Published Online April 26, 2012

Occupational activities and osteoarthritis of the knee

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Background: The prevalence of knee osteoarthritis (OA) is rising and the search for interventions to mitigate risk is intensifying. This review considers the contribution of occupational activities to disease occurrence and the lessons for prevention.

Sources: Systematic search in Embase and Medline covering the period 1996 to November 2011.

Areas of agreement: Reasonably good evidence exists that physical work activities (especially kneeling, squatting, lifting and climbing) can cause and/or aggravate knee OA. These exposures should be reduced where possible. Obese workers with such exposures are at additional risk of knee OA and should therefore particularly be encouraged to lose weight.

Areas of uncertainty/research need: Workplace interventions and policies to prevent knee OA have seldom been evaluated. Moreover, their implementation can be problematic. However, the need for research to optimize the design of work in relation to knee OA is pressing, given population trends towards extended working life.

Keywords: gonarthrosis/employment/occupational/aetiology

Accepted: April 3, 2012

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About a quarter of British adults aged ≥55 years have knee pain on most days in a month over the course of a year, and about half of those in pain also have radiographic knee osteoarthritis (OA).[1] This common chronic disease of older life causes significant disability and impaired quality of life, and its development often heralds a material reduction in a patient's capacity to undertake daily activities, including their ability to work.

DOI:10.1093/bmb/lds012

The prevalence of knee OA is rising in parallel with population ageing,[2,3] making the search for interventions to reduce disease occurrence and progression ever more pressing. The aetiology of the disorder is likely to depend in part on mechanical insults to the joint and in part on a generalized predisposition to OA.[4] Established risk factors include obesity, increasing age, female sex, knee joint injury and menisectomy.[5] Additionally, a significant body of evidence has accrued suggesting that occupational mechanical loading of the knee joint can cause or aggravate the disease.[5–8] Of particular concern in this last respect is the trend (and necessity) among patients to remain in employment to older ages.[9] If certain work causes or aggravates knee OA, then the move to prolong its duration could further swell the rising tide of morbidity, in which case the optimal design of work assumes a greater significance.

The problems of work participation in older patients with OA knee are reviewed in a companion report.[10] In this paper two principal questions are addressed: (i) To what extent does work cause OA knee? Correspondingly, might work be designed better to avoid OA knee? (ii) Are there other preventive measures that might be applied if work exposures prove difficult to avoid?

Emphasis is given to the research challenges inherent in answering these questions, as well as to appraising the current state of knowledge by means of a targeted literature search.

Search strategy and data abstraction

To investigate occupational physical activity as a cause of knee OA, a search was undertaken in Medline and Embase covering the period 1948 to November 2011. Medical subject headings (MeSH terms) and key words were chosen to represent knee OA and combined with terms for occupation, work and job. Searches were limited to papers with an abstract in English. Titles and potentially eligible abstracts were examined, duplicates and irrelevant references were eliminated, paper copies were obtained of all primary reports and reviews judged potentially relevant and the references of retrieved papers and reviews were checked for further material. At the final pass, reports were only retained that contributed quantitative estimates of risk for knee OA (or knee joint surgery) in relation to one or more of six pre-specified activities (squatting, kneeling, climbing, lifting, standing, physical workload), or according to a comparison of job titles.

From eligible papers a standard list of information was abstracted on sources of recruitment, study design and study period; definitions of knee OA; methods of exposure assessment and the timing of assessed exposures relative to onset of disease, diagnosis or study recruitment;

exposure definitions and contrasts; and estimated relative risks (RR) with 95% confidence intervals (95% CI) for each type of reported exposure, overall and by relevant subgroups, e.g. by sex or timing of exposure. (Where several sub-analyses were presented, analysis focused on the exposure contrasts that were most comparable across studies. Sometimes RRs were approximated by odds ratios or prevalence rate ratios, and sometimes expressed as incidence rate ratios.) Where available, data were also abstracted on the effects of combinations of exposure and of exposures in workers with high body mass index (BMI). Studies were rated according to their potential for bias, error and confounding.

Methodological issues

This area of research involves several methodological challenges, as exposures of interest are not allocated at random. Rather, those recruited into physically demanding jobs and remaining in them may be fitter and have less joint disease than those who choose other employment and job leavers (healthy hire and healthy survivor selection bias). Also, workers in physically demanding jobs may seek health care more readily when affected, and thus be more readily diagnosed and treated than other affected workers in sedentary employment (ascertainment or diagnostic bias). Exposures are mostly assessed in retrospect by the patient's own account, there being relatively few prospective studies because of the long latency of disease. However, exposures may be recalled more fully by motivated cases than by non-cases (recall bias), and exposures that are difficult to self-estimate (e.g. the number of stairs climbed/day over a lifetime) may be recalled imprecisely. Random errors in diagnosis may also arise.

These potential errors and biases do not all operate in the same direction. Thus, healthy survivor bias tends to lead to underestimation of RRs, as only the relatively less-affected survivors are studied; ascertainment bias may lead to an overestimation of RRs, as may recall bias; while random errors will lead to non-differential misclassification, the impact often being to flatten exposure–response relationships and bias risk estimates towards the null. Additionally, the exposure sufficient to cause OA is not known *a priori* and nor is the disease latency: if the duration and intensity of exposure are too small, or some of the counted exposure is too recent to influence disease onset, effects may be missed.

Several design strategies can be used to reduce the scope for error and bias. For example, the healthy survivor effect may be minimized by censoring the most recent work experience of subjects and focusing on exposure at earlier times (the interval should be such that few cases will have had symptoms at the point of censoring); ascertainment bias will be less likely where diagnosis is independent of health seeking (e.g. through sampling everyone in the population and applying diagnostic procedures uniformly, rather than taking cases recruited from hospital), or where healthcare seeking happens after, rather than before retirement; to overcome the problem of recall bias subjects are sometimes assigned an exposure value by experts, blinded to clinical history, according to their job title (this may substitute bias towards the null if exposures vary within jobs but are counted as identical); errors of recall may be reduced by making exposure metrics simpler (e.g. recall may be easier when the queried exposure happens 'almost all of the time' than '5 or more times per hour for at least 3 h/day') and more extreme in contrast; and in principle the impact on estimated RRs of different exposure metrics and assumed latencies can be explored in analysis, provided that studies collect the data to do so. Certain of the challenges can be minimized by prospective design with full follow-up, as groups are assembled on the basis of exposure rather than disease, with exposures assessed before disease onset and with scope to monitor job change and its reasons.

The way in which such biases play out in practice can be seen in occasional reviews with meta-analysis. For example, McWilliams *et al.*[6] estimated higher risks from physical work (i) in case–control (retrospective) than in cohort (prospective) studies, (ii) in studies from health care as compared with community settings and (iii) in relation to exposures without censoring.

