. low lifting:</i> M: 1905–1924 OR = 1.2 (0.9–1.5) M: 1925–1945 OR = 1.4 (1.1–1.9)* W: 1905–1924 OR = 1.4 (0.6–3.2) W: 1925–1945 OR = 1.9 (1.3–2.9)* <i>Occupations:</i> M: Firefight OR = 2.93 (1.32–5.46)* Farmers OR = 1.46 (1.23–1.98)* Construct OR = 1.36 (1.13–1.79)* W: Cleaners OR = 2.18 (1.26–3.00)*

Table 1 *Continued*

Author (Date) [Country]	Study sample	Study design	Exposure measurement	Adjusted for covariates	Outcome	Results: OR (95% CI)
Kivimäki et al. (1992) ²³ [Finland]	<i>n</i> = 314 M: 314 Age: mean 38.5 (SD 6.8) y (range 25–49 y)	C	Job title (floor-layers and painters) and video recording of kneeling activities	Age, smoking, BMI, knee injury	Osteophytes and joint space narrowing	Floor-layers vs. painters: TFJ OR = 0.87 (0.17–0.36) Knee osteophytes OR = 1.96 (1.25–3.06)* PFJ (caudal) OR = 2.85 (1.85–4.4)* PFJ (cranial) OR = 1.3 (0.98–1.94)
Schouten et al. (1992) ²² [Netherlands]	<i>n</i> = 142 M: 58 W: 84 Age: mean 57.2 (SD 6.1) y (range 46–68 y)	C	Questionnaire	Age, BMI, sex	Knee OA: KL ≥ 2	<i>Lifting heavy objects:</i> Medium exposure: OR = 1.00 (0.33–3.02) High exposure: OR = 0.65 (0.19–2.28) <i>Squatting, kneeling, or crawling:</i> Medium exposure: OR = 1.18 (0.36–3.89) High exposure: OR = 0.31 (0.09–1.04)
Cooper et al. (1994) ²⁴ [England]	<i>n</i> = 327 (Cases = 109, Controls = 218) M: 90 W: 237 Age: mean = 73 y (range 55–90 y)	CC	Questionnaire detailing 8 specific physical activities	BMI, Heberden's nodes	Symptomatic knee OA: KL 3–4 TFJ + PFJ	<i>Lifting > 25kg/d:</i> M & W: OR = 1.4 (0.5–3.7) <i>Kneeling > 30min/d:</i> OR = 3.4 (1.3–9.1)* <i>Squatting > 30min/d:</i> OR = 6.9 (1.8–26.4)* <i>Heavy lifting/kneeling squatting or stairs:</i> OR = 5.4 (1.4–21.0)* <i>Climbing stairs:</i> OR = 2.7 (1.2–6.1)*
Sahlström & Montgomery (1997) ²⁷ [Sweden]	<i>n</i> = 729 (Cases = 266, Controls = 463) Age: mean 73 y (range 47–96 y)	CC	Questionnaire	Sitting, overweight, knee injury	Knee OA: Ahlback score ≥ 1	<i>Weight bearing knee bending:</i> Unadjusted OR = 1.9 (1.4–2.7)* Adjusted OR = 1.1 (0.7–1.8)
Coggon et al. (2000) ²⁵ [England]	<i>n</i> = 1,036 (Cases = 518, Controls = 518) M: 410 W: 626 Age: mean 71.5 y (range 47–93 y)	CC	Interview regarding occupations held for > 1 y	BMI, Heberden's nodes, previous knee injury	Cases waiting for surgery secondary to knee OA	<i>Lifting > 10kg for 10 y, 10 ×/w vs. no lifting:</i> M: OR = 1.9 (1.0–3.3); W: OR = 1.5 (1.0–2.3) <i>Lifting > 25kg:</i> M: OR = 1.7 (0.9–3.0); W: OR = 1.7 (1.0–2.8) <i>Lifting > 50kg:</i> M: OR = 1.7 (0.9–3.2); W: OR = 1.2 (0.6–2.4) <i>Kneeling/squatting > 1 h/d:</i> 1–9.9 y M: OR = 3.0 (1.4–6.1)*; W: OR = 2.8 (1.4–5.5)* 10–19.9 y M: OR = 1.3 (0.5–3.2); W: OR = 0.8 (0.3–2.0) > 20 y M: OR = 1.7 (0.7–4.0); W: OR = 3.2 (0.8–13.0) <i>Kneeling/squatting and lifting:</i> M: OR = 2.7 (1.0–7.1); W: OR = 0.3 (0.03–4.1) <i>Climbing ladder/stairs:</i> *M: OR = 2.3 (1.3–4.0); W: OR = 0.7 (0.3–1.6)

