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Hip osteoarthritis and occupational mechanical exposures: A reference document

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Foreword

In Denmark, hip osteoarthritis as a result of occupational mechanical exposures is considered an occupational disease. Due to new national and international scientific studies, the Danish Labour Market Insurance and the Occupational Diseases Committee have requested a reference document to re-evaluate the existing guidelines of the exposure requirements. A reference document was conducted in form of a systematic review and meta-analysis to study the association between occupational mechanical exposures and hip osteoarthritis.

The reference document was conducted by research assistant Alexander Jahn, Professor Johan Hviid Andersen, associate professor David Høyrup Christiansen, Professor Andreas Seidler, and associate professor Annett Dalbøge. Professor Karen Walker-Bone and Professor Bengt Järvholm independently evaluated the reference document. The reference document followed specific guidelines for preparation and quality approval provided by the Danish Work Environment Research Fund, which is part of The Ministry of Employment administered by the Danish Working Environment Authority. The reference document was funded by The Danish Work Environment Research Fund with grant no 51-2021-04 20205100371.

Contents

1. Introduction

Osteoarthritis (OA) is a chronic disease causing erosion in the articular cartilage and alterations in the subchondral bone, capsule, and ligaments.[1] Almost any joint can be affected by OA, but the condition most often causes problems in the knees, hips, and small joints of the hands. Cardinal symptoms of hip OA consist of pain in or near the hip joint, stiffness, weakness, and audible clicking sounds when moving the hip. Clinical diagnosis of hip OA is made on the basis of cardinal symptoms in combination with imaging modalities (e.g., MRI or x-ray) and physical examination (e.g., range of motion and tenderness).[2]

Hip OA is considered a global problem having harmful consequences on quality of life, a negative impact on healthcare systems, and an increased risk of years lived with disability.[2 3] The global prevalence of radiographic primary hip OA in the general adult population has been reported in a systematic review from 2009.[4] Based on 23 studies, the overall prevalence ranged from 0.9% to 27% with a mean prevalence of 8.0% (standard deviation (SD)=7.0%). In a systematic review from 2011 including 27 studies of self-reported, radiographic, and symptomatic hip OA, the prevalence based on a meta-analysis was 10.90% (95% CI 10.55-11.25%); 7.35% (95% CI 6.96-7.77) for self-reported hip OA, 15.14% (95% CI 14.52-15.77) for radiographic hip OA, and 6.16% (95% CI 5.71-6.62) for symptomatic hip OA. No sex difference in prevalence was found; 11.6% (95% CI 11.1-12.1) for women and 11.5% (95% CI 11.0-12.1) for men.[5] In European studies, hip OA prevalence ranged from 2% to 9% for people under 75 years of age.[6-10] The global age-standardised incidence proportion of hip OA have increased from 17.02 per 100,000 persons in 1990 to 18.70 per 100,000 persons in 2019, which correspond to an estimated annual percentage change of 0.32%.[11] In Denmark, severe hip OA causes approximately 12.000 hip arthroplasty surgeries a year including 10% reoperations.[12]

Risk factors associated with hip OA include e.g., Body Mass Index (BMI),[13] waist-to-hip ratio,[14] obesity,[15 16] age,[16 17] sex,[18] genetic,[16 17 19] high-impact sports/long-distance running,[17 20 21] previous trauma,[17] arthritis of other joints,[16 22] and occupational mechanical exposures.[23-28] The risk of hip OA has been reported to be higher in workers with high occupational mechanical exposures. In a systematic review from 2022, Unverzagt et al (2022)[29] evaluated the influence of occupations with high mechanical exposures on the development of hip OA in men. Based on 11 studies, an elevated risk of hip OA was shown for six occupational groups (i.e., workers in agriculture, fishery or forestry, food production or sales, construction, metal workers, and men driving vehicles with whole-body vibration). Working in agriculture, including fishery, forestry, and food production, doubled the risk of hip OA. Construction, metal working, and sales, as well as exposure to whole body vibration while driving vehicles, increased the risk by roughly 50 to 60%. Unskilled or basic-level workers, who were frequently exposed to repetitive heavy manual work, had nearly a doubled risk (relative risk (RR) 1.89, 95% CI 1.29-2.77) compared to workers with lower exposure.

Since 2010, six systematic reviews of the association between occupational mechanical exposures and hip OA have been published.[23-28] Sulsky et al (2012)[23] included 30 studies, but only three studies provided sufficient information to study exposure-response relations. It was concluded that the risk of hip OA might increase with long-term exposures to heavy lifting (N=3 studies) and standing (N=3 studies), and there was some indication that long-term exposure to stair climbing (N=2 studies) might increase the risk. Moreover, sitting (N=2 studies) was not associated with an increased risk.

Bergmann et al (2017)[24] included 23 studies investigating occupational mechanical exposures as risk factors for hip OA. Lifting heavy loads (N=7 studies) and the combination of different mechanical exposures (N=3 studies) were found to increase the risk of hip OA. Furthermore, a greater risk of hip OA was found in men compared to women. In addition, Seidler et al (2018)[25] analysed the relation between lifting loads and hip OA based on the systematic review from Bergmann et al (2017).[24] The results indicated a double dose for men: 1) between 6100 and 14000 cumulative tons of weights $\leq$20 kg handled, 2) between 6000 and 10,500 cumulative tons of weights $\geq$20 kg handled >10 times/day, and 3) between 218,000 and 514,000 cumulative lifting and/or carrying operations of weights $\geq$20 kg.

Sun et al (2019)[26] included 10 studies investigating exposure-response relations between occupational mechanical exposures and hip OA among men and women. Based on two studies, a positive exposure-response relation was found for heavy lifting in males. Furthermore, for the male population the doubling dose was estimated to be between 14,761 and 18,522 tons.

Gignac et al (2019)[27] included 28 studies investigating the association between occupational mechanical exposures and hip OA. Among men and women, strong evidence of an association was found for occupational lifting (N=12 studies), while moderate evidence was found for the combination of different mechanical exposures (cumulative physical load, N=3 studies) and full-body vibration (N=4 studies) in men. Conversely, strong evidence of no association was found for sitting, standing, and walking (N=11 studies) in men.

Finally, Canetti et al (2020)[28] included 28 studies published within the last 15 years, investigating the association between lifting loads, awkward postures, kneeling, squatting, standing, and crawling and hip OA. In the meta-analysis including three studies, occupational lifting was found to be associated with hip OA. Only one study was included to evaluate the effect of awkward postures, kneeling, squatting, and standing with OR between 1.11 and 2.28.

Among the six systematic reviews, lifting loads was the most often studied occupational mechanical exposure with all six reviews finding some level of an association.[23-28] For other occupational mechanical exposures, 1-2 systematic reviews exist including very few studies. Meta-analyses were only conducted for lifting loads and exposure to the combination of different mechanical exposures.

In Denmark, hip OA as a result of occupational mechanical exposures is considered an occupational disease. Due to new national and international scientific studies, the Danish Labour Market Insurance and the Occupational Diseases Committee have requested a reference document to re-evaluate the existing guidelines of the exposure requirements. The aim of this reference document was to conduct a systematic review and meta-analysis to summarise the existing epidemiological evidence of the association between occupational mechanical exposures and hip OA.

2. Methods

2.1 Protocol and study registration

The reference document was conducted as a systematic review and meta-analysis using guidelines provided by the PRISMA-P 2015 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).[30 31] To ensure the methodological quality of our systematic review, we complied with guidelines provided by AMSTAR (Assessing the Methodological Quality of Systematic Reviews).[32] A protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) with registration number CRD42022355902.

The systematic review and meta-analysis were funded by The Danish Working Environment Research Fund, part of The Ministry of Employment administered by the Danish Working Environment Authority with grant no 51-2021-04 20205100371.

2.2 Literature search

A systematic literature search was designed, tested, and performed in collaboration with a research librarian, optimised for each specific database and their syntax in National Library of Medicine

(Medline) to the 31st of May 2022, Excerpta Medica Database (EMBASE) to the 31st of May 2022, PsycInfo to the 31st of May 2022, Cumulative Index to Nursing and Allied Health Literature (CINAHL) to the 1st of June 2022, Cochrane Library to the 16th of June 2022, and Web of Science to the 23rd of June 2022. Our search strategy consisted of three blocks, each containing MeSH terms and free-text words in combinations using Boolean operators within and between blocks. The search string for MEDLINE is presented in Appendix 1. Our literature search was supplemented by hand-searching all bibliographies of included articles and reviews published after 2010. Finally, using the Google and the Google Scholar search engine, we searched for literature by screening the first 100 hits for potentially relevant articles.

All potential relevant articles identified from the literature search were transferred to the review management software Covidence.[33] Here, duplicates were identified and removed. Afterward, the selection of relevant articles was carried out by two of the review authors (AJ, JHA, or AD), who independently screened all articles using a two-step model. At first, articles were screened based on title/abstract followed by full-text reading. A third review author resolved any disagreements between the two review authors.