Quality assessment

In this review, included studies were scored separately for their control of inflationary bias (tendency to overestimate RR) and of downward bias or bias to the null (tendency to underestimate RR). Studies were rated better from the first viewpoint if diagnosis was made independently of healthcare seeking or of symptoms, or if health-care seeking happened after retirement and if exposure assessment happened prospectively, independently of outcome, or was assigned independently of case history (e.g. through an expert rated job exposure matrix). Studies were rated better in their control of downward bias if there was censoring of recent work history (ideally at or before symptom onset, but alternatively at diagnosis or less satisfactorily at an arbitrary age or time), and if care was taken to reduce the measurement error in diagnosis (by using validated objective criteria) and in exposure assessment (by offering simple metrics with extremes of contrast with a plausibly 'sufficient' high band). Studies were scored on a five-point scale (0, 0/+, +, ++, +++), the higher score denoting better control or less tendency to be affected by the bias in question.

Finally, studies were scored for their capacity to control for several potential confounders: (i) age; (ii) sex; (iii) BMI; (iv) previous knee injury and (v) generalized OA (e.g. as evidenced by Heberden's nodes). Studies that allowed for all five factors were rated as 'very good' in their control of confounding, those that allowed for four as 'good', those that controlled three as 'fair' and those that considered only one or two as 'poor'.

Results

In all, 43 relevant papers were found covering 40 primary studies.[11–53] Table 1 records their main characteristics. Most studies diagnosed OA radiographically (typically as ≥Grade 2 on the Kellgren–Lawrence scale) or took cases from patients awaiting or in receipt of a knee joint replacement. In 14 of the 40 studies, subjects were recruited from the general population, in 15 from healthcare settings, in 10 from individual workplaces and in 1 from retired workers receiving a disability pension. In all, there were 7 cohort studies, 16 case–control studies and 17 cross-sectional studies. Between them, 17 studies reported on squatting and/or kneeling at work, 14 on lifting, 11 on standing, 10 on each of walking and climbing and 16 on physical workload defined broadly or as a combination of exposures, while 17 presented comparisons by job title.

As Table 1 illustrates, there were notable differences in approach to the timing and minimum allowable duration of exposure. Inquiries sometimes focused on exposures current at interview but in others on exposures >20 years before study entry. Some researchers attempted to reconstruct a lifetime cumulative exposure history, whereas others focused on the content of the longest held job, or even the first job, and some required jobs to be held for a minimum stipulated interval.

Table 2 summarizes the quality assessment of the studies by study design. About 30% overall (12 of 40) were rated as prone to inflationary bias, control being least good in case–control studies, while 58% (23/40) were deemed prone to downward bias or bias to the null—control being less good in retrospective studies of both case–control and cross-sectional design. Only 28% of studies overall achieved 'good' or 'very good' control of confounding, with only 12% (2/17) of cross-sectional studies matching this standard. Only five studies were rated well across all metrics relating to control of bias and confounding.

Table 1 Features of the reviewed studies.

First author (year) (ref.), country	Study period	Age (years)	Definition of outcome	Exposure			Method of exposure assessment	Control of bias			Control of confounding
				Types	Timing	Length		Up	Down	Null	
Population recruited											
Cohort											
Hart (1999),[11] England	1989–93	Mean 54[a]	Development over follow-up of new radiographic osteophytes or joint space narrowing	Physical workload	Not stated	N/S	Interview-administered questionnaire	+++	?	+	Very good: a, s, b, h, i
Felson (1991),[12] USA	1983–85	Mean 73[+]	Kellgren–Lawrence OA, ≥Grade 2	Physical workload	Jobs held in 1948–51 and 1958–61 (i.e. >20 years before radiography)	N/S	Interview-administered questionnaires: exposures assigned from job title	+++	+/++	+/++	Good: a, s, b, i
Schouten (1992),[13] The Netherlands	1975–89	*c.* 34–56[a]	Radiographic change in joint space width over follow-up (scored from −4 to +4); Kellgren–Lawrence OA, ≥Grade 2 initially	Kneeling, squatting, lifting, standing, walking, physical workload	Up to questionnaire	N/S	Self-administered questionnaire	+++	0	+	Fair: a, s, b
Toivanen (2010),[14] Finland	1978–2001	≥30[a]	'Definite' OA at follow-up, absent at baseline: (1) convincing history of diagnosed knee OA or knee arthroplasty or (2) at least moderately restricted knee flexion or (3) slightly restricted knee flexion with either: a less clearly evidenced history of knee OA or typical knee OA symptoms (no radiographic criteria)	Physical workload	Current at baseline (i.e. 22 years before follow-up)	N/S	Interview-administered questionnaire	+++	+++	0	Good: a, s, b, i
Case–control											
Cooper (1994),[15] England	*c.* 1993	≥55–90 (mean 73)	(1) Tibiofemoral, Kellgren–Lawrence Grade ≥3; patellofemoral, Grade 3 for both joint space narrowing and osteophyte formation *and* (2) Knee pain on most days for ≥1 month in past 12 months	Kneeling, squatting, lifting standing, walking, climbing, combination of exposures	Before symptom onset	Longest held job	Interviewer-administered questionnaire	++	+++	+	Good: a, s, b, h

Dahaghin (2009),[16] Iran	2004–05	Not stated	ACR criteria: (1) knee pain *and* (2) 3 of 6 features: age ≥50, >30 min morning stiffness, crepitus, bony tenderness, bony enlargement, no palpable warmth (no specific radiographic criteria)	Squatting, knee bending, lifting, standing, walking, climbing	Lifetime to questionnaire (cumulative exposure)	≥1 year	Interviewer-administered questionnaire	+	0	0	Fair: a, s, b
Cross-sectional studies											
Allen (2010),[17] USA	1999–2004	≥45	(1) Kellgren–Lawrence OA, ≥Grade 2 ± (2) Pain/aching/stiffness in knee on most days	Kneeling, squatting, lifting, standing, walking, climbing physical workload	Up to questionnaire	Longest held job	Interviewer-administered questionnaire	++	0	+++	Good: a, s, b, i
Anderson (1988),[18] USA	1971–5	35–74	Kellgren–Lawrence OA, ≥Grade 2	Physical workload	Current	N/S	Interviewer-administered questionnaire	++	0	++	Fair: a, s, b
Bagge (1991),[19] Sweden	1971–2	79	Kellgren–Lawrence OA, ≥Grade 2	Physical workload	Cumulative lifetime	N/S	Interviewer-administered questionnaire	++	0	++	Weak: a, s, b (but only crude analysis possible)
Bernard (2010),[20] USA	1988?	≥40	Kellgren–Lawrence OA, ≥Grade 2	Squatting, standing, climbing	Up to questionnaire	Longest held job	Self-completed questionnaire	++	0	+	Fair: a, s, b
D'Souza (2008),[21] USA	2001	≥60	(1) Kellgren–Lawrence OA (≥2 = all, 3–4 = severe) ± (2) Knee pain	Kneeling, lifting, standing, walking	Up to questionnaire	Longest held job of ≥5 years	Interviewer-administered questionnaire: exposures assigned from job title	++	0	++	Fair: a, s, b
Kim (2010),[22] Korea	2007	>53 (mean 70)	(1) Kellgren–Lawrence OA (≥2 = all, 3–4 = severe) ± (2) Knee pain/aching/stiffness lasting ≥1 month	Physical workload	At interview	N/S	Interviewer-administered questionnaire	++	0	+	Weak: a, b
Muraki (2009),[23] Japan	2005–07	23–95 (mean 71)	Kellgren–Lawrence OA, ≥Grade 2	Kneeling, squatting, lifting, standing, walking, climbing	Up to questionnaire	Longest held job	Interviewer-administered questionnaire	+	0	+	Fair: a, s, b
Zhang (2004),[24] China	*c.* 2002	≥60	Tibiofemoral: Kellgren–Lawrence Grade ≥2; patellofemoral; osteophyte or joint space narrowing ≥2	Squatting	At age 25 yrs (i.e. ≥35 yrs previously)	N/S	Interviewer-administered questionnaire	++	+++	+	Good: a, s, b, i
Healthcare recruited											
Cohort											
Jarvholm (2008),[25] Sweden	1987–98	40–79	Discharge register diagnosis of knee OA or knee replacement (excluding secondary revisions)	Various occupational titles within the construction industry	1971–1992 (ie about 6–27 yrs before entry)	N/S (but for 74% ≥3–5 yrs)	Job title registered at initial health surveillance	+++	+++	+	Fair: a, s, b