Table 1 Continued

Author (Date) [Country]	Study sample	Study design	Exposure measurement	Adjusted for covariates	Outcome	Results: OR (95% CI)
Jensen et al. (2000) ²⁸ [Denmark]	n = 149 M: 149 Age: 26–72 y	CS	Job title (floor-layers, carpenters, and composers)	Age	Knee OA: KL ≥ 2	% Radiographic knee OA: Floor layers: 14 Carpenters: 8 Composers: 6 > 50 y symptomatic radiographic OA: Floor layers: 29% (17–44%) Carpenters: 9% (1–26%) Composers: 1% (1–10%)
Sandmark et al. (2000) ¹³ [Sweden]	n = 1,173 (Cases = 625 Controls = 548) M: 589 W: 584 Age: 55–70 y	CC	Questionnaire & interview	Age, BMI, sports	TKR surgery	<i>Lifts at work:</i> Med M: OR = 2.5 (1.5–4.4); W: OR = 1.2 (0.7–1.9)* High M: OR = 3.0 (1.6–2.9); W: OR = 1.7 (1.0–2.9)* > Work 10 y in heavy jobs: M: OR = 2.5 (1.7–3.6)*; W: OR = 2.5 (1.6–3.9)* <i>Squatting/knee bending:</i> Med. M: OR = 1.3 (0.8–2.2); W: OR = 1.2 (0.7–1.9) High M: OR = 2.9 (1.7–4.9); W: OR = 1.1 (0.6–1.9)* <i>Kneeling:</i> Med. M: OR = 1.4 (0.9–2.2); W: OR = 1.5 (1.0–2.3) High M: OR = 2.1 (1.4–3.3); W: OR = 1.5 (0.9–2.4)* <i>Climbing stairs:</i> Med M: OR = 1.2 (0.8–1.9); W: OR = 1.7 (1.1–2.5)* High M: OR = 1.2 (0.7–2.1) W: OR = 1.4 (0.8–2.3) <i>Occupations:</i> M: Construction OR = 3.1 (1.5–6.4)*, Farmers OR = 3.2 (2.0–5.2)*, Forestry OR = 2.1 (1.0–4.6) W: Farmers OR = 2.4 (1.4–4.1)*
Lau et al. (2000) ²⁶ [China]	n = 1316 (Cases = 658, Controls = 658) M: 332 W: 984	CC	Interview	Age, sex	28% TKR, 15% waiting for TKR, 57% knee OA: KL3–4	<i>Lifting 10kg, 1–10 ×/w:</i> M: OR = 1.5 (0.6–3.5); W: OR = 1.2 (0.7–2.0) <i>Lifting 10kg > 10 ×/wk</i> M: OR = 5.4 (2.4–12.4)*; W: OR = 2.0 (1.2–3.1)* <i>Climbing > 15/flights stairs:</i> M: OR = 2.5 (1.0–6.4); W: OR = 5.1 (2.5–10.2)*

Table 1 Continued

Author (Date) [Country]	Study sample	Study design	Exposure measurement	Adjusted for covariates	Outcome	Results: OR (95% CI)
Manninen et al. (2002) ²⁹ [Finland]	<i>n</i> = 805 (Cases = 281, Controls = 524) M: 195 W: 610 Age: mean 69.2 (SD 5.4) y (range 55–75 y)	CC	Computer-assisted telephone interview	BMI, knee injury, exercise	Arthroscopic surgery for knee OA	<i>Physical workload:</i> Med: M: OR = 2.23 (0.64–7.72); W: OR = 1.60 (0.83–3.06) High M: OR = 1.53 (0.42–5.56); W: OR = 2.03 (1.03–3.99)* <i>Lifting:</i> Med M: OR = 1.35 (0.57–4.16); W: OR = 0.90 (0.55–1.50) High M: OR = 0.92 (0.50–2.39); W: OR = 1.11 (0.71–1.75) <i>Kneeling/squatting > 2 h:</i> M: OR = 1.68 (0.66–4.28); W: OR = 1.81 (1.11–2.95)* <i>Climbing stairs:</i> Med: M: OR = 3.06 (1.25–7.5)*; W: OR = 1.08 (0.71–1.63) High: M: OR = 2.79 (0.96–8.2); W: OR = 1.50 (0.81–2.77)
Dawson et al. (2003) ³⁰ [England]	<i>n</i> = 111 (Cases = 29, Controls = 82) W: 111 Age: 50–70 y	CC	Interview	None	TKR, surgical wait list	<i>Lifting > 25 y:</i> W: OR = 7.31 (2.01–26.7)* <i>Lifting > 33y:</i> W: OR = 3.58 (0.89–14.4) <i>Kneeling < 15 y:</i> W: OR = 2.70 (0.76–9.58) <i>Kneeling > 26 y:</i> W: OR = 4.18 (1.26–13.8)*
Holmberg et al. (2004) ⁴⁴ [Sweden]	<i>n</i> = 1,473 (Cases = 778, Control = 695) M: 631 W: 842 Age: mean 62.6 (SD 5.2) y	CC	Questionnaire	Heridity, weight, smoking, civil status, knee injury, sports	Knee OA: physician diagnosed	M: <i>Construction (y worked)</i> 1–10 y: OR = 1.5 (0.5–4.5); 11–30 y: OR = 3.7 (1.2–11.3)*; > 30 y: OR = 1.6 (0.6–4.6) <i>Farmers (y worked)</i> 1–10 y: OR = 1.3 (0.6–2.1); 11–30 y: OR = 0.8 (0.3–2.1); > 30 y: OR = 1.7 (0.7–4.0) W: <i>Farmers (y worked)</i> 1–10 y: OR = 0.8 (0.4–1.9); 11–30 y: OR = 2.1 (1.0–4.5); > 30 y: OR = 2.0 (0.7–5.5) <i>Cleaners</i> OR = 1.1 (0.6–1.7)
Yoshimura et al. (2004) ³² [Japan]	<i>n</i> = 202 (Cases = 101, Controls = 101) W: 202 Age: mean 73.3 (SD 9.8) y	CC	Questionnaire	Heaviest weight, knee injury	Knee OA: KL ≥ 3	<i>Lifting > 25kg 1st job:</i> W: OR = 1.0 (0.50–2.00) <i>Lifting > 25 kg main job:</i> W: OR = 1.91 (0.92–3.96) <i>Kneeling > 1 h 1st Job:</i> W: OR = 0.95 (0.52–1.76) <i>Kneeling > 1 h Main job:</i> W: OR = 0.87 (0.48–1.58) <i>Squatting > 1 h 1st job:</i> W: OR = 1.05 (0.57–1.94) <i>Squatting > 1 h main job:</i> W: OR = 1.20 (0.66–2.17)