2.3 Study inclusion criteria

Study inclusion criteria was described based on components of PECOS (Population, Exposure, Comparison, Outcome, and Study design).

2.3.1 Population

We included studies with a population in or above the working-age with current or former employment, and with no limitations to sex, demographic, or ethnicity.

2.3.2 Exposure

Exposure included occupational mechanical exposures, which we divided into 12 exposure variables: lifting/carrying loads, awkward postures, standing, walking, standing/walking, kneeling, squatting, kneeling/squatting, climbing stairs, sitting, combined occupational mechanical exposures, and other occupational mechanical exposures. Combined occupational mechanical exposures included different mechanical exposures e.g., lifting, walking, awkward postures. Other occupational mechanical exposures contained exposures that could not be categorised into the aforementioned 11 exposure variables. Studies with exposure assessment based on self-reports, observations, expert ratings, technical measures, or combinations were included. Exposure assessments based solely on proxy measures (e.g., job titles) were excluded.

2.3.3 Comparison

We defined comparison as a measure of association between occupational mechanical exposures and hip OA or possible to calculate. Measures of association comprised e.g., relative risks (RR), odds ratios (OR), hazard ratios (HR), and prevalence ratios (PR). Moreover, comparison between groups should consist of an exposed versus less exposed group.

2.3.4 Outcome

We included studies that defined hip OA in accordance to the following criteria:

- Diagnosis according to criteria stated by American College of Rheumatology.
- ICD-codes or diagnosis from, e.g., registers.
- Hip replacement caused by OA.
- Radiographic assessed by, e.g., Kellgren and Lawrence.
- Hip pain with physical examination measuring stiffness and physical limitations.
- Self-reported hip OA.

If OA occurred in several different joints, was caused by trauma, inherent pain, or the diagnosis was solely based on hip pain, the study was excluded. Furthermore, studies based on admissions or surgery codes with OA secondary to other diseases, such as rheumatoid arthritis, were excluded.

2.3.5 Study design

We included original quantitative epidemiological studies investigating the effect of occupational mechanical exposures on hip OA. The eligible study designs were cohort studies, case-control studies, and cross-sectional studies. All other study designs were excluded (e.g., reviews, case series/case reports, in vitro studies, qualitative studies, and studies based on health economics). Each study should include at least 30 persons and be written in English, Danish, Swedish, or Norwegian with no date restriction applied.

2.4 Data extraction

Two study data extraction tables were predefined; one containing the descriptive information and one containing the analytical information. In the descriptive table, we included information regarding study characteristics (i.e., author, study design, population, outcome definition, outcome assessment, exposure definition, and exposure assessment). In the analytical table, we included information regarding confounders, exposure groups (including number of participants), stratifications, and measure of association with its corresponding 95% confidence interval (CI).

One author extracted all relevant data from the included studies (AJ). The extraction was quality checked by three other review authors (AD, JHA, and DHC), and any disagreements in the data extraction were resolved by a third review author.

2.5 Risk of bias assessment

We used an epidemiological risk of bias tool developed for chronic diseases used in several previous systematic reviews to critically appraise the methodological quality og each included study (Appendix 2).[34-38] The risk of bias tool consisted of five major risk domains and three minor risk domains: (I) Study design & selection, (II) Exposure, (III) Outcome, (IV) Enrolment or Non-participants, (V) Analysis method, (VI) Funding, (VII) Chronology, and (VIII) Conflict of interest. Based on ratings from all domains, the overall risk of bias of each included study was rated as either low, moderate, or high risk of bias. A study was considered having low risk of bias if all major domains and at least one minor domain was rated as low risk of bias. For a study to be considered as having moderate risk of bias, four out of five major domains and at least one minor domain should be rated as low risk of bias. All other combinations were considered as high risk of bias.

For each included study, the risk of bias assessment was performed independently by two authors (AJ, AD, JHA, and DHC). Afterward, we compared all risk of bias assessments, and if the individual assessments differed, the risk of bias assessments were discussed with all authors until consensus was reached.

2.6 Statistical analysis

Meta-analysis was conducted to visualise whether an association between occupational mechanical exposures and hip OA across studies could be indicated. Before conducting the meta-analysis, studies based on identical source populations were identified, and all except one were excluded to avoid double-counting. If identical source population occurred, we excluded the study with the highest risk of bias. If both studies had the same risk of bias assessment, we excluded the study with the smallest population. OR was used in the meta-analysis as the measure of association. If a study provided a measure of association other than OR, it was considered equivalent to an OR if the incidence proportion of the outcome was <10%.[39] Furthermore, if a study had no measure of association but provided sufficient information on the number of participants in each exposure group, we calculated the OR with its corresponding 95% CI.

In the meta-analysis, we included the measure of association for the highest exposure group vs. the lowest exposure group. The selection of relevant measures of association was based on a hierarchical approach: (I) high contrast between exposure groups, (II) the most adjusted measure of association, (III) the measure of association containing most participants, and (IV) certainty in the outcome measure. For exposure to lifting/carrying loads, we extracted estimates that were most comparable with each other to evaluate potential exposure thresholds.

For each exposure variable, pooled estimates were calculated using random-effects model based on the assumption that there may be different effect sizes underlying different studies and that any differences between studies are not only due to random error.[40] Meta-analysis and forest plots were constructed for 11 out of the 12 exposure variables: lifting/carrying loads, awkward postures, standing, walking, standing/walking, kneeling, squatting, kneeling/squatting, climbing stairs, sitting, combined occupational mechanical exposures. Due to severe heterogeneity, other occupational mechanical exposures were not included in the meta-analyses. In the forest plots, a combined measure of association for sex was prioritised, but if only sex-specific estimates were available, the measure of association for each sex was presented.

Heterogeneity between studies was calculated using I^2 statistics, describing what proportion of observed variance reflects real differences among studies. I^2 was quantified using the restricted maximum likelihood method (REML)[41] and Cochrane's thresholds for interpretation of the I^2 statistics were used:[42]

- 0% to 40%: might not be important.
- 30% to 60%: may represent moderate heterogeneity.
- 50% to 90%: may represent substantial heterogeneity.
- 75% to 100%: considerable heterogeneity.

We evaluated publication bias using funnel plots and tested the asymmetry of funnel plots using Egger's test for the 11 exposure variables. If a study provided more than one estimate (e.g., men and women), the exposure group containing the highest number of participants was included.

Exposure-response relations were examined by extracting results from statistical test (e.g., trend tests) provided in a study. If an exposure-response relation was not statistically examined, we constructed scatter plots including the risk estimates and 95% CI for each level of exposure from studies providing ≥3 exposure groups to graphically indicate whether an exposure-response relation existed.

Finally, sensitivity analyses were conducted by repeating the meta-analyses stratifying studies according to low/moderate vs high risk of bias in order to evaluate the effect of risk of bias in the measure of an association. We also performed sensitivity analysis based on study type (cohort/case-control vs cross-sectional study), and outcome measurement (total hip replacement vs other outcomes) in order to evaluate any potential differences between effect sizes. All analyses were performed using STATA 17.0 (Stata Corp, College Station, TX, USA).