Continued

Table 1 *Continued*

First author (year) (ref.), country	Study period	Age (years)	Definition of outcome	Exposure			Method of exposure assessment	Control of bias			Control of confounding
				Types	Timing	Length		Up	Down	Null	
Vingard (1991),[26] Sweden	1981–83	35–75	Hospital discharge register record of knee OA (no specific radiographic criteria)	Various occupational titles	Held at censuses in 1960 and 1970 (i.e. 11 to 13 years previously)	≥10 years	Register-based linkage to occupational census	+++	+++	+	Weak: a, s
Case–control											
Coggon (2000),[27] England	*c.* 1997–98	Adults	On waiting list for total knee arthroplasty, osteotomy or patella replacement (OA (no specific radiographic criteria, but 78% at Kellgren–Lawrence Grade 3–4)	Kneeling, squatting, lifting, standing, walking, climbing, combination of exposures	Jobs held ≥10 years before interview (for most subjects before symptom onset)	From <1 to ≥20 years	Interviewer-administered questionnaire	+	+++	+++	Very good: a, s, b, h, i
Dawson (2003),[28] England	*c.* 1999	50–74	On a waiting list within the past 12 months for total knee replacement for symptomatic primary OA (no specific radiographic criteria)	Kneeling, squatting, lifting	Lifetime to questionnaire	From <24 to >33 yrs	Interviewer-administered questionnaire	0	0	+	Weak: a, s
Franklin (2010),[29] Iceland	2002	74	Total knee replacement [no specific radiographic criteria)	Various occupations (technicians/clerks, service and shop workers, farmers, fishermen, craft workers, operators and unskilled labour (vs. managers)	Up to questionnaire	Longest held job	Questionnaire on job title	++	0	+	Fair: a, s, b
Holmberg (2004),[30] Sweden	1999–2000	Mean 63	Hospital register record of: radiographically confirmed moderate/ severe tibiofemoral OA or past history of osteotomy or prosthesis	Various occupational titles (building and construction, cleaning, farming, forestry, health care, postal)	Lifetime to questionnaire (cumulative exposure)	From >1 to >30 years	Self-completed questionnaire	++	0	++	Good: a, s, b, i
Klussmann (2010),[31] Germany	*c.* 2009	25–75 (mean 51–60)	Kellgren–Lawrence OA, ≥Grade 2 or ≥Grade 2 on Outerbridge scale at arthroscopy or surgery	Kneeling, squatting, lifting	Lifetime cumulative exposure to diagnosis	N/S	Interviewer-administered questionnaire	0	++	++?	Fair: a, s, b
Kohatsu (1990),[32] USA	1977–88	≥55 (mean 71)	(1) Kellgren–Lawrence OA, ≥Grade 3 and (2) severe chronic knee pain, treated by total knee arthroplasty	Physical workload	Lifetime to questionnaire	N/S	Self-completed questionnaire	+	0	+	Weak: a, s

Lau (2000),[33] Hong Kong	1998	Adults	Attending orthopaedic clinic, Kellgren–Lawrence OA, ≥Grade 2	Kneeling, squatting, lifting, walking, climbing	Up to questionnaire	Main job held >1 year	Interviewer-administered questionnaire	0	0	+	Good: a, s, b, i
Manninen (2001, 2002),[34,35] Finland	1992–93	55–75	First knee arthroplasty for primary knee OA (no specific radiographic criteria)	Kneeling, squatting, lifting, standing, walking, climbing, physical workload	Up to age 49 years (i.e. ∼6–26 years previously)	N/S	Telephone administered questionnaire	0	+/++	++	Good: a, s, b, i
Riyazi (2008),[36] The Netherlands	2000–03	40–70	ACR criteria: (1) knee pain and (2) 3 of 6 features: age ≥50, >30 min morning stiffness, crepitus, bony tenderness, bony enlargement, no palpable warmth (no specific radiographic criteria)	Physical workload	Up to questionnaire	N/S	Self-completed questionnaire confirmed in outpatient clinics	0	0	0	Fair: a, s, b
Sahlstrom (1997),[37] Sweden	1982–86	47–96	(1) Grade 1 OA, Ahlback classification and (2) knee pain	Physical workload	Up to questionnaire (and at various ages)	N/S	Self-completed questionnaire on activities, classified by expert assessors	0	+	+	Good: a, s, b, i
Sandmark (2000),[38] Sweden	1991–95	55–70	Prosthetic surgery for primary tibiofemoral OA (no specific radiographic criteria)	Kneeling, squatting, lifting, standing, climbing	Lifetime to questionnaire	>10 years	Telephone questionnaire: comparison of job titles	++	0	+++	Fair: a,s,b
Seidler (2008),[39] Vrezas (2010),[40] Germany	*c.* 2007	25–70	(1) Kellgren–Lawrence OA, ≥Grade 2 and (2) knee pain, recruited through orthopaedic clinics	Kneeling, squatting, lifting; various occupational titles	Cumulative to year of diagnosis	N/S	Interviewer-administered questionnaire	+/0	++	++	Fair: a, s, b
Yoshimura (2004, 2006),[41,42] Japan	*c.* 2001	≥45	(1) Tibiofemoral OA: Kellgren–Lawrence Grade ≥3 and (2) knee pain with walking difficulties	(1) Kneeling, squatting, standing, lifting, walking, climbing and (2) various job titles	First job and longest job up to questionnaire	N/S	Interviewer-administered questionnaire	0	0	+	Fair: a, s,b
Disability pensioners											
Case control											
Vingard[a] (1992),[43] Sweden	1979–81, 84	<65	OA knee as the reason for disability pension award (no specific radiographic criteria)	Physical workload; various occupations	Last 20 years of work	>10 years	Estimate of workload assigned by experts on the basis of job title	++	0	0/+	Weak: a, s
Occupational recruitment											
Cohort											
Sandmark (2000),[44] Sweden	1996	53–72	Self-reported knee OA (no specific radiographic criteria)	PE teacher (vs. age-matched referents from population register)	Exposure assigned from training registration (∼31–39 years before enrolment)	≥10 years	Self-completed questionnaire	+++	+++	+	Weak: s; a or b or i