Table 1 Continued

Author (Date) [Country]	Study sample	Study design	Exposure measurement	Adjusted for covariates	Outcome	Results: OR (95% CI)
Jensen (2005) ⁴³ [Denmark]	n = 149 M: 149 Age: 26–72 y	CS	Questionnaire & video recording of knee straining work	Age, BMI, sports, smoking	Knee OA: KL $\geq$ 2	<i>Kneeling/squatting:</i> M: low/mod OR = 2.96 (0.5–17.2); med/high OR = 4.20 (0.6–27.9); high/very high OR = 4.92 (1.1–21.9)*
Yoshimura et al. (2006) ³¹ [Japan]	n = 74 (Cases = 37, Controls = 37) M: 74 Age: mean 70.0 (SD 6.6) y	CC	Questionnaire	Heaviest weight, knee injury	Knee OA: KL $\geq$ 3	<i>Physical work as principal job</i> *M: OR = 6.20 (1.40–27.5)
Amin et al. (2008) ³⁴ [United States]	n = 192 M: 192 Age: mean 69 (SD 9) y	CS	Validated questionnaire	Age, BMI, history of injury/surgery	MRI: cartilage changes >grade 2; osteophyte	<i>Squatting, lifting, and kneeling:</i> M: PFJ OR = 1.8, (1.1–3.2)*; Medial TFJ OR = 1.6 (0.9–3.0)
Järnholm et al. (2008) ³³ [Sweden]	n = 204,741 M: 204,721 Age: 15–67 y	C	National health database in Sweden	Age, BMI	Hospitalized for knee OA or TKR	M: Floor-layers OR = 4.7 (1.8–2.3)*; Asphalt worker OR = 2.81 (1.11–7.13)*; Brick layers OR = 2.14 (1.08–4.25)*; Plumbers OR = 2.29 (1.19–4.43)*; Rock worker OR = 2.59 (1.18–5.69)*
Mounach et al. (2008) ³⁵ [Morocco]	n = 190 (Cases = 95, Controls = 95) M: 52; W: 138 Age: mean 59.7 (SD 8.5) y (range 37–76 y)	CC	Questionnaire & interview	Obesity, age, sex	Symptomatic radiographic Knee OA: KL $\geq$ 3 for < 1 y	<i>Climbing stairs (>50/d)</i> M & W: OR = 0.48, (0.26–0.91)*
Seidler et al. (2008) ¹¹ [Germany] Vrezas et al. (2010) ³⁶ [Germany]	n = 622 (Cases = 295, Controls = 327) M: 622 Age: 25–70 y	CC	Structured computer-assisted personal interview	Age, BMI, jogging or athletics	Knee OA: KL $\geq$ grade 2	<i>Cumulative kneeling/squatting</i> OR = 2.4 (1.1–5.0)* <i>Cumulative lifting/carrying:</i> OR = 2.6 (1.1–6.1)* <i>Combined kneeling/lifting:</i> OR = 7.9 (2.0–31.5)* <i>Occupations > 10 y:</i> Metalwork OR = 3.0 (1.5–6.2)* Roofer OR = 4.5 (1.1–19.4) Woodwork OR = 5.7 (1.2–28.0)* Physical service OR = 4.3 (1.6–11.7)* <i>High BMI & lifting/carrying:</i> M: OR 5.0 (2.4–10.5)* <i>High BMI & kneeling/squatting:</i> M: OR 5.3 (2.4–11.5)*
Rytter et al. (2009) ³⁷ [Denmark]	n = 254 (Cases = 134, Controls = 120) M: 254 Age: cases = mean 52.6 y, controls = mean 57.9 y	CC	Questionnaire	BMI, knee straining sports	Knee OA: Ahlback score $\geq$ 1	Floor layers vs. graphic designers $\leq$ 49 y: TFJ OR = 1.1 (0.1–13.1); PFJ OR = 0.1 (0.01–1.3) 50–59 y: TFJ OR = 3.6 (1.1–12.0)*; PFJ OR = 1.3 (0.5–3.8) $\geq$ 60 y: TFJ OR = 1.9 (0.4–7.8); PFJ OR = 0.1 (0.01–1.1)