2.7 Evidence of an association

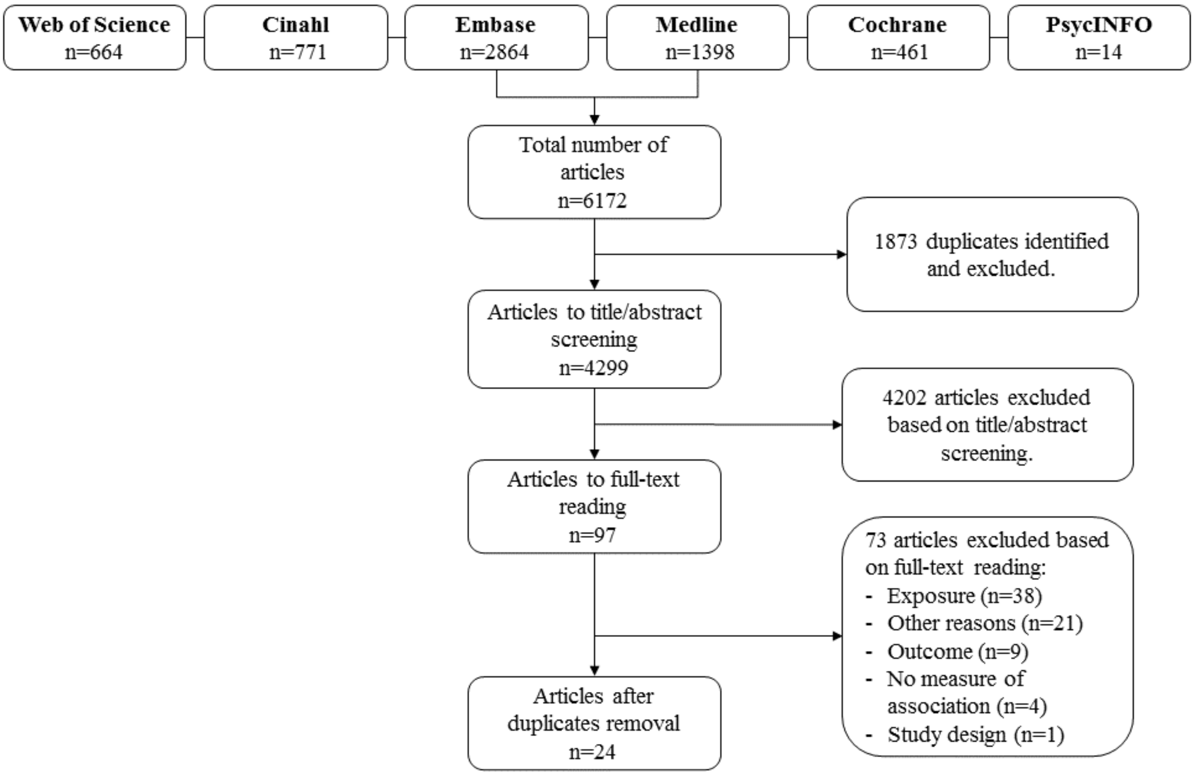
The evidence of a causal association between occupational mechanical exposures and hip OA was assessed according to guidelines provided by The Danish Work Environmental Fund (Appendix 3). The quality of evidence could be rated strong (+++), moderate (++), limited (+), insufficient (0) evidence of an association, or evidence suggesting lack of a causal association (-). Strong evidence of an association was rated when *"A causal relationship is very likely. A positive relationship between exposure to the risk factor and the outcome has been observed in several epidemiological studies. It can be ruled out with reasonable confidence that this relationship is explained by chance, bias or confounding."* The assessment was performed independently by two reviewers (AJ and AD), and further discussed by all authors.

3. Results

3.1 Study selection

Figure 1 presents the flow chart of the literature search and exclusion of articles. The literature search yielded 6172 articles identified from the six scientific databases, including 1873 duplicates. A total of 4299 articles were screened based on title/abstract, which led to the exclusion of 4202 articles. After 97 full-text readings, 24 articles were deemed eligible for inclusion. Reasons for study exclusion based on full-text reading are provided in Appendix 4.

Figure 1. Flow chart of literature search and exclusion of articles



Abbreviations: n=numbers.

3.2 Overall study characteristics

Table 1 summarises the descriptive characteristics of the 24 included articles.[43-66] In total, six cohort studies, 13 case-control studies, and five cross-sectional studies were included. The outcome was assessed using imaging modalities in 10 studies, data from registers (ICD-codes or hip-replacement-records) in seven studies, a combination of imaging modalities and register data in two studies, clinical examinations in two studies, a questionnaire in one study, a combination of questionnaire and data from general practitioners in one study, and information on total hip replacements gathered directly from orthopaedic clinics in one study.

Information on occupational mechanical exposures was assessed using questionnaires in 12 studies, interview in seven studies, and job-exposure matrices (JEMs)/expert ratings in five studies.

Studies were conducted in Denmark,[60 61] Sweden,[49 55 63-65] Norway,[47] Finland,[48 50-52 62] England,[44 45] Netherlands,[57 58] Croatia,[46] United States,[43 59] Canada,[56] Hong Kong,[53 54] and Japan.[66] The studies were published between 1987 and 2020.

Table 1. Characteristics of the 24 included studies. Abbreviations is explained in the footnote.

			Outcome		Exposure	
Author	**Design**	**Study population**	**Definition**	**Assessment**	**Definition**	**Assessment**
Allen, 2010[43]	Cross-sectional.	The sample consisted of 2506 individuals from the state of North Carolina, USA, presented with symptomatic hip osteoarthritis. Participants eligible for the analysis were enrolled from baseline (1991-1997 and from the first follow-up (1999-2004). The mean age of the total sample was 63.6 (SD=10.5).	Hip osteoarthritis was examined by radiographic criteria, irrespective of symptoms. Supine anteroposterior pelvis radiographs were obtained on all men and women 50 years of age and older (due to reproductive issues among women). All radiographs were read according to the Kellgren-Lawrence score, and interrater and intra-rater reliability was calculated. Symptomatic hip OA was assessed by asking "On most days, do you have pain, aching, or stiffness in right/left hip?". Hip osteoarthritis was divided into a radiographic group (presence of radiographic osteoarthritis and symptoms in the same joint) and a symptomatic group.	Radiographic and symptomatic.	Mechanical exposure on the longest job participants held was assessed as walking, lifting/carrying/moving objects weighing > 10 pounds, sitting, standing, bending/twisting/reaching, squatting, climbing stairs, crawling on knees, crouching or kneeling, and heavy work while standing.	Questionnaire.
Coggon, 1998[44]	Case-control.	868 men and women were identified. 611 were included (210 men and 401 women) as cases. Cases comprised residents of two English cities, Portsmouth and North Staffordshire (1993-1995), on a waiting list for total hip replacement for osteoarthritis over an 18-month period aged 45 years and over. For each case, a control of the same sex and age (within 4 years) was selected from the list of the same general practice. The mean age of all participants was 70 (SD=9).	A register was established in each district whereby the orthopaedic surgeons recorded all men and women who were placed on the waiting list for primary total hip arthroplasty. The pelvic radiographs of each case were evaluated for the presence of osteoarthritis using: measurements of minimal joint space, an overall Kellgren-Lawrence score, and the anatomical pattern of joint involvement (superolateral or medical/concentric).	Radiographic.	Mechanical exposures on jobs held longer than one year since leaving school was assessed as lifting weights of at least 10 kg, at least 25 kg, and at least 50 kg for more than 10 times in an average working week. Furthermore, information was gathered on sitting, standing, kneeling, squatting, driving, walking, and climbing.	Questionnaire.
Croft, 1992[45]	Case-control.	353 cases and 434 referents (all men aged 60-75 years) who had undergone intravenous urography were identified from x-ray registers. Cases and referents were ascertained through the radiology departments of the North Staffordshire and Shrewsbury hospitals, England (1982-1987). A total of 245 cases and 294 referents were included.	Cases were defined as those who had a total hip replacement for osteoarthritis and those in whom the shortest distance between the femoral head and the acetabular roof was ≤2.5 mm in at least one hip. Cases were divided into a subset of "severe cases" with a hip replacement or a minimal joint space of ≤1.5 mm. Referents had a joint space >3.5 mm in both hips and showed no other radiographic evidence of osteoarthritis.	Radiographic.	Mechanical exposures were defined as how long a participant had been exposed to each of the following activities (years): sitting, standing, bending, kneeling, squatting, walking, running, climbing, lifting or moving weights (>25.4 kg), and driving.	Interview.
Cvijetic, 1999[46]	Cross-sectional.	678 participants were randomly selected from city records in Zagreb, Croatia (1981-1983). 590 participants were enrolled consisting 292 women and 298 men. Mean age for women was 62.5 (SD=10.3) and 63.5 (SD=11) for men.	Hip joints were examined for pain, stiffness and range of motion. Radiographs of the right hip were taken from all participants and the degree of osteoarthritis in the individual joint was graded on a five-point scale according to the standard of	Radiographic.	Subjects were divided in 4 groups according to physical demands pertinent to their occupation.: Category 1 – mostly sedentary jobs, >80% of time in the sitting position Category 2 – >80% of time in the standing position; Category 3 – >80% of time in non-sitting positions	Interview.