Continued

Table 1 *Continued*

First author (year) (ref.), country	Study period	Age (years)	Definition of outcome	Exposure			Method of exposure assessment	Control of bias			Control of confounding
				Types	Timing	Length		Up	Down	Null	
Cross-sectional studies											
Jensen (2000),[45] Denmark	*c.* 1999	26–72	Kellgren–Lawrence OA, ≥Grade 2	Floor layers (vs. carpenters and compositors)	Current job	N/S	Comparison of job titles	+++	0	+	Weak: a, s
Jensen (2005),[46] Denmark	*c.* 2004	26–72	Kellgren–Lawrence, ≥Grade 2	Kneeling, squatting (in floor layers, carpenters and compositors)	Current job	N/S	Telephone-administered questionnaire used to construct an exposure index	+++	0	+++	Fair: a, s, b
Kivimaki (1992),[47] Finland	*c.* 1992	Working age	Osteophytes in the inspected joint margins	Carpet and floor layers (vs. painters)	Current job	≥5 years	Job analysis based on videotapes and direct observations in a sample of workers	+++	0	0	Weak: a, s
Lawrence (1995),[48] England	*c.* 1954	41–50	OA on Kellgren–Lawrence scale (grade not defined)	Coalminers (face, roadway) vs. dockers, light manual and sedentary office workers	Current job	N/S	Comparison of job titles	+++	0	+	Weak: s
Lindberg (1987),[49] Sweden	1987	Mean 66	OA on Ahlback scale (grade not defined)	Labourers from various trades (vs. white collar workers and men from the population)	Lifetime to assessment	>30 years	Comparison of job titles	+++	0	+	Weak: a, s
Partridge (1968),[50] UK	*c.* 1962	15–65	Physician-diagnosed OA (no specific radiographic criteria)	Civilian dockers vs. civil servants	Current job	N/S	Comparison of job titles	+++	0	0	Weak: s
Rytter (2009),[51] Denmark	2004	30–70	OA on modified Ahlback scale: joint space narrowing ≥ 1 grade (scored for tibiofemoral and patellofemoral compartments)	Floor layers (vs. graphic designers)	Current job	N/S	Comparison of job titles	++	0	+	Fair: a, s, b
Thun (1987),[52] USA	*c.* 1986	25–74	Self-reported arthritis (no specific radiographic criteria)	Floor layers and tile setters (vs. blue collar mixed controls)	Current job	≥1.5 years (mean 24–31 years)	Comparison of job titles	+++	0	+	Fair: a, s, i
Wickstrom (1983),[53] Finland	*c.* 1981	20–64	Degenerative changes of osteophytosis, joint space narrowing, or subchondral sclerosis	Concrete reinforcement workers and painters	Current job	N/S (mean 15 years)	Comparison of job titles	+++	0	+	Weak: (a), s

For scoring of control over bias, see text. N/S, not stated; OA, osteoarthritis; a, age; s, sex; b, body mass index; i, previous knee injury; h, Heberden's nodes.
[a]Age at baseline; + age at radiography.

Table 2 Quality of the 40 investigations of physical work activity as a cause of knee OA.

	Cohort studies ($n = 7$)	Case–control studies ($n = 16$)	Cross-sectional studies ($n = 17$)	All studies ($n = 40$)
Control of inflationary bias				
+++ or ++	7	5	16	28
+ or 0	0	11	1	12
Control of downward bias and/or bias to the null (highest score)				
+++ or ++	5	7	5	17
+ or 0	2	9	12	23
Control of confounding				
Very good or good	3	6	2	11
Moderate	2	7	7	16
Weak	2	3	8	13
Good control of bias and confounding[a]	2	1	2	5

[a]At least ++ for *both* control of inflationary bias and downward/bias to the null, plus good or very good control of confounding.

Tables 1 and 2 indicate therefore a lot of available information on knee OA and work activities, but also limitations in quality, with potential for errors and bias (in conflicting directions) and a relative shortage of cohort data, especially by exposure type (e.g. only one of 17 studies on kneeling and/or squatting was of cohort design).

Tables 3 and 4 present estimates of RR by activity and by job title. When exposures were defined by activity (Table 3), as well as relating to different time periods, there were differences in their definition between studies. For example, lifting was variously defined in terms of a minimum combination of weight, daily repetition and years of such work, or as a lifetime estimate of the number of kilograms or tons occupationally lifted or as 'lifting heavy objects' for '>20% of the work day'. The occupations compared (Table 4) varied considerably, not only in choice but in grouping (sometimes involving several job titles) and in their comparator (sometimes white collar but sometimes blue collar).

These differences notwithstanding, Table 5 provides a summary of the estimated RRs from Table 3 by activity and by study design. It may be seen that the evidence for an association between work activity and knee OA is reasonably good, being strongest for squatting/kneeling, lifting and physical workload (more data, generally higher estimates of RR, and with most RRs statistically significant and at least $\geq$1.5, and often $\geq$2.0); somewhat weaker for climbing; and somewhat against an important effect from standing or walking.

A caveat to simple causal interpretation is that many of the higher RRs came from hospital-based case–control studies (Table 5), with the possibility that, irrespective of whether work initiated OA, patients in arduous jobs may have struggled to cope and more readily sought treatment. However, aggravation is an important clinical end point in itself. Moreover, several studies from Table 3 display exposure–response

Table 3 Association of knee OA with occupational physical activities.