Table 1 Continued

Author (Date) [Country]	Study sample	Study design	Exposure measurement	Adjusted for covariates	Outcome	Results: OR (95% CI)
Allen et al. (2010) ³⁸ [United States]	n = 2637 M: 933 W: 1796 Age: mean 63.8 (SD 10.8) y	CS	Interview administered questionnaire	Age, race, gender, BMI, prior knee injury, household tasks, smoking	Radiographic knee OA: KL > 2; Symptomatic knee OA: Radiographic knee OA, plus pain, aching, and stiffness most days	Radiographic knee OA No statistically significant association with any occupational tasks Symptomatic knee OA: Lifting > 10 lbs: M & W: OR = 1.42 (1.13–1.80)* Heavy work M & W: OR = 1.44 (1.03–2.02)*
Bernard et al. (2010) ³⁹ [United States]	n = 3436 M: 1098 W: 2450 Age: M: mean 63.4 (SD 10.9) y; W: mean 61.4 (SD 10.7) y	CS	Questionnaire	Age, sex, BMI	Knee OA: KL ≥ grade 2	Stair climbing: M: OR = 1.61 (1.11–2.32)*; W: OR = 1.14 (0.87–1.49) Squatting: M: OR = 1.56 (0.89–2.75); W: OR = 0.89 (0.50–1.61)
Franklin et al. (2010) ⁴⁰ [Iceland]	n = 2,490 (Cases = 1,408, Controls = 1,082) M: 1,066; W: 1,424 Age: M: >60 y, mean 73.9 (SD 6.5) y	CC	Questionnaire	Age, sex, BMI, recreational activity	TKR	M: Farmer OR = 5.1 (2.1–12.4)* Fisherman OR = 3.3 (1.3–8.4)* W: No occupations increased risk.
Klussmann et al. (2010) ¹⁴ [Germany]	n = 1,310 (Cases = 739, Controls = 571) M: 569; W: 741 Age: W: mean 62 (SD 9.6) y, M: 25–75 y	CC	Standardized questionnaire and semi-structured interview	BMI, sports, mal-alignment, genetics, child knee pain, smoking	Symptomatic Radiographic Knee OA: KL > 2 or arthroscopic surgery and pain	Cumulative lifting/carrying: > 1,088 tons/life W: OR = 2.13 (1.14–3.98)* Cumulative kneeling: > 8,934 h/life W: OR = 2.52 (1.35–4.68)*; 3,574 – 12,244 h/life M: OR = 2.16 (1.24–3.77)*; > 12,244 h/life M: OR = 2.47 (1.41–4.32)*
Teichtahl et al. (2010) ⁴¹ [Australia]	n = 96 W: 96 Age: mean 46.5 (SD 9.1) y (range 26–62 y)	CS	Questionnaire	Age, BMI, frontal knee plane alignment	MRI measured tibial and patellar cartilage volume and defects	PFJ: Heavy lifting/bending/squatting W: OR = 1.8 (1.0–3.1) Knee bending: W: OR = 1.8 (1.0–3.1) Stair climbing: W: OR = 2.9 (1.4–6.0)*
Hashikawa et al. (2011) ⁴² [Japan]	n = 586 W: 586 Age: mean 64.2 (SD 9.6) y (range 40–89 y)	CS	Questionnaire	Age, BMI, injury, antioxidants	Knee OA: KL ≥ 2	Proportion with knee OA: 13.3% farmers vs. 7.0% other occupations (p = 0.02). OR ~1.3 (0.75–2.75)

*Statistically significant as determined by each study.

OR (95% CI) = odds ratio (95% CI); M = men; y = years old; CS = cross-sectional design; KL = Kellgren-Lawrence scale; W = women; CC = case control; C = cohort; h = hour BMI = body mass index; TKR = total knee replacement; PFJ = patellofemoral joint; TFJ = tibiofemoral joint.

Table 2 Results Summary

	No. of eligible studies (articles)	Study design, no.	Found positive relationship to knee OA, no. (%) (OR)	High quality, no.	Level of evidence
Occupational physical loading tasks					
Heavy lifting	17 (18)	C 3 CC 12 CS 3	11/18 (61) (1.4–7.3)	10	Limited
Kneeling or knee bending	16 (15)	C 2 CC 9 CS 4	11/15 (73) (1.5–6.9)	9	Limited
Combined heavy lifting and kneeling	6	C 1 CC 3 CS 2	5/6 (83) (1.8–7.9)	4	Moderate
Climbing stairs	8	C 0 CC 6 CS 2	7/8 (88) (1.6–5.1)	7	Limited
Occupational groups					
Type of occupation involving heavy lifting and/or kneeling	(12)	C 2 CC 5 CS 5	9/12 (75) (1.4–4.7)	3	Limited
Occupational physical loading by sex—MEN	21 (22)	C 3 CC 11 CS 7	20/22 (91) (1.4–7.9)	13	Moderate
Occupational physical loading by sex—WOMEN	15	C 2 CC 9 CS 4	9/15 (60) (1.4–7.3)	10	Limited

C = cohort design; CC = case-control design; CS = cross-sectional design; OR = odds ratio

moderate evidence of a significant relationship between these combined occupational physical loading tasks and knee OA.