			Kellgren and co-workers. Grades 2, 3, and 4 were considered definite signs of osteoarthritis.		(frequent walking and standing, but with low physical strain, lifting and carrying light objects of up to 5 kg). Category 4 – jobs with high physical strain, >80% of time in non-sitting position (frequent walking and standing, lifting and carrying heavy objects of over 5 kg).	
Flugsrud, 2002[47]	Cohort.	The study invited 56,818 persons, and 52,143 responded. For the analysis, 50,034 persons were eligible. All participants were sampled from 3 Norwegian counties and underwent a cardiovascular screening performed by nurses (from 1977-1983). The occurrence of the first total hip replacement for primary osteoarthritis was recorded during follow-up (1989-1998). Median age at the start of follow-up was 54.9 (range 46-67 years).	All total hip replacements and hip implant revisions done in Norwegian hospitals were collected from the Norwegian Arthroplasty Register. For every total hip replacement (and hip implant revision), a form was completed to record previous hip surgery in either hip, the indication for surgery, the implants used, and other parameters related to the operation.	Register data on total hip replacements.	Mechanical exposures were assessed as physical activity at work divided into: - Sedentary (mostly sedentary work). - Moderate (work leading to much walking). - Intermediate (work leading to much walking and lifting). - Intensive (Heavy manual labour).	Questionnaire.
Heliovaara, 1993[48]	Cross-sectional.	The study sample consisted of 3637 men and 4363 women drawn from a population register in Finland, aged ≥30. 7217 persons participated in a screening phase and a diagnostic phase from 1977 to 1980.	Participants with a least one symptom from the screening phase were asked to participate in the diagnostic phase. Coxarthrosis was diagnosed by a physician if there was either a convincingly documented history or definite findings in the physical status of one or both hips from: - Physical examination. - Medical history. - Prescriptions, health records, radiographs, and physician's certificates.	Clinical diagnosis.	Mechanical exposures included the participant's present and/or previous occupations involving exposure to lifting or carrying heavy objects, stooped, twisted or otherwise awkward work posture, vibration of the whole body or use of vibrating equipment, a continuously repeated series of movements, and working speed determined by a machine. The total number of these factors was designated "the sum index of physical stress at work".	Questionnaire.
Jacobsson, 1987[49]	Case-control.	Male participants from Skövde in Sweden were recruited consisting of 85 with coxarthrosis and 262 patients with intravenous urogram for prostatic hyperplasia.	Urography films were examined and graded into three groups: 1. Normal joint space. 2. Reduced joint space greater than 3 mm 3. A joint space of less than 3 mm. The fourth group consisted of patients on waiting list for operation. Cases consisted of participants from group 3 and 4 whereas controls consisted of participants from group 1 and 2.	Radiographic.	Participants was asked if they had been subject to heavy labour, particularly to farming, forestry, industrial work or heavy lifting, or too much walking, standing, or tractor driving.	Questionnaire.
Juhakoski, 2009[50]	Cohort.	Baseline data was collected in 1978-1980 from a representative sample of 8000 people from Finland. A total of 7217 subjects participated in the screening phase. Subjects were asked to attend a clinical examination if they had experienced any difficulties in walking due to hip pain or were found to have difficulty in performing the	Specially trained physicians carried out the clinical examinations and diagnosed hip osteoarthritis according to a standardised written protocol (disease history, symptoms, and clinical findings according to standard criteria).	Clinical examination.	Mechanical exposure was defined as physical workload (6 categories): - Light sedentary work (sitting involving only in light manual work). - Other sedentary work (sedentary work but involves handling fairly heavy objects).	Questionnaire.

		function tests. In 2000-01, 1286 were re-invited and re-examined. A total of 909 participated. At follow-up, the mean age was 63 years (SD=8). The study comprised 840 subjects (371 men and 469 women).			- Physically light standing work (mostly standing work without cumbersome movements without carrying heavy burdens). - Fairly light or medium-heavy work (great deal of moving and a fair amount of stooping down or carrying light objects). - Heavy manual work (standing involving much lifting of light objects or lifting and carrying heavy objects). - Very heavy manual work (mostly continuous heavy movements).	
Kaila-Kangas, 2011[51]	Cross-sectional.	A nationally representative sample of 8028 subjects was sampled from different clusters in Finland in 2010. The study comprised 6556 subjects who participated in both a clinical examination and home interview (3110 men and 3446 women). The mean age of the study participants was 51 years (SD=14) for the men and 53 (SD=14) for the women.	The diagnosis of hip OA was made from disease history, symptoms and clinical findings according to predefined diagnostic criteria. Radiographs was taken of a sub-sample to rate the agreement.	Clinical examination.	Only lifting was examined and was assessed with the question: "Did your work involve the manual handling of heavy objects, such as lifting, carrying or pushing loads over 20 kg on average of at least 10 times per working day?"	Interview.
Kontio, 2020[52]	Cohort.	A national representative sample from Finland, 2010, consisting of 5254 participants aged between 30 to 59 years. Participants were followed from baseline until the first hospitalisation of hip osteoarthritis, death, or end of follow-up in December 2015. 4642 were eligible for the present study (2247 men and 2395 women).	The diagnoses were classified according to the International Classification of Diseases (ICD). The diagnoses of primary interest were hip OA (ICD-8: 713.00; ICD-9: 175.15; and ICD-10: M16).	Register.	The following mechanical exposures were assessed: - Physically heavy work. - Manual handling of heavy loads (lifting ≥ 20 kg >10 times a day). - Kneeling and squatting for 1 hour per day. - Standing or walking for ≥5 hour per day. - Cumulative exposure for each mechanical exposure.	Interview.
Lau, 2000[53]	Case-control.	Participants with hip osteoarthritis were recruited from the orthopaedic units of seven regional hospitals in Hong Kong, comprising 30 men and 108 women. Controls were recruited in eight government general practice clinics located in the same region as those for the study, matched on sex and age. Controls comprised 90 men and 324 women.	Medical records of all hip osteoarthritis patients were reviewed. Orthopaedic surgeons managing the patients graded the patients according to Kellgren and Lawrence scale using radiographs of the hip. Only patients with grade 3 or 4 OA were included.	Radiographic.	For each job held for a year or more, following activities were obtained on mechanical exposures: - Walking for ≥2 hours/day. - Squatting for ≥1 hour/day. - Kneeling for ≥1 hours/day. - Climbing ≥15 flights of stairs/day. - Driving for ≥4 hours/day. - Lifting of loads weighing ≥10 kg for ≥1–10 times. - Use of vibration tools for ≥1 hours/day.	Interview.
Lau, 2007[54]	Case-control.	Participants with hip osteoarthritis was recruited from the orthopaedic units of seven regional hospitals in Hong Kong, comprising 30 men and 108 women. Controls were recruited in eight government general practice clinics located in the same region as those for the study, matched on sex and age. Controls comprised 90 men and 324 women.	Medical records of all hip osteoarthritis patients were reviewed. Orthopaedic surgeons managing the patients graded the patients according to Kellgren and Lawrence scale using radiographs of the hip. Only patients with grade 3 or 4 OA were included.	Radiographic.	For each job held for a year or more, following activities were obtained on mechanical exposures: - Walking for ≥2 hours/day. - Squatting for ≥1 hour/day. - Kneeling for ≥1 hour/da., - Climbing ≥15 flights of stairs/day. - Driving for ≥4 hours/day. - Lifting of loads (weighing ≥10 kg and ≥50 kg) for 1–10 times or >10 times each week.	Interview.

					- Use of vibration tools for ≥1. hours/day.	
Olsen, 1994[55]	Case-control.	The study comprised all Swedish men between the age of 50 to 70 years living in areas around four large hospitals in Stockholm. Data was collected from 1984 to 1988. Cases were men (n=239) who received first time prosthesis as a result of idiopathic osteoarthrosis. Controls (n=302) were randomly selected from the study base.	The cases were those men in the study population who received a first-time prosthesis of the hip joint as a result of idiopathic osteoarthrosis. The orthopaedic clinics involved were contacted each week; they delivered the names and addresses of new patients.	Registers.	Mechanical exposures: - Cumulative number of hours exposed to dynamic workloads. - Cumulative number of hours working in a twisted locked position. - Cumulative number of tons lifted. - Total number of jumps. Cumulative exposures were calculated from the start of the occupational carrier up until the age of 49 years. Three exposure groups were defined according to the loads in the reference group.	Interview.
Ratzlaff, 2011[56]	Cohort.	The source population consisted of community-dwelling members of the Canadian Association of Retired Persons. Over 100,000 persons were approached either through e-mail or newsletters, and 4258 completed the baseline survey in 2005. A follow-up survey was sent between 2006 and 2007. In total, 2918 participants were enrolled with a mean age of 61.6 (SD=7.3).	Subjects were asked to report health-professional-diagnosed hip osteoarthritis on at least one of the two follow-up surveys. The questionnaire used pain diagrams and items specific to osteoarthritis and specifically informed subjects that osteoarthritis was distinct from other musculoskeletal diseases.	Self-report.	Mechanical exposures were analysed as cumulative peak force index estimating time spend in specific occupational activities (hours), body weight, and the peak hip joint force for each activity (%body weight), and divided into quintiles. It was based on the following questions: - Duration of participation in each occupation. - Type of employment and length of the average season. - Hours per week working. - Time spend walking, standing, lifting, carrying, using heavy tools, squatting etc.	Questionnaire.
Rijs, 2014[57]	Cross-sectional.	Participants were enrolled in a continuing population-based cohort study (Longitudinal Aging Study Amsterdam) and were a random sample of 55- to 85-year-olds drawn from population registries in 11 municipalities in 3 regions of the Netherlands, consisting of 3107 participants. After exclusions, an analytic sample of 1676 participants were eligible.	Hip osteoarthritis was defined by an algorithm using self-report and general practitioner data and categorised as no, possible, or definite osteoarthritis. Finally, osteoarthritis categories were collapsed as no and possible/definite osteoarthritis.	Self-report and general practitioner data.	Information on mechanical exposures was gathered from a general population job-exposure matrix. Occupational classes were classified as having a low, moderate, or high probability of exposure based on self-reported levels of work exposure gathered from the Netherlands Work Condition Survey. Classifications (cut-offs) were chosen depending on the proportion of reporting to physical demands. The following categories were used: - Use of force (lifting, pushing, pulling, carrying, or force with tools). - Perform work in an uncomfortable position. - Repetitive movements.	Job-exposure matrix.
Riyazi, 2008[58]	Case-control.	191 sibling pairs (382 cases) from the Netherlands with familial osteoarthritis at multiple sites were included in the study. 345 controls were recruited by random sampling of the population using random-digit-dialling and returned the questionnaire. The mean age of cases was 60 years, and the mean age of	Radiograph of the hips (Posterior-Anterior, weight bearing) were scored by an experienced musculoskeletal radiologist using the Kellgren-Lawrence method. A score of ≥2 depicts osteoarthritis.	Radiographic.	Job title classification of physically demanding work was based on a revised classification scheme of physical and mental work demands into different categories according to an expert judgment of job titles used in the Netherlands. Mechanical exposures were assessed as physically demanding work characterised by lifting of heavy	Revised classification scheme based on expert assessments.