Author (date)	Exposure contrast	Subgroup	RR	95% CI
Squatting and/or kneeling				
Cohort studies				
Schouten (1992)	Medium vs. low		0.31	0.09–1.04
	High vs. low		1.18	0.36–3.89
Case–control studies				
Coggon (2000)	Squatting >1 vs. ≤1 h/day for ≥1 year	Men	2.2	1.0–4.9
		Women	2.8	1.1–7.2
	Kneeling >1 vs. ≤1 h/day for ≥1 year	Men	1.7	1.0–3.0
		Women	2.0	1.1–3.5
	Getting up from squatting/kneeling >30×/day for ≥1 year	Men	2.0	1.1–3.5
		Women	1.8	1.0–3.2
Cooper (1994)	>30 min/day (squatting)		6.9	1.8–26.4
	>30 min/day (kneeling)		3.4	1.3–9.1
Dahaghin (2009)	Squatting >30 vs. <30 min/day		1.51	1.12–2.04
Klussmann (2010)	<3542 h/life	Women	1.50	0.83–2.69
	3452–8934 h/life		1.36	0.78–2.37
	>8934 h/life		2.52	1.35–4.68
	<3574 h/life	Men	1.70	0.96–3.00
	3574–12 244 h/life		2.16	1.24–3.77
	>12 244 h/life		2.47	1.41–4.32
Lau (2000)	Squatting ≥2 h/day	Men	1.2	0.7–2.0
		Women	1.1	0.8–1.5
	Kneeling ≥2 h/day	Men	1.4	0.7–3.0
		Women	0.9	0.6–1.3
Manninen (2002)	≥2 vs. 0 h/day (kneeling or squatting)	All	1.73	1.13–2.66
		Men	1.68	0.66–4.28
		Women	1.81	1.11–2.95
Sandmark (2000)	>0−70 000 vs. 0 squats	Men	1.3	0.8–1.5
	70 000–312 000 vs. 0 squats		2.9	1.7−4.9
	>3000–58 000 vs. 0–2000 squats	Women	1.2	0.7–1.9
	59 000–236 000 vs. 0–2000 squats		1.1	0.6–1.9
Seidler (2008)	>0–<870 h vs. none	Men	0.5	0.2–1.2
	870–<4757 h vs. none		0.8	0.4–1.5
	4757–<10 800 h vs. none		1.6	0.8–3.4
	>10 800 h vs. none		2.4	1.1–5.0
Dawson (2003)	15–<26 vs. <15 years, regular kneeling	Women	2.70	0.76–9.58
	≥26 vs. ≤15 years, regular kneeling		4.18	1.26–13.8
	15–<27 vs. <15 years, squatting	Women	2.54	0.88–7.34
	≥27 vs. ≤15 years, squatting		1.53	0.51–4.56
Yoshimura (2004)	Squatting ≥1 vs. <1 h/day	Initial job	1.05	0.57–1.94
	Squatting ≥1 vs. <1 h/day	Main job	1.20	0.66–2.17
	Kneeling ≥1 vs. <1 h/day	Initial job	0.95	0.52–1.76
	Kneeling ≥1 vs. <1 h/day	Main job	0.87	0.48–1.58
Cross-sectional studies				
Allen (2010)	Squatting >50% of the time		1.03	0.74–1.44
	Squatting often or always		1.27	0.97–1.68
Bernard (2010)	Squatting a lot	Men	1.56	0.89–2.75
		Women	0.89	0.50–1.61
D'Souza (2008)	Kneeling >14% of working day	Men: all OA	3.08	1.31–7.21

Continued

Table 3 *Continued*

Author (date)	Exposure contrast	Subgroup	RR	95% CI
	Kneeling >14% of working day	Men: severe OA	3.04	0.94–9.87
	Kneeling >14% of working day	Women: all OA	1.31	0.56–3.07
	Kneeling >14% of working day	Women: severe OA	1.30	0.46–3.68
Jensen (2005)	Low-moderate vs. none		2.96	0.5–17.2
	High vs. none		4.20	0.60–26.6
	Very high vs. none		4.92	1.1–21.9
Muraki (2009)	Squatting ≥1 vs. <1 h/day	Men	0.95	0.58–1.61
		Women	1.09	0.80–1.48
		All	1.05	0.81–1.38
	Kneeling ≥1 vs. <1 h/day	Men	0.95	0.55–1.70
		Women	0.97	0.70–1.35
		All	0.96	0.72–1.28
Zhang (2004)	1–2 vs. <0.5 h/day	Men	1.0	0.6–1.6
	2–3 vs. <0.5 h/day		1.7	0.8–3.5
	≥3 vs. <0.5 h/day		2.0	0.9–4.3
	1–2 vs. <0.5 h/day	Women	1.3	0.9–2.0
	2–3 vs. <0.5 h/day		1.2	0.8–1.9
	≥3 vs. <0.5 h/day		2.4	1.3–4.4
Climbing				
Case–control studies				
Coggon (2000)	Climbing ladder >30×/day for ≥1 year	Men	2.3	1.3–4.0
		Women	0.7	0.3–1.6
Cooper (1994)	>10 flights/day		2.7	1.2–6.1
Dahaghin (2009)	>30 stories/day		0.99	0.69–1.42
Lau (2000)	Climbing stairs ≥15 flights/day	Men	2.5	1.0–6.4
		Women	5.1	2.5–10.2
Manninen (2002)	Highest vs. lowest tertile cumulative	Men	2.79	0.96–8.16
		Women	1.50	0.81–2.77
		All	1.61	0.96–2.71
Sandmark (2000)	105 000–1 432 000 ≤ 103 000 steps	Men	1.2	0.8–1.9
	≥1 461 000 vs. ≤103 000 steps	Men	1.2	0.7–2.1
	170 000 – 2 494 000 ≤ 166 000 steps	Women	1.7	1.1–2.5
	≥2 557 000 vs. ≤166 000 steps	Women	1.4	0.8–2.3
Lau (2000)	≥15 flights/day	Men	2.5	1.0–6.4
	≥15 flights/day	Women	5.1	2.5–10.2
Yoshimura (2004)	≥30 steps/day	Initial job	0.87	0.41–1.82
	≥30 steps/day	Main job	1.19	0.61–2.31
Cross-sectional studies				
Allen (2010)	Often or always		0.96	0.73–1.26
Bernard (2010)	Stair climbing >5×/day	Men	1.61	1.11–2.32
		Women	1.14	0.87–1.49
Muraki (2009)	Climbing ≥1 vs. <1 h/day	Men	1.09	0.68–1.78
		Women	0.98	0.67–1.44
		All	1.02	0.76–1.38
Lifting				
Cohort studies				
Schouten (1992)	Lifting heavy objects: medium vs. low		1.00	0.33–3.02
	Lifting heavy objects: high vs. low		0.65	0.19–2.28