Climbing stairs

Eight studies—six case-control studies^{13,24–26,29,35} and two cross-sectional studies^{39,41}—investigated the association between stair climbing and knee OA. Seven of these showed a positive relationship (OR = 1.6–5.1),^{13,24–26,35,39,41} but one showed an inverse relationship.²⁹ Seven studies were rated as having high methodological quality,^{13,25,26,29,35,39,41} including the three most recent publications.^{35,39,41} None of the studies used a cohort design to minimize bias, and there were inconsistencies in the statistical significance of results at different levels of exposure.²⁹ Given these methodological shortcomings and inconsistent findings, we concluded that there is limited evidence for a relationship between stair climbing and knee OA.

Occupational groups

Twelve articles examined the relationship between knee OA and occupations involving heavy lifting and/or kneeling. These include two cohort studies,^{21,33} five case-control studies,^{11,13,37,40,44} and five cross-sectional

studies.^{17,18,23,28,42} Nine studies reported a positive relationship between knee OA and occupation (OR = 1.4–4.7),^{11,13,17,21,23,37,40,44} but only three scored high on methodological quality.^{13,37,40} Many studies in this subgroup are older and have procedural flaws, such as failing to control for relevant covariates^{17,21} or low participation rates.^{11,37} Two high-quality papers^{37,40} were published after 2004. Based on the updated literature, there is limited evidence that people in certain occupations, particularly farming and construction, are at increased risk of developing knee OA.

Occupational physical loading by sex

Twenty-two articles reported results on the relationship between occupational physical loading tasks and knee OA in men only, including three cohort studies,^{9,21,33} 12 articles from 11 case control studies,^{11,13,14,25,26,29,31,34,36,37,40,44} and seven cross-sectional studies.^{17–19,23,28,39,43} Twenty studies found a statistically significant relationship between occupational physical loading and knee OA (OR = 1.4–7.9); of these, 13 received high quality scores.^{9,13,14,19,25,26,29,31,34,37,39,40,43} All three cohort studies reported significant results for men.^{9,21,33} Considering the consistent results across all

study designs, we concluded that there is moderate evidence of a relationship between occupational joint loading and knee OA in men.

Fifteen studies examined the relationship between occupational physical loading tasks and knee OA in women, including two cohort studies,^{9,21} nine case control studies,^{13,14,25,26,29,30,32,40,44} and four cross-sectional studies.^{19,39,41,42} Nine studies showed a significantly positive association between an occupational exposure and knee OA in women (OR = 1.4–7.3).^{9,13,14,19,21,25,29,30,41} Ten studies were rated high quality;^{9,13,14,19,25,26,29,39–41} of these, seven showed a statistically significant relationship.^{13,14,19,25,26,29,41} Of the two large cohort studies, one high-quality study⁹ did not find a significant association between any physically demanding tasks and knee OA in women, while the other study, which was rated as lower-quality,²¹ found an association in women aged 45–55 years but not in women aged 55–75 years. Given the methodological limitations and the ambiguity in results for women, we concluded that there is limited evidence for the association between occupational knee joint loading and OA in women.

DISCUSSION

Our principal finding is that there is moderate evidence indicating that knee OA is related to occupations involving combined heavy lifting and kneeling activities. The evidence is more limited regarding occupational exposure to heavy lifting, kneeling or knee bending, and stair climbing, as well as for specific occupational groups, largely because the lack of cohort studies makes it impossible to rule out bias, confounders, and methodological flaws. However, the magnitude of the increased risk due to occupational loading is large: most studies show at least a doubled risk of knee OA in people with high exposure to these tasks. When we analyzed the results by sex, we found moderate evidence of a relationship between occupational physical loading tasks and knee OA in men, but limited evidence in women.

Our findings concur with previous reviews in indicating a need for more high-quality prospective longitudinal cohort studies in this area.^{6,7} Since we began our study, two other groups have published reviews on this topic.^{47,48} Fransen and colleagues,⁴⁷ who examined the role of occupational factors in hip and knee pain, reported a significant association between heavy lifting, kneeling or squatting, and symptomatic knee OA. They identified eight new publications on knee OA since the review by Jensen and colleagues,⁶ five of which were also included in our review (the other three failed to fit our inclusion criteria for radiographically or MRI-confirmed signs of knee OA). Although Fransen and colleagues also examined occupational tasks individually, they did not examine the risks separately for men and women. In a second review, McWilliams and colleagues⁴⁸ performed a meta-analysis on 51 observational

studies to assess the relationships between occupational factors (“heavy work,” “kneeling activity,” elite sports participation, job titles) and knee OA. Their meta-analysis found a statistically significant association between occupational physical loading and knee OA; however, they did not assess the methodological quality of the studies. McWilliams and colleagues acknowledged noticeable heterogeneity among studies and evidence of publication bias. Although they reported a disparity in the numbers of men and women included in research on occupational risk factors and knee OA, they did not perform a separate analysis to examine gender differences. Because neither of these new reviews provides an in-depth analysis on the discrepancies between women and men with respect to occupational loading, this will be a primary focus of our discussion.