		controls was 57 years. Cases consisted of 82 % women whereas controls consisted of 64 % women.			objects, handling of heavy tools, stooping, frequently in combination with standing or walking.	
Roach, 1994[59]	Case-control.	Male patients attending outpatient clinics at a large Department of Veterans Affairs hospital in the metropolitan of Chicago were drawn as both cases and controls. Cases were identified from the computerised radiology database of all patients receiving an outpatient radiograph of hip pain or following a total hip arthroplasty from 1989 to June 1990. Controls were screened for possible hip OA using intravenous pyelogram films and selected from the population of patients receiving this screening. 99 cases and 233 controls were used in the analysis, with a mean age of 68.2 (SD=6.4) for cases and 67.7 (SD=7.1) for controls.	Computerised radiology reports, information from the Veteran's Affair patient database, and medical records were used to determine whether subject meet the American College of Rheumatology criteria for hip OA.	Radiographic and register data.	Mechanical exposures were assessed as number of years exposed to: 1. Light work standing. 2. Work sitting. 3. Heavy work standing. 4. Work kneeling or crouching. 5. Work walking. Mechanical exposures were classified as either heavy or light work: - Heavy = work standing, work walking, and work kneeling or crouching.	Questionnaire.
Rubak, 2013[60]	Cohort.	All Danish men and women born between 1925 and 1964 with at least 10 years of full-time employment between 1964 and 2006, was eligible for this cohort study. Information was obtained in 2007 from the Danish Civil Registration System. In total, 899549 women and 1010944 men were included. At the start of the individual follow-up, mean age was 48.2 for men and 49.1 years for women.	Total hip replacement due to osteoarthritis was assessed using ICD-codes (M16.0, M16.1, or M16.9) and surgical procedure codes (Nordic Medico-statistical Committee Classification of Surgical Procedures codes KNFB20, KNFB30, KNFB40, or KNFB99) gathered from Danish National Patient Register.	Register data.	An industry exposure matrix was developed rating the overall physical workload to the hip on a 3-point scale (0= minimal load, 1=moderate load, 2=high load). Exposures that were taken into consideration: - Total load lifted per day - Frequency of lifting burdens weighing ≥20 kg - Whole-body vibration - Standing/walking the majority of the working day. For each individual, point-years, a cumulative estimate of physical workload, were calculated as the number of employment years (adjusted to full-time employment) in a specific industry times the corresponding score of physical workloads from the industry exposure matrix and summarised across all registered employments.	Industry-exposure matrix.
Rubak, 2014[61]	Nested case-control in cohort.	All Danish men and women born between 1935 and 1964 with at least 10 years of full-time employment before January 1, 2006, were eligible. Cases with first-time total hip replacement due to primary osteoarthritis were identified in 2005 and 2006. For each case, 2 controls matched on age and sex were sampled. Of 7445 unique persons, 5495 responded. Altogether, 1776 case-control sets (862 sets of women and 915 sets of men) were available for the analysis with ages ranging from 41 to 69 years.	Total hip replacement was due to osteoarthritis was assessed using ICD-codes (M16.0, M16.1, or M16.9) and surgical procedure codes (Nordic Medico-statistical Committee Classification of Surgical Procedures codes KNFB20, KNFB30, KNFB40, or KNFB99) gathered from Danish National Patient Register.	Register data.	Mechanical exposures were assessed by combining self-reported job titles with a job-exposure matrix (The lower body matrix). The matrix provides estimates of the total load lifted per day and daily frequency of lifting loads weighing ≥20 kg as well as hours of exposure to standing/walking, sitting, kneeling/squatting, and whole-body vibrations during an 8-hour working day. Cumulative mechanical exposure was calculated as: - 1 ton-year standardised as lifting 1 ton per day for 1 year, and 1 frequent heavy lifting–year as lifting loads weighing ≥20 kg ≥10 times per day for 1	Job-exposure matrix.

					year.	
Solovieva, 2018[62]	Cohort.	Random sample of the Finish population. The cohort consisted of 574,617 men and 561,037 women living in Finland on December 31, 2004, aged 30 to 60 years who had gainful jobs on January 1, 2005. Data were obtained from the National register of the Finnish Centre for Pensions.	Information on osteoarthritis was obtained from the Finnish Centre for Pensions register. It provides information on all disability retirement events classified according to ICD classification. The outcome was all full-time disability retirement (temporary or permanent) as result of hip osteoarthritis (ICD-10 code = M16) from 2005 until 2013.	Register data.	A sex-specific job-exposure matrix was used to gather information on: - Heavy physical work. - Kneeling or squatting. - Manual handling of heavy loads. - Sitting. - Standing or moving at work.	Job-exposure matrix.
Thelin, 1997[63]	Case-control.	All radiological examinations of hip or pelvis joints performed between 1986 to 1988 at three different hospitals in Skaraborg, Sweden were re-evaluated in 1989. Controls were selected using a local population register. A total of 216 male cases answered the questionnaire and 479 male controls matched on age, and place of residence were selected from a local population register. All participants were under 70 years of age.	All hip joints were assessed with radiographic and a joint space of <3 mm was classified as coxarthrosis, unless special information showed that it was a question of a congenital condition.	Radiographic.	Mechanical exposure was assessed as heavy physical work at young age (before 16 years of age). This was defined as full time working with what they themselves regarded as heavy physical work for a period longer than half a year.	Questionnaire.
Vingård, 1991[64]	Case-control.	The study population comprised men aged between 50 and 70 years, living in referral areas of four large hospitals in Stockholm, Sweden. Information was collected from 1984 until 1988. 233 cases were those men who received a first-time prosthesis of the hip joint as a result of idiopathic osteoarthrosis. 302 controls were randomly selected from the study population.	Information on first time hip prosthesis was gathered from contacting the orthopaedic clinics that were involved in the study. They delivered names and addresses of the patients.	First time hip prosthesis.	Information on mechanical exposures was collected from questions on hours per week spent: - Sitting, standing, walking, stair climbing, driving, spent in a twisted position. Lifting was assessed as how many kilograms were lifted per week. Mechanical exposures were then categorised into: - Static (working in a twisted locked position). - Dynamic (walking with burdens and stair climbing). - Lifted tons (number of lifted kilograms). - Number of lifts (the number of times the person lifted heavy burdens - >40 kg). - Number of jumps (the number of jumps between different levels).	Questionnaire.
Vingård¸ 1997[65]	Case-control.	The study comprised women aged between 50 and 70 years, living in five counties in western Sweden from 1991 to 1994. 230 cases and 273 controls agreed to participate and were enrolled. Cases and controls were matched on age and county or hospital referral area.	In the National registry, information on total hip replacements were obtained based on primary hip osteoarthrosis. Preoperatively, all patients are clinically and radiographically assessed according to defined protocols.	Register.	The following mechanical exposures were assessed: - How many hours spent sitting. - How many hours spent standing or twisted position. - Any lifting, and if so, the weight of the lifted items. - Jumps or movements between different levels. - How many stairs climbed.	Questionnaire.
Yoshimura, 2000[66]	Case-control.	Out of 126 potential cases, 114 cases agreed to participate and were identified from the registration systems of five hospitals in the city	All cases were listed for total hip arthroplasty due to osteoarthritis. Radiographs of all cases were assessed using Kellgren-Lawrence grading	Radiographic.	For each job, the following mechanical exposures were assessed:	Questionnaire.

	of Wakyama and Arita, Japan (103 women and 11 men). The mean age was 63.8 years (SD=10.9). For each case, 1 control was drawn (n=114) from the local population register matched on age, sex, and district of residence.	system for osteoarthritis by a single trained observer.		- Lifting weights of ≥10 kg more than once during an average working week. - Lifting weights of ≥25 kg more than once during an average working week. - Lifting weights of ≥50 kg more than once during an average working week. - Sitting ≥2 hours/day. - Standing ≥2 hours /day. - Kneeling ≥1 hour /day. - Squatting ≥1 hour /day. - Driving ≥4 hours /day. - Walking 3 hours /day. - Climbing ≥30 flights of stairs.