Continued

Table 3 *Continued*

Author (date)	Exposure contrast	Subgroup	RR	95% CI
Case–control studies				
Coggon (2000)	≥10 kg >10×/week ≥1 year	Men	1.9	1.0–3.3
		Women	1.5	1.0–2.3
	≥25 kg >10×/week ≥1 year	Men	1.7	0.9–3.0
		Women	1.7	1.0–2.8
	≥50 kg >10×/week ≥1 year	Men	1.7	0.9–3.2
		Women	1.2	0.6–2.4
Cooper (1994)	>25 kg lifted in average working day		1.4	0.5–3.7
Dahaghin (2009)	2–4 vs. <2 kg/day		1.12	0.84–1.50
	>4 vs. <2 kg/day		1.24	0.87–1.76
Dawson (2003)	>24–33 vs. <24 years	Women	7.31	2.01–26.7
	>33 vs. <24 years		3.58	0.89–14.4
Klussmann (2010)	Sometimes	Women	0.88	0.44–1.77
	<1088 tons/life		0.69	0.38–1.24
	≥1088 h/life		2.13	1.14–3.98
Lau (2000)	Lifting ≥10 kg, >10×/week	Men	5.4	2.4–12.4
		Women	2.0	1.2–3.1
Manninen (2002)	Highest vs. lowest tertile cumulative	Men	0.92	0.50–2.39
		Women	1.11	0.71–1.75
		All	1.04	0.70–1.55
Sandmark (2000	114 000 −5 891 000 vs. ≤107 000 kg	Men	2.5	1.5–4.4
	≥5 907 000 vs. ≤107 000 kg	Men	3.0	1.6–5.5
	5000–438 000 vs. ≤4000 kg	Women	1.2	0.7–1.9
	≥440 000 vs. ≤4000 kg	Women	1.7	1.0–2.9
Seidler (2008)	>0–<630 kg × h vs. none	Men	1.2	0.6–2.3
	630 −<5120 kg × h vs. none		2.0	1.1–3.6
	5120–<37 000 kg × h vs. none		2.0	1.1–3.9
	≥37 000 kg × h vs. none		2.6	1.1–6.1
Lau (2000)	≥10 kg >10×/week	Men	5.4	2.4–12.4
	≥10 kg >10×/week	Women	2.0	1.2–3.1
Yoshimura (2004)	>25 kg	First job	1.00	0.50–2.00
	>25 kg	Main job	1.91	0.92–3.96
	Heaviest load >55–62 vs. <55 kg		4.42	1.17–16.64
	Heaviest load >62 vs. <55 kg		3.13	0.94–10.48
Cross-sectional studies				
Allen (2010)	50 kg ≥10×/week		0.98	0.67–1.43
	>10 lbs often or always		1.42	1.13–1.80
D'Souza (2008)	Heavy lifting >20% of work day	Men: all OA	2.72	1.14–6.50
		Men: severe OA	3.04	0.94–9.87
		Women: all OA	4.94	0.99–24.48
		Women: severe OA	1.18	0.54–2.59)
Muraki (2009	Lifting ≥10 kg ≥1×/week	Men	1.09	0.69–1.72
		Women	1.23	1.01–1.55
		All	1.15	0.91–1.45
Walking				
Cohort studies				
Schouten (1992)	Medium vs. low		2.09	0.61–7.20
	High vs. low		1.47	0.36–6.03

Continued

Table 3 *Continued*

Author (date)	Exposure contrast	Subgroup	RR	95% CI
Case–control studies				
Coggon (2000)	>2 miles/day in total for ≥1 year	Men	1.7	0.8–3.6
		Women	2.1	1.4–3.2
Cooper (1994)	>2 miles/day		0.9	0.5–1.5
Dahaghin (2009)	>3 vs. <1 h/day on flat ground		0.92	0.62–1.37
Manninen (2002)	Highest vs. lowest tertile cumulative	Men	1.47	0.55–3.89
		Women	1.06	0.64–1.76
		All	1.06	0.68–1.64
Lau (2000)	≥2 h/day	Men	1.0	0.5–2.1
	≥2 h/day	Women	0.8	0.5–1.1
Yoshimura (2004)	≥3 km/day	First job	0.88	0.50–1.56
	≥3 km/day	Longest job	1.29	0.73–2.27
Cross-sectional studies				
Allen (2010)	>50% of the time		1.24	0.99–1.55
	Often or always		1.46	1.12–1.90
D'Souza (2008)	>30% of work day	Men: all OA	1.59	0.48–5.23
	>30% of work day	Men: severe OA	0.50	0.12–2.18
	>30% of work day	Women: all OA	2.00	0.84–4.75
	>30% of work day	Women: severe OA	2.72	0.91–8.16
Muraki (2009)	Walking ≥3 km/day	Men	0.89	0.57–1.40
		Women	1.04	0.79–1.37
		All	1.00	0.79–1.26
Standing				
Cohort studies				
Schouten (1992)	Medium vs. low		3.80	1.03–13.96
	High vs. low		2.09	0.43–10.31
Case–control studies				
Coggon (2000)	>2 h/day for ≥1 year (standing or walking)	Men	4.1	0.3–65.5
		Women	1.5	0.8–2.9
Cooper (1994)	>2 h/day		0.8	0.4–1.4
Dahaghin (2009)	>3 vs. <1 h/day		0.85	0.58–1.24
Manninen (2002)	High vs. low level	Men	0.36	0.15–0.90
		Women	0.70	0.42–1.16
		All	0.62	0.40–0.95
Sandmark (2000)	51 000–96 000 vs. ≤51 000 h	Men	1.5	0.9–2.4
	≥96 000 vs. ≤51 000 h	Men	1.7	1.0–2.9
	58 000–94 000 vs. ≤58 000 h	Women	1.2	0.7–1.9
	≥94 000 vs. ≤58 000 h	Women	1.6	1.0–2.8
Yoshimura (2004)	≥2 h/day	First job	1.17	0.54–2.52
	≥2 h/day	Longest job	1.64	0.77–3.46
Cross-sectional studies				
Allen (2010)	Often or always		1.38	1.08–1.77
Bernard (2010)	≥2 h/day	Men	1.12	0.81–1.55
		Women	1.36	1.06–1.73
D'Souza (2008)	>36% of work day	Men: all OA	1.37	0.68–2.77
	>36% of work day	Men: severe OA	0.43	0.09–1.96
	>36% of work day	Women: all OA	1.44	0.66–3.14

Continued

Table 3 *Continued*

Author (date)	Exposure contrast	Subgroup	RR	95% CI
	>36% of work day	Women: severe OA	1.44	0.52–3.88
Muraki (2009)	Standing ≥2 h/day	Men	1.14	0.61–2.04
		Women	1.10	0.77–1.57
		All	1.11	0.81–1.50
Physical workload and combined exposures				
Cohort studies				
Hart (1999)	Physically active job (Y vs. N)	Osteophytes	1.48	0.34–5.64
		Joint space narrowing	0.56	0.18–1.79
Schouten (1992)	Medium vs. low		1.50	0.48–4.69
	High vs. low		0.43	0.11–1.76
Felson (1991)	Knee bending with medium, heavy or very heavy demands (vs. no bending and sedentary or light demands)	Men	2.22	1.38–3.58
		Women	0.36	0.09–1.40
Toivanen (2010)	Physically strenuous work (vs. 1 = mildest)	2	1.6	0.5–4.9)
		3	1.1	0.6–2.1
		4	1.3	0.7–2.6
		5	1.7	0.8–3.9
		6 (heaviest)	18.3	4.2–79.4
Case–control studies				
Coggon (2000)	Both kneeling/squatting and heavy lifting (vs. neither)	Men	2.9	1.3–6.6
Cooper (1994)	Heavy lifting (>25 kg/day) with any of: kneeling (>30 min/day) or squatting (>30 min/day) or stair climbing (>10 flights/day)		5.4	1.4–2.1
Kohatsu (1990)	Moderate to heavy work	20–29 years	2.3	0.9–6.1
		30–39 years	3.4	0.9–10.8
		40–49 years	3.0	0.9–11.4
Manninen (2001)	Heavy vs. low physical stress judged by job title	Men	0.43	0.19–0.98
		Women	1.18	0.71–1.75
Manninen (2002)	Frequent vs. not sweating/rapid heart beat	Men	1.53	0.42–5.56
		Women	2.03	1.03–3.99
		All	2.02	1.11–3.65
Riyazi (2007)	Physically demanding job (e.g. construction, forestry) vs. not		1.9	1.1–3.3
Sahlstrom (1997)	Weight bearing knee bending		1.1	0.7–1.8
Seidler (2008)	(vs. no squatting/kneeling/lifting)			
	Medium kneeling/squatting *or* lifting	Men	2.7	1.5–4.8
	High kneeling/squatting *or* lifting		3.4	1.8–6.3
	High kneeling/squatting *and* lifting		7.9	2.0–31.5
Vingard (1992)	Medium vs. low load occupation	Men	4.5	2.6–7.6
	High vs. low load occupation		14.3	8.1–25.4