Occupational loading in women

Our review found no high-quality studies involving only female participants. Eleven high-quality studies recruited both men and women before conducting subgroup analyses for each sex. The three studies^{30,32,42} involving women only were rated as medium quality because of vague exposure definitions³⁰ or low participation rates,^{32,42} and all three failed to show significant support for the relationship between occupational physical loading tasks and knee OA in women: results were all non-significant with multi-variable analyses. The authors of one study also acknowledged the omission of “domestic duties” from the category of occupational exposure as a reason for their findings.⁴² Others have argued that it is harder to recruit enough women with high levels of occupational loading to achieve significant results,^{6,9} but this may apply only when a traditional, potentially gender-biased definition of “occupational” is used. New research has suggested that, overall, women have higher cumulative joint loading from physical activity than men.⁴⁹ Ratzlaff et al. measured lifetime joint loading of the hips and knees by calculating a time × joint force product involving years of force and body weight, which they called cumulative peak force index (CPFI). They found that overall, women had higher CPFI scores than men, especially in the realm of household chores.

Measuring women’s physical activity, including occupational activity, in a way that accurately reflects the complex nature of their lives has been considered very challenging.⁵⁰ Historically, women have tended to spend fewer hours working outside the home, have been more likely to move in and out of the workforce, and have changed careers more often than men to have families.⁵¹ This creates additional challenges in accurately tracking their lifetime exposure to occupational physical loading tasks. For example, previous research has based estimates of occupational physical loading exposure on “longest held job”^{26,40} or “current job,”^{29,41} but these measures

may have little validity for women who have had multiple occupations over their lifetime.

Performing household tasks as a full-time homemaker or otherwise has been shown to account for a significant portion—greater than leisure or sport participation—of women's overall activity level.⁴⁹ Studies using diaries to record daily physical activity have reported that women spend up to 6 hours per day on household chores or family care activities.⁵² Estimates from the US Employment Census and Statistics Canada indicate that approximately 5 million American women⁵³ and 1.4 million Canadian women⁵⁴ are stay-at-home mothers. Thus, by discounting homemaking as an occupation, previous studies may have underestimated knee-joint loading experienced by women and created a gender bias in the literature on occupational activity.⁵⁵

Homemaking involves many repetitive tasks such as kneeling, lifting, and carrying that have been considered strenuous on knee joints in occupational research.^{6,11} Biomechanical studies have reported that squatting and climbing stairs each increase tibiofemoral contact stress by over five times one's body weight.^{56,57} Many of these tasks also require significant knee flexion, which increases shear stress and retropatellar load, predisposing a person to patellofemoral pathology.⁵⁸ A 1975 study examined the homemaking tasks performed by 48 women and found that their physical demands were akin to those of a "patrolman."⁵⁹

Two recent studies examining occupational exposure and knee OA have tried to address the gap surrounding women's occupational exposure by including homemakers as an occupational group.^{13,14} In 2010, using a case-control design, Klusmann and colleagues analyzed data from 1,310 men and women on the time spent in different positions and on performance of physical tasks at their job, including tasks performed in the home.¹⁴ Among women, occupational predictors of symptomatic radiographic knee OA included kneeling and squatting (OR = 1.36; 95% CI, 0.78–2.37 for 3,542–8,934 hours/life; OR: 2.52; 95% CI, 1.4–4.7 for >8,934 hours/life) and daily lifting and carrying of loads (OR: 0.69; 95% CI, 0.38–1.24 for <1,088 tons/life; OR: 2.13; 95% CI, 1.1–4.0 for >1,088 tons/life). Klusmann and colleagues claimed that their study was the first to show a dose-response relationship between kneeling/squatting or lifting/carrying and symptomatic radiographic OA in women. Similarly, Sandmark and colleagues found that women performing physically demanding tasks in the home had a $2.2 \times$ (95% CI, 1.3–2.6) greater risk of knee OA than those not performing these tasks.¹³ These two studies indicate that the homemaker occupation should be accounted for when studying occupational exposure as a risk factor for knee OA. They highlight the fact that most studies examining occupation in women have continued to omit homemakers, which may be a large contributing factor to the discrepancies in results found between sexes.