ICD: International Classification of Diseases, kg: kilogram, mm: millimeter, n: numbers, OA: osteoarthritis, SD: Standard deviation,

3.3 Risk of bias assessment

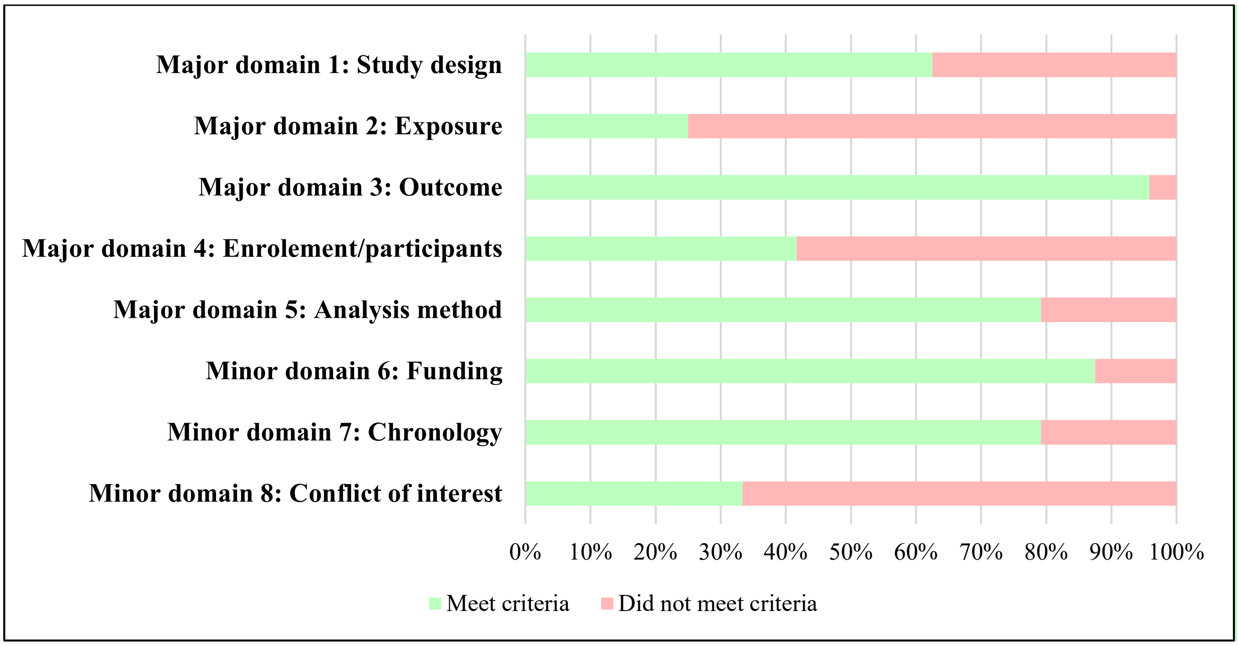
Table 2 and Figure 2 present the risk of bias assessment of the 24 included studies. In summary, two studies were assessed as having a low risk of bias, six studies as having a moderate risk of bias, and 16 studies were assessed as having a high risk of bias. The most frequent major domains receiving a low risk of bias assessment was "Outcome" followed by "Analysis method". Conversely, the most frequent major domains receiving high risk of bias assessment was "Exposure" followed by "Enrolment/participants".

Table 2. Risk of bias assessment of the 24 included studies.

References	Quality score	Domains							
		Major					Minor		
		1	2	3	4	5	6	7	8
Allen, 2010[43]	High risk	+	-	+	-	+	+	+	+
Coggon, 1988[44]	High risk	+	-	+	-	+	+	+	?
Croft, 1992[45]	High risk	+	-	-	-	-	+	+	?
Cvijetic, 1999[46]	High risk	-	+	+	-	-	-	+	?
Flugsrud, 2002[47]	Moderate risk	+	-	+	+	+	+	+	+
Heliovaara, 1993[48]	High risk	+	-	+	-	+	-	-	?
Jacobsson, 1987[49]	High risk	-	-	+	?	-	-	-	?
Juhakoski, 2009[50]	High risk	-	-	+	+	+	+	+	+
Kaila-Kangas, 2011[51]	High risk	+	-	+	-	+	+	-	+
Kontio, 2020[52]	Moderate risk	+	-	+	+	+	+	+	+
Lau, 2000[53]	High risk	-	-	+	?	+	+	+	?
Lau, 2007[54]	High risk	-	-	+	+	+	+	-	?
Olsen, 1994[55]	High risk	-	-	+	-	+	+	+	?
Ratzlaff, 2011[56]	Low risk	+	+	+	+	+	+	+	+
Rijs, 2014[57]	High risk	-	-	+	+	-	+	+	+
Riyazi, 2008[58]	High risk	-	-	+	-	+	+	-	+
Roach, 1994[59]	High risk	-	-	+	+	+	+	+	?
Rubak, 2013[60]	Low risk	+	+	+	+	+	+	+	?
Rubak, 2014[61]	Moderate risk	+	+	+	-	+	+	+	?
Solovieva, 2018[62]	Moderate risk	+	+	+	-	+	+	+	?
Thelin, 1997[63]	High risk	+	-	+	+	-	+	+	?
Vingård, 1991[64]	Moderate risk	+	+	+	-	+	+	+	?
Vingård, 1997[65]	Moderate risk	+	-	+	+	+	+	+	-
Yoshimura, 2000[66]	High risk	+	-	+	-	+	+	+	?

(+) comply with criteria; (-) does not comply with criteria; (?) no information was provided.

Figure 2. A summary of risk of bias assessments presented as percentage of the distribution between the 24 studies for each domain's criteria.



3.4 Association between occupational mechanical exposures and hip osteoarthritis

Measures of association between occupational mechanical exposures and hip OA reported in the 24 studies are presented in appendix 5. Among the 12 exposure variables, 13 studies reported on lifting/carrying loads,[43-45 49 51 53-55 61 62 64-66] five studies on awkward postures,[43 45 57 64 65] seven studies on standing,[43-46 49 65 66] seven studies on walking,[43-45 49 53 54 66] three studies on "standing or walking",[52 61 62] six studies on kneeling,[43-45 53 54 66] six studies on squatting,[43-45 53 54 66] two studies on "kneeling or squatting",[52 62] seven studies on climbing stairs,[43-45 53 54 65 66] six studies on sitting,[43-45 62 65 66] 15 studies on combined occupational mechanical exposures,[43 46-50 52 56-60 62-64] and 10 studies on other occupational mechanical exposures.[43-45 53-55 57 63 65 66]

Three studies provided a measure of association using HR[52 56 62] and three studies provided a measure of association using RR.[47 64 65] Based on the assumption that an incidence proportion of an outcome <10% can approximate an OR, the measure of association from all six studies were treated equally as an OR.[39] Furthermore, two studies did not provide a risk estimate but gave sufficient information to calculate an OR with a 95 % CI.[43 49]

3.4.1 Lifting/carrying loads

The methodological quality of the 13 studies of lifting/carrying loads was rated as moderate risk of bias in four studies and high risk of bias in the remaining nine studies. Among the 13 studies, lifting/carrying loads were defined somewhat heterogeneously. The most common unit of exposure was years exposed to lifting reported by four studies and expressed between 10 to 50 kg repetitively during a working day or week. In the remaining eight studies, the unit of the measure included a dichotomous approach as exposed vs. not-exposed to heavy lifting at work with or without an indication of kilograms or repetitions.

Of the 13 eligible studies, we identified two studies using the same study population,[53 54] and one study[53] was therefore excluded from the meta-analysis. Furthermore, one study[55] did not provide a 95% CI pertaining to the measure of association and was therefore also excluded from the meta-analysis. Therefore, 11 studies were included in the meta-analysis containing 13 exposure groups. Most studies found an increased risk of hip OA; OR ranged between 1.0 and 3.2. We found a pooled OR of 1.6 (95% CI 1.3–1.9) showing a substantial degree of heterogeneity (I^2=70.95%) (Figure 3). The funnel plot indicated publication bias (Appendix 6) and Egger's test provided a statistically significant p-value (0.014).

Exposure-response analyses were not conducted in any of the included studies. Among eight studies presenting a measure of association containing ≥3 exposure groups, scatterplots of six studies indicated an increase in OR with increasing exposure levels (Appendix 7). No exposure threshold could be established due to heterogeneity.