Continued

Table 3 *Continued*

Author (date)	Exposure contrast	Subgroup	RR	95% CI
Cross-sectional studies				
Anderson (1988)	Strength demand of job (in 55–64 year age band)	Men	1.88	0.88–3.99
		Women	3.13	1.04–9.39
	Knee bending demand of job (in 55–64 year age band)	Men	2.45	1.21–4.97
		Women	3.49	1.22–10.52
Bagge (1991)	Index of physical workload based on daily activities and duration of work (≥4 vs. <4)	Men	1.3	0.6–2.8[a]
		Women	0.8	0.4–1.6[a]
Allen (2010)	Heavy work while standing >50% of job		1.32	1.02–1.72
	Heavy work while standing often or always		1.44	1.03–2.02
Interaction of work activity with BMI				
Case–control studies				
Coggon (2000)	(vs. BMI <25.0 and no kneeling/ squatting >1 h/day)			
	BMI 25–<30, no kneeling/squatting		3.4	2.2–5.2
	BMI 25–<30 + kneeling/squatting		6.1	3.4–10.9
	BMI ≥30, no kneeling/squatting		8.2	4.6–14.4
	BMI ≥30 + kneeling/squatting		14.7	7.2–30.2
Vrezas (2010)	(vs. BMI <24.92 and no kneeling/ squatting)			
	BMI ≥24.92		2.5	1.5–4.3
	BMI < 24.92 and total ≥4757 h		1.8	0.8–3.9
	BMI ≥24.92 and total ≥4757 h		5.3	2.4–11.5
	(vs. BMI <24.92 and no lifting)			
	BMI ≥24.92		2.4	1.2–4.7
	BMI <24.92 and total ≥5120 h		2.4	1.1–5.4
	BMI ≥24.92 and total ≥5120 h		5.0	2.4–10.5

[a]Derived OR and 95% CI.

relationships (e.g. those by Klussmann *et al.*[31] or Zhang *et al.*[24] on squatting/kneeling, or by Sandmark *et al.*[38] and Seidler *et al.*[39] on lifting), and when *combinations* of exposures were assessed together, even higher risks pertained (e.g. Cooper *et al.*,[15] Coggon *et al.*[27] and Seidler *et al.*[39]), with risks elevated 3- to 8-fold when lifting was combined, say, with kneeling or squatting.

On balance then, quite a strong case can be made that certain work activities increase the risk of knee OA and make certain work more difficult, combinations of exposure carrying even higher risks.

In the UK this position is formally recognized, in that occupations where risks of OA knee are more than doubled (coal miners and carpet and floor layers under certain employment conditions) may qualify for no-fault state compensation under the Industrial Injuries Disablement Benefit Scheme, attribution to occupation being likely on the balance of probabilities.[54,55]

Table 4 Risk of knee OA by occupation.

Authors (date)	Exposure contrast	Subgroups	RR	95% CI
Cohort studies				
Jarvholm (2007)	(vs. white collar workers)			
	Asphalt workers		2.81	1.11–7.13
	Brick layers		2.14	1.08–4.25
	Concrete workers		1.80	1.00–3.25
	Floor layers		4.72	1.80–12.33
	Plumbers		2.29	1.19–4.43
	Rock workers		2.59	1.18–5.69
	Sheet-metal workers		2.60	1.06–5.37
	Wood workers		2.02	1.11–3.69
Sandmark (2000)	PE teachers (vs. matched population referents)	Men	2.7	1.6–4.6
		Women	4.0	2.0–8.2
Vingard (1991)	Registry-based comparison of hospitalization rates by occupation (vs. panel of low demand blue-collar jobs)	Men		
		Firefighters	2.93	1.32–5.46
		Truck and crane operators	1.50	0.92–2.37
		Farmers	1.46	1.23–1.98
		Unskilled manual workers	1.40	0.83–2.70
		Construction workers	1.36	1.13–1.79
		Women:		
		Cleaners	2.18	1.26–3.00
		Warehouse workers	1.50	0.53–3.90
		Farmers	1.36	0.57–3.53
		Waitresses and hairdressers	1.31	0.82–2.32
Case–control studies				
Franklin (2010)	Various occupations (vs. managers/professionals)	Men		
		Technicians/clerks	2.0	0.71–5.7
		Farmers	5.1	2.1–12.4
		Fishermen	3.3	1.3–8.4
		Craft workers	2.5	1.0–6.2
		Operators/unskilled labour	1.4	0.5–3.8
		Women		
		All RR $\leq$ 1.4 and $P < 0.05$		
Holmberg S	Farm work: 11–30 vs. $<$1 year	Men	0.8	0.2–2.1
		Women	2.1	1.0–4.5
	Farm work: $>$30 vs. $<$1 year	Men	1.7	0.7–4.0
		Women	2.0	0.7–5.5
	Forestry: $>$1 vs. $<$1 year	Men	1.6	0.7–3.3
	Building and construction: 1–10 vs. $<$1 year	Men	1.5	0.5–4.5
	Building and construction: 11–30 vs. $<$1 year	Men	3.7	1.2–11.3
	Building and construction: $>$30 vs. $<$1 year	Men	1.6	0.6–4.6
	Letter carrier: $>$1 vs. $<$1 year	Men	1.7	0.4–7.0