Future research in occupational joint loading

High-quality cohort studies involving both men and women are needed to substantiate the findings from the many case-control and cross-sectional studies examining occupational joint loading. Continuing to include homemakers as an occupational group is important as well, not only for women but also for men, since paid work and time spent on domestic labour are becoming more evenly distributed among men and women.⁶⁰ Data from the 1986, 1998, and 2010 General Social Survey (GSS), which examines changes in participation and time spent on paid and domestic work of individuals, illustrates this change: in 1986, men worked 1.4 more paid hours per day than women, but this dropped to 1.1 hours per day in 2010; women did 1.2 hours more housework per day than men in 1986, but only 0.4 hours more in 2010. Men, on average, are assuming more homemaking tasks. In 1976, women were the main income earners in only 4% of single-earner husband-wife families with children, but in 1997 that figure had increased to 16%.⁵⁴ Relative to this shifting workforce, the number of stay-at-home women has decreased by half, from 2,955,000 in 1976 to 1,140,000 in 1997, while the number of stay-at-home men has increased from 41,000 to 77,000 over the same period. Based on these numbers, it is apparent that a significant number of women, as well as an increasing number of men, spend time in homemaker roles and that there is an ongoing shift in the distribution of household chores and the homemaker role between men and women.

The constant evolution of occupations becomes apparent when we examine changes in the workforce. In Canada, women made up nearly half of the paid labour force as of December 2011.⁶¹ Employment rates for women have been steadily on the rise for three decades; as of 2009, 72.9% of women with children were employed outside the home, nearly twice the 1976 rate of 39.1%.⁶¹ Many occupations traditionally held by men are attracting an increasing number of women; for example, in British Columbia, women represent 11.33% of trade helpers, construction workers, and laborers⁶²—traditionally male occupations that have been considered to have high joint loading in previous research.³³ Moving forward, it is likely that evidence regarding occupational exposure in women will continue to evolve to match these changes to the traditional paid labour force.

Our review has several limitations. First, only one reviewer (AE) completed the literature search, data extraction, and quality assessment. Acknowledging this limitation, we have made every attempt to minimize errors by having the reviewer work closely with the second author (LL) to review the data synthesis and interpretation. Second, by using only two databases and limited search terms, we may have missed some relevant literature. However, because the search strategy that was employed captured all eligible papers in previous and

recent reviews, we are confident that the strategy was adequate despite limitations. On the other hand, the tendency for studies with positive results to be published more frequently than those with negative results (publication bias) may have distorted the body of literature available.

CONCLUSION

The multi-factorial nature of knee OA represents a challenge for researchers and clinicians. Modifiable risk factors such as high BMI⁴ and previous injury⁴⁵ have been proven in the literature to play a large role in the development and progression of knee OA. Exposure to occupational physical loading is a modifiable risk factor that should also be addressed. Physiotherapists with primary access to patients have an opportunity to educate patients about occupational joint loading; most clinicians likely already inquire about occupation during history taking, but perhaps not enough attention is paid to these activities. If physiotherapists are to take a more active role in primary prevention, addressing this OA risk factor is an ideal platform.

Workplace and household interventions and policies to prevent knee OA are difficult to implement and have seldom been evaluated.⁶³ To date, minimal research has been done on the potential of any prevention strategies. For example, in a systematic review, Fransen and colleagues found no randomized controlled trials investigating prevention of symptomatic OA.⁴⁷ Ideas such as adopting new work methods, using better tools and equipment, implementing administrative controls, and better training and education of workers to minimize future harm have been proposed.⁴⁷ Issues with worker compliance and education may need to be addressed to facilitate successful change. As discussed above, physiotherapists may be able to influence occupational loading risks through public education on the role of occupation in OA.

This review found moderate evidence that occupational tasks involving combined heavy lifting and kneeling tasks are associated with the presence of knee OA, while the evidence for performing heavy lifting, kneeling, or stair climbing independently is more limited due to lack of prospective cohort studies. The evidence for a relationship between occupational physical loading and knee OA in women continues to be limited, as most studies fail to take homemaking into account as a valid occupation. Future high-quality prospective studies are warranted to improve our understanding of how specific occupational tasks affect the development of knee OA.

KEY MESSAGES

What is already known on this topic

Exposure to high levels of occupational physical loading tasks is thought to be a risk factor for the development of knee osteoarthritis (OA). Previous reviews have found moderate evidence in men that jobs with heavy

lifting and kneeling increase the odds of developing knee OA.

What this study adds

Recently, better-quality studies that examine occupational physical loading as a risk factor for knee OA have been published. The evidence continues to support the possibility that heavy lifting and kneeling activities contribute to knee OA in men, but the evidence for women remains limited. This review hypothesizes reasons for this discrepancy, including the lack of high-quality studies including women participants, the challenges in measuring occupational exposure in women, and the way in which “occupation” has traditionally been defined for women. This review emphasizes that physiotherapists who provide public education on bone and joint health should be knowledgeable about the role of occupational activities as a modifiable risk factor for the development of knee OA.