In the sensitivity analysis, studies assessed as having low/moderate risk of bias showed a pooled OR of 1.3 (95% CI 1.0–1.7), while high risk of bias studies showed a pooled OR of 1.8 (95% CI 1.5–2.2). In additional analysis, pooled OR in cohort/case-control studies was 1.6 (95% CI 1.3–1.9) vs 1.6 (95% CI 1.2–2.3) for cross-sectional studies, and 1.6 (95% CI 1.1–2.2) vs 1.6 (95% CI 1.0–2.0) in studies with outcome defined as total hip replacement and other outcomes, respectively.

Based on the existing literature, a causal association is likely. Statistically significant associations were found in 9 out of 11 studies (pooled OR of 1.6), however it cannot be ruled out with reasonable confidence that the association could be explained by chance, bias, confounding (pooled OR in moderate/low risk of bias of 1.3), or publication bias (Egger's test=0.014), although this is not a very likely explanation. Based upon this, we assessed the degree of evidence between exposure to lifting/carrying loads and hip OA as moderate evidence of an association (appendix 9.3).

3.4.2 Awkward postures

The methodological quality of the five studies on awkward postures was rated as moderate risk of bias in two studies and a high risk of bias in three studies. Among the five studies, awkward postures were defined somewhat heterogeneously. The unit of exposure was hours per day in two studies, while the remaining three studies had a dichotomous approach as either exposed vs not exposed, high vs low exposure, or moderate vs low exposed groups.

No identical populations were observed, and all five studies were therefore included in the meta-analysis containing five exposure groups. All studies found an increased risk of hip OA with OR between 1.5 and 2.9. The meta-analysis showed a pooled OR of 1.7 (95% CI 1.4–2.1) (Figure 4). The heterogeneity could not be statistically evaluated. The funnel plot showed no indication of publication bias (Appendix 6), and the Egger's test showed no statistically significant p-value (0.37).

Exposure-response analyses were not conducted in any of the included studies. Among three studies presenting a measure of association containing ≥3 exposure groups, the scatterplots all indicated an increased OR with increasing exposure (Appendix 7). No exposure threshold could be established.

In the sensitivity analysis, studies assessed as low/moderate risk of bias showed a pooled OR of 2.2 (95% CI 1.2–3.9), while high risk of bias studies showed a pooled OR of 1.6 (95% CI 1.3–2.0). In additional analysis, pooled OR was 2.1 (95% CI 1.4–3.2) in cohort/case-control studies vs 1.6 (95% CI 1.2–2.0) in cross-sectional studies. Pooled OR in studies with outcome defined as total hip replacement was 2.1 (95% CI 1.4–3.2) vs 1.6 (95% CI 1.2–2.0) with other outcomes.

Based on the existing literature, a causal association is possible. Statistically significant associations were found in 3 out of 5 studies with a pooled OR of 1.7 in the 5 studies. It is not unlikely that the association could be explained by chance, bias, or confounding (pooled OR in moderate/low risk of bias of 2.2). Based upon this, we assessed the degree of evidence between exposure to awkward postures and hip OA as limited evidence of an association (appendix 9.3).

3.4.3 Standing

The methodological quality of the seven studies were rated as low risk of bias in none, moderate risk of bias in one, and high risk of bias in six studies. Standing was defined relatively homogenously with the most common exposure unit defined as years exposed to standing ≥2 hours/day in three studies.

No identical populations were observed, and therefore all seven studies were included in the meta-analysis containing eight exposure groups. Several of the studies found an increased risk of hip OA, but not all: OR ranged between 0.6 and 3.2. The meta-analysis showed a pooled OR of 1.3 (95% CI

1.0–1.8) and an I^2 value of 44.74% indicating a moderate to minimal degree of heterogeneity (Figure 5). The funnel plot indicated a tendency towards publication bias (Appendix 6), with Egger's test showing a close to a statistically significant p-value (0.07).

Exposure-response analyses were not conducted in any of the included studies. Among four studies presenting a measure of association containing ≥3 exposure groups, scatterplots of three studies indicated an increase in OR with increasing exposure levels (Appendix 7). No exposure threshold could be established.

In the sensitivity analysis, studies assessed as low/moderate risk of bias showed an OR of 1.6 (95% CI 0.9–2.8), while high risk of bias studies showed a pooled OR of 1.3 (95% CI 0.9–1.8). In additional analysis, pooled OR in cohort/case-control studies was 1.2 (95% CI 0.8–1.8) vs 1.6 (95% CI 1.0–2.6) in cross-sectional studies. Pooled OR in studies with outcome defined as total hip replacement was 1.8 (95% CI 1.1–3.0) vs 1.2 (95% CI 0.9–1.7) studies with other outcomes.

Based on the existing literature, a causal association is possible. Statistically significant associations were found in 2 out of 7 studies (pooled OR of 1.3), however, it is not unlikely that the association could be explained by chance, bias, confounding (pooled OR in moderate/low risk of bias of 1.6), or publications bias (Egger's test=0.07). Based upon this, we assessed the degree of evidence between exposure to standing and hip OA as limited evidence of an association (appendix 9.3).

3.4.4 Walking

The methodological quality of all seven studies was rated as high risk of bias. Walking was defined quite homogenous with the most common unit of exposure defining the length of walking at work in kilometres.

Of the seven eligible studies, two studies were identified as having identical populations,[53 54] so one study[53] was excluded from the meta-analysis. Six studies were therefore included in the meta-analysis containing six exposure groups with OR between 1.2 and 1.6. We found a pooled OR of 1.3 (95% CI 1.1–1.5) (Figure 6). The heterogeneity could not be statistically evaluated. The funnel plot showed no indication of publication bias (Appendix 6), and the Egger's test showed no statistically significant p-value (0.66).

Exposure-response analyses were not conducted in any of the included studies. Among two studies presenting a measure of association containing ≥3 exposure groups, the scatter plot of both studies indicated an increase in OR with increasing exposure levels (Appendix 7). No exposure threshold could be established.

Sensitivity analyses based on the risk of bias assessment was not conducted as all studies were assessed as having high risk of bias. In additional analysis, pooled OR in cohort/case-control studies was 1.3 (95% CI 1.0–1.7) vs 1.2 (95% CI 0.9–1.6) in cross-sectional studies. Pooled OR in studies with outcome defined as total hip replacement was 1.6 (95% CI 0.5–5.1) vs 1.3 (95% CI 1.1–1.5) in studies with other outcomes.

Based on the existing literature, a causal association is possible. Statistically significant associations were found in 0 out of 6 studies (pooled OR of 1.3), and it is not unlikely that the association could be explained by chance, bias, or confounding (no studies assessed as low or moderate risk of bias). Based upon this, we assessed the degree of evidence between exposure to walking and hip OA as limited evidence of an association (appendix 9.3).

3.4.5 Standing/walking

All three studies were rated as having moderate risk of bias. Standing/walking was defined somewhat homogenous with the unit of exposure defined as ≥5 or ≥6 hours/day in two studies and dichotomous in the third study (yes vs low).

No identical study populations were observed, and all studies were included in the meta-analysis containing five exposure groups. All studies found OR between 1.0 and 1.2. with a pooled OR of 1.1 (95% CI 1.0–1.2) (Figure 7). The heterogeneity could not be statistically evaluated. The funnel plot was difficult to interpret due to few studies (Appendix 6), but Egger's test showed no statistically significant p-value (0.42).

Exposure-response analyses were not conducted in any of the included studies. Among two studies presenting a measure of association containing ≥3 exposure groups, the scatter plots did not indicate exposure-response relationships (Appendix 7). Furthermore, no exposure threshold could be identified.

Sensitivity analysis based on risk of bias was not conducted as all studies were assessed as having moderate risk of bias. In additional analysis, pooled OR was 1.0 (95% CI 0.8–1.2) in studies with total hip replacements vs 1.2 (95% CI 1.0–1.3) in studies with outcome defined as other outcomes. No additional sensitivity analyses were conducted as all studies were cohort/case-control studies.

Based on the existing literature, we assessed the degree of evidence between exposure to standing/walking and hip OA as insufficient evidence of an association (appendix 9.3) due too few studies (N=3).

3.4.6 Kneeling

The six studies on kneeling were rated as having high risk of bias. Based on exposure assessments in each study, kneeling was defined somewhat identical. The most common unit of measure was years exposed to ≥30 min/day or ≥1 hour/day of kneeling.

Of the six eligible studies, two studies were identified as having identical populations,[53 54] so one study[53] was excluded from the meta-analysis. Five studies were therefore included in the meta-analysis containing five exposure groups with OR between 1.0 and 1.7. We found a pooled OR of 1.2 (95% CI 0.9–1.5) (figure 8) and the heterogeneity could not statistically be evaluated. The funnel plot did not indicate publication bias (Appendix 6), and the Egger's test showed no statistically significant p-value (0.99).

Exposure-response analyses were not conducted in any of the included studies. Of the two studies presenting a measure of association containing ≥3 exposure groups, the scatter plot of both studies did not indicate exposure-response relation (Appendix 7). Furthermore, no exposure threshold could be identified.