	Cleaning: >1 vs. <1 year	Women	1.1	0.6–1.7
	Health care: >1 vs. <1 year	Women	0.9	0.6–1.4
Manninen (2002)	(vs. professional workers)			
	Agriculture, forestry, fishing	All	1.52	0.91–3.20
	Manufacturing, construction, mining	All	1.36	0.64–2.89
	Transportation and traffic	All	3.07	1.19–7.90
	Commerce and trade	All	1.68	0.74–3.83
	Health care and social work	Women	1.42	0.68–2.97
	Service	All	1.33	0.65–2.74
Sandmark (2000)	Farmers (vs. non-heavy jobs)	Men	3.2	2.0–5.2
		Women	2.4	1.4–4.1
	Farm workers (vs. non-heavy jobs)	Men	1.4	0.8–2.6
		Women	1.4	0.8–2.6
	Construction workers	Men	3.1	1.5–6.4
	Forestry workers	Men	2.1	1.0–4.6
Seidler (2008)	Agricultural, animal and forestry	Men, >10 years in job	2.0	0.4–13.0
	Chemical and plastics processors		16.1	3.1–84.4
	Metal processors, blacksmiths		5.1	0.7–35.4
	Machine fitters, assemblers, mechanics		3.0	1.5–6.2
	Construction workers		2.1	0.5–8.7
	Plasterers, insulators, glaziers, construction carpenters, upholsterers		5.7	1.2–28.0
	Storemen, nurses, refuse collectors		4.3	1.6–11.7
Vingard (1992)	(vs. jobs with low physical workload)			
	Farmers	Men	5.3	1.4–19.7
	Painters, carpet layers		23.1	3.0–178.3
	Construction workers		5.1	2.6–10.0
	Metal workers		3.2	1.7–5.9
	Secretarial workers		2.0	0.7–6.0
Yoshimura (2006)	Work in factory, construction, agriculture or fishery (vs. not)	Main job	6.20	1.40–27.5
Cross-sectional studies				
Kivimaki (1992)	Carpet layers (vs. painters)	Employed ≥5 years	2 vs, 2%	
Thun (1987)	Floor layers (vs. controls)		1.1	0.7–1.8[a]
	Tile setters (vs. controls)		2.0	1.2–3.3[a]
Wickstrom (1983)	Concrete reinforcement workers (vs. painters)		1.1	0.7–1.8[b]
Lawrence (1955)	Coalminers (vs. dockers and light manual workers)		2.6	1.3–5.9[b]
	Coalminers (vs. dockers, light manual and office workers)		3.0	1.6–6.1[b]
Muraki (2009)	(vs. clerical workers/technical experts)			
	Agricultural/forestry/fishery workers	All	1.46	1.02–2.11
	Factory/construction workers	Male	1.52	0.76–3.22
Partridge (1968)	Civilian dockers (vs. civil servants)	Right knee	2.1	0.7–7.6[b]
		Left knee	2.6	0.9–9.4[b]
Lindberg (1987)	Labourers (vs. white-collar and population referents)	Longest job (mean 30 years)		
Jensen (2000)	Floor layers vs. carpenters and compositors		14 vs. 6–8%	

[a]90% CI.
[b]Derived OR and 95%CI.

Table 5 Estimates of risk of knee OA by work activity and by study design.

	No. of studies (no, $P < 0.05$) with			No. (%) of studies with both RR $\geq$1.5 and $P < 0.05$
	RR <1.5	RR = 1.5–2.0	RR >2.0	
Work activity				
Squatting/kneeling	5 (0)	3 (2)	9 (9)	11/17 (65)
Lifting	6 (0)	1 (1)	7 (7)	8/14 (57)
Standing	7 (2)	2 (1)	2 (1)	2/11 (18)
Walking	7 (1)	–	3 (1)	1/10 (20)
Climbing	4 (0)	2 (2)	4 (3)	6/10 (60)
Physical workload	5 (1)	2 (1)	9 (9)	10/16 (63)
Design				
Cohort	4 (0)	1 (0)	4 (3)	3/9 (33)
Case–control	16 (0)	7 (6)	24 (22)	28/47 (60)
Cross sectional	14 (4)	2 (1)	6 (5)	6/22 (27)
All	34 (4)	10 (7)	34 (30)	37/78 (47)

Each study contributed one estimate of RR per activity to this table. However, most studies reported on more than one activity. Where a study provided several estimates of RR for a given activity, the highest RR from Table 3 was counted.

Interactions with BMI

Table 3 also reports two studies which looked at the interaction of obesity with kneeling/squatting and lifting (Coggon *et al.*[27] and Vrezas *et al.*[40]), and these carry an important message for clinicians. In both studies, squatting/kneeling and high BMI carried independent risks of knee OA, but their combination was particularly injurious with RRs raised 5- to 15-fold; and Vrezas *et al.*[40] reported a similar interaction between high lifetime cumulative lifting and high BMI, with RRs raised 5-fold. Clearly, primary prevention in the workplace should be geared towards reducing physical loading on the knee, by task and workplace redesign, provision of lifting aids and other measures[56]—an action on employers. Clinicians have no authority to alter the work environment other than through persuasion, but they can advise overweight patients that in terms of preventing knee OA, losing weight will be especially important if their work entails substantial kneeling/squatting (defined by Coggon as >1 h/day for >1 year[27]) or substantial heavy lifting.

Design of work

Clinicians can go further, in concert with experts from other disciplines (e.g. ergonomists), in defining and promoting the principles of better work design. Fransen *et al.*[8], for example, have advocated a 'risk management' approach in which risks of knee OA are systematically assessed, prioritized and controlled using a hierarchical method common to most health and safety planning (beginning where possible with avoidance at source, and if necessary involving new work methods and administrative controls, worker education and assistive devices).

A real example can be offered from the floor laying industry, where the prevalence of occupational squatting and knee OA is notably high. In Denmark, new telescopic sticks with job-specific interchangeable end fittings have been introduced to enable the tasks of gluing, filling, welding and up-cutting to be performed from a standing rather than a squatting position.[57] Problems of non-compliance initially beset implementation of the new working methods and further modifications were needed; but encouragingly, a participatory strategy comprising additional worker education and support improved take-up among the floor layers by 4-fold, after which a reduced level of knee pain was reported by 28% of those using the new tools weekly or daily (vs. 6% of those using them never or only occasionally).[58] The impact was greatest when the new tools were adopted before the initial onset of knee pain.

The evidence base on well-evaluated workplace interventions is wanting at present: a systematic search by Fransen *et al.*[8] found no truly randomized controlled trials for prevention of work-related knee injuries or symptomatic OA. However, the Danish model suggests that progress can be made, provided that efforts are concerted and sustained.

Conclusions

Knee OA is an increasingly common cause of morbidity and work limitation in later life. Occupational activities that physically load the joint—notably, squatting and kneeling for substantial parts of the working day, regular heavy lifting, climbing and high physical workload—are likely to contribute to disease occurrence and/or progression and to symptom aggravation. Where possible these exposures should be minimized at source by job design, difficult though this may be to achieve in practice. In any event, workers who are overweight and who have these elements in their daily work should be strongly encouraged to lose weight.

Acknowledgements

Thanks are due to Clare Harris and Cathy Linaker, who assisted with the search that is described in the paper and checked the main data abstractions. Sue Curtis helped prepare the manuscript.

Funding

The author is in receipt of core funding from the Medical Research Council.

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