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APPENDIX 1: MEDLINE search strategy

1. knee osteoarthritis.mp
2. exp Osteoarthritis, knee/
3. Osteoarthritis, knee/ or Osteoarthritis/ or knee Joint/
4. 1 or 2 or 3
5. occupation*.mp
6. Occupations/
7. Workplace/
8. Occupational Disease/
9. 5 or 6 or 7 or 8
10. 4 and 9

APPENDIX 2: Assessment of study quality

Design and material (0–3) one point for each of the following:

Study design and inclusion/exclusion criteria described (1)

Participation rate >70% for cases and controls (1)

Sufficient description of baseline characteristics, size, information on withdrawals (1)

Exposure (0–3) one of the following categories:

Defined by job titles (1)

Measured by interviews specified by different physical activities (2)

Assessed by video observation (3)

Outcome (0–3) one of the following categories:

Radiological exam sum of;

Standardized for cases and controls (1)

Weight bearing (1)

Blinded (1)

Total joint replacement sum of;

Criteria for assessment identical in studied population (1)

Criteria for TKR validated (1)

Radiological exam re-assessed (1)

Medical records sum of;

Diagnosis code (1)

Confounders (0–3) one of the following categories:

Age or sex (1)

Age and sex (2)

At least age and sex plus one of earlier trauma, smoking, sports activities, Heberden's nodes (3)

Data presentation and statistical analysis (0–3) Sum of:

Frequencies of most important outcome given (1)

Appropriate analysis techniques used (2)

This table has been adapted from: 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 Jul;65:72–89.

Appendix 3: Levels of evidence of observational studies

Strong evidence	A causal relationship is very likely (chance, bias, and confounding could be ruled out with reasonable confidence) between an exposure to a specific risk factor and a specific outcome. A positive relationship has been observed between exposure to the risk factor and the outcome in several studies (two or more high quality cohort, several case control, and cross sectional.)
Moderate evidence	Some convincing epidemiological evidence (chance, bias, and confounding are not likely) for a causal relationship between exposure to a specific risk factor and a specific outcome. A positive relationship has been observed between exposure to the risk factor and the outcome in several studies (one high quality cohort and two or more case control studies.)
Limited evidence	Some convincing epidemiological evidence exists in some studies (case control or cross-sectional studies) for a causal relationship between exposure to a specific risk factor and a specific outcome. A positive relationship has been observed between exposure to the risk factor and the outcome, but chance, bias, and confounding cannot be ruled out.
Insufficient evidence	Available studies are of insufficient quality, consistency, or statistical power to permit a conclusion regarding a causal relationship between exposure to risk factor and outcome.
No evidence	No studies could be found.

APPENDIX 4: Evaluation of study quality

Author, date	A Design and materials	B Measurement of exposure	C Measurement of outcome	D Adjusted for confounders	E Data presentation and analysis	Total Score*
Kellgren and Lawrence, 1952 ¹⁷	2	0	2	1	2	7
Wickström et al., 1983 ¹⁸	2	0	2	3	2	9
Anderson and Felson, 1988 ¹⁹	3	2	1	2	3	11
Kohatsu and Schurmann, 1990 ²⁰	1	0	2	1	0	4
Vingård et al., 1991 ²¹	2	1	1	2	2	8
Felson et al., 1991 ⁹	2	2	3	2	2	11
Schouten et al., 1992 ²²	1	2	2	1	2	8
Kivimäki et al., 1992 ²³	2	0	2	3	2	9
Cooper et al., 1994 ²⁴	1	1	3	2	2	9
Sahlström and Montgomery, 1997 ²⁷	3	0	1	0	2	6
Jensen et al., 2000 ²⁸	2	0	2	3	1	8
Coggon et al., 2000 ²⁵	2	3	3	2	3	13
Lau et al., 2000 ²⁶	3	2	2	2	2	11
Sandmark et al., 2000 ¹³	3	3	3	2	3	14
Manninen et al., 2002 ²⁹	3	3	3	2	3	14
Dawson et al., 2003 ³⁰	1	0	3	2	2	8
Yoshimura et al., 2004 ³²	2	0	2	2	2	8
Holmberg et al., 2004 ⁴⁴	3	3	1	1	2	10
Jensen, 2005 ⁴³	2	3	2	3	3	13
Yoshimura et al., 2006 ³¹	2	2	1	3	3	11
Järvholm et al., 2008 ³³	2	1	1	2	1	7
Amin et al., 2008 ³⁴	3	2	1	3	3	12
Mounach et al., 2008 ³⁵	2	2	1	3	3	11
Seidler et al., 2008 ¹¹	2	2	0	3	3	10
Vrezas et al., 2010 ³⁶	2	2	0	3	3	10
Rytter et al., 2009 ³⁷	2	1	3	0	2	11
Allen et al., 2010 ³⁸	2	2	3	3	3	13
Bernard et al., 2010 ³⁹	2	2	3	3	3	13
Franklin et al., 2010 ⁴⁰	3	1	2	3	3	11
Klussmann et al., 2010 ¹⁴	2	2	1	3	3	11
Teichtahl et al., 2010 ⁴¹	2	2	3	3	3	13
Hashikawa et al., 2011 ⁴²	2	1	2	3	1	9

* Poor quality (scored 1–5); medium quality (6–10); high quality (11–15).