No sensitivity analysis based on risk of bias were performed as all studies had high risk of bias. In additional analysis, pooled OR in cohort/case-control studies was 1.2 (95% CI 0.9–1.6) vs 1.1 (95% CI 0.8–1.7) in cross-sectional studies. Pooled OR in studies with total hip replacements was 1.0 (95% CI 0.3–3.3) vs 1.2 (95% CI 0.9–1.5) in studies with outcome defined as other outcomes.

Based on the existing literature, we assessed the degree of evidence between exposure to kneeling and hip OA as insufficient evidence of an association (appendix 9.3) due too insufficient quality and inconsistency (all studies assessed as having a high risk of bias).

3.4.7 Squatting

The six studies were rated as having high risk of bias. Squatting was defined somewhat homogenously, and the most common exposure unit was years exposed to ≥30 min/day or ≥1 hour/day of squatting.

Of the six eligible studies, two studies were identified as having identical populations,[53 54] so one study[53] was excluded from the meta-analysis. Five studies were therefore included in the meta-analysis containing five exposure groups with ORs between 0.9 and 1.6. We found a pooled OR of 1.1 (95% CI 0.9–1.4) (Figure 9) and the heterogeneity could not statistically be evaluated. The funnel plot showed no indication of publication bias (Appendix 6), and the Egger's test showed no statistically significant p-value (0.45).

Exposure-response analyses were not conducted in any of the included studies. Of one study presenting a measure of association containing ≥3 exposure groups, the scatter plot did not indicate exposure-response relation (appendix 7). Furthermore, no exposure threshold could be established.

No sensitivity analyses were conducted based on risk of bias, as all studies were assessed as having high risk of bias. In additional analysis, pooled OR in cohort/case-control studies was 1.2 (95% CI 0.8–1.7) vs 1.1 (95% CI 0.8–1.6) in cross-sectional studies. Pooled OR in studies with outcome defined as total hip replacement was 1.3 (95% CI 0.4–3.9) vs 1.1 (95% CI 0.9–1.4) in studies with other outcomes.

Based on the existing literature, we assessed the degree of evidence between exposure to squatting and hip OA as insufficient evidence of a causal association (appendix 9.3) due too insufficient quality and inconsistency (all studies assessed as having a high risk of bias).

3.4.8 Kneeling/squatting

The two studies were rated as having moderate risk of bias. Based on exposure assessments in each study, "kneeling/squatting" was defined somewhat homogenously. The exposure unit differed between the two studies, with one assessing kneeling/squatting ≥1 hour/day in years and the other using a dichotomous approach. No identical populations were observed, and both studies were included in a meta-analysis containing three exposure groups with OR between 1.2 and 1.5. The meta-analysis showed a pooled OR of 1.3 (95% CI 1.1–1.7) and an I^2 value of 56.58%, indicating a moderate degree of heterogeneity (Figure 10). The funnel plot was difficult to interpret due to few studies (Appendix 6), but Egger's test showed no statistically significant p-value (0.84).

Exposure-response analyses were not conducted in any of the included studies. Of one study presenting a measure of association containing ≥3 exposure groups, the scatterplot did not indicate an exposure-response relation (appendix 7). Furthermore, no exposure threshold could be established.

No sensitivity analyses could be conducted as all studies were assessed as having low/moderate risk of bias, were cohort/case-control studies, and outcome was defined as other.

Based on the existing literature, we assessed the degree of evidence between exposure to standing/walking and hip OA as insufficient evidence of a causal association (appendix 9.3) due too few studies (N=2).

3.4.9 Climbing stairs

The seven studies were rated as having moderate risk of bias in one study and a high risk of bias in six studies. Based on exposure assessments in each study, climbing stairs was defined as somewhat homogenous. The unit of exposure in two studies was years climbing >30 flights of stairs per day, with the remaining studies categorising the exposure in two or three groups.

Of the six eligible studies, two studies were identified as having identical populations,[53 54] and therefore one study[53] was excluded from the meta-analysis. Five studies were included in the meta-analysis containing six exposure groups with OR between 1.1 and 4.1. We found a pooled OR of 1.6 (95% CI 1.1–2.2) and an I^2 value of 49.79%, indicating a moderate degree of heterogeneity (Figure 11). The funnel plot did not indicate publication bias (Appendix 6), and Egger's test showed no statistically significant p-value (0.23).

Exposure-response analyses were not conducted in any of the included studies. Of the two studies presenting a measure of association containing ≥3 exposure groups, the scatter plot of both studies indicated a possible exposure-response relation (appendix 7). Furthermore, no exposure threshold could be identified.

In the sensitivity analysis, studies assessed as low/moderate risk of bias showed an OR of 2.1 (95% CI 1.2–3.6), while high risk of bias studies showed a pooled OR of 1.5 (95% CI 1.0–2.2). In additional analysis, pooled OR in cohort/case-control studies was 1.8 (95% CI 1.2–2.6) vs 1.2 (95% CI 0.8–1.6) in cross-sectional studies. Pooled OR in studies with outcome defined as total hip replacement was 1.7 (95% CI 1.0–2.9) vs 1.6 (95% CI 1.0–2.7) in studies with other outcomes.

Based on the existing literature, a causal association is possible, however, it is not unlikely that the association could be explained by chance, bias, or confounding (5 out of 6 studies were assessed as having a high risk of bias). Based upon this, we assessed the degree of evidence between exposure to walking and hip OA as limited evidence of an association (appendix 9.3).

3.4.10 Sitting

The six studies were rated as having moderate risk of bias in two studies and a high risk of bias in four studies. Sitting was defined quite homogenously. The most common exposure unit was sitting for ≥2 hours/day assessed in years for two studies, ≥2 hours/day for one study with a dichotomous approach, and the remaining two studies using categorisation as being exposed (yes vs no).

No identical populations were observed, but one study did not provide a 95% CI to the pertaining measure of association and was excluded from the meta-analysis. Five studies were included in the meta-analysis containing six exposure groups with OR between 0.4 and 0.9. We found a pooled OR of 0.6 (95% CI 0.5–0.9) and an I^2 value of 78.17%, indicating substantial degree of heterogeneity (Figure 12). The funnel plot indicated publication bias (Appendix 6), and the Egger's test did not show a statistically significant p-value (0.24).

Exposure-response analyses were not conducted in the included studies. Of two studies presenting a measure of association containing ≥3 exposure groups, the scatter plot did not indicate an exposure-response relation in any (Appendix 7). Exposure thresholds could not be identified.

In the sensitivity analysis, studies assessed as having low/moderate risk of bias found a pooled OR of 0.5 (95% CI 0.4–0.5), while high risk of bias studies showed a pooled OR of 0.8 (95% CI 0.7–1.0). In additional analysis, pooled OR in cohort/case-control studies was 0.6 (95% CI 0.4–0.8) vs 0.8 (95% CI 0.6–1.0) cross-sectional studies. Pooled OR in studies with outcome defined as total hip replacement was 0.8 (95% CI 0.3–1.9) vs 0.6 (95% CI 0.5–0.9) in studies with other outcomes.

Based on the existing literature, a causal association is possible, however, it is not unlikely that the association could be explained by chance, bias, or confounding (4 out of 5 studies were assessed as having a high risk of bias). Based upon this, we assessed the degree of evidence between exposure to walking and hip OA as limited evidence of an association (appendix 9.3). Exposure to occupational sitting might be a protective factor against developing hip OA.

3.4.11 Combined mechanical exposures

The 15 studies were rated as having low risk of bias in two studies, moderate risk of bias in four studies, and high risk of bias in nine studies. The combination of mechanical exposures varied considerably between studies, e.g., "lifting heavy objects, handling heavy tools frequently in combination with standing and walking", "heavy lifting or too much walking, standing or tractor driving", and "working in a twisted locked position and walking with burdens and stair climbing" while other studies defined the combination as physically demanding work, heavy labour work with or without specifications. The exposure unit was very heterogeneously defined. In two studies, the exposure unit was physical load/physical strain measured in years, while the remaining studies used a spectrum from low/none to heavy physical work load to define exposure categories.

No identical populations were observed, and all 15 studies were included in the meta-analysis containing 19 exposure groups with OR between 1.0 and 6.7. Meta-analysis showed a pooled OR of 1.7 (95% CI 1.4–2.0) and an I^2 value of 72.74%, indicating a substantial degree of heterogeneity

(Figure 13). The funnel plot indicated publication bias (Appendix 6) with Egger's test also showing a statistically significant p-value (0.0001).

Flugsrud et al (2002)[47] found significant trend tests for men and women, and Heliovaara et al (1993)[48] found significant trend tests for uni- and bilateral hip OA. Of six studies presenting a measure of association containing $\geq$3 exposure groups, eight exposure groups were included in a scatter plot. Scatter plots of six exposure groups indicated an exposure-response relation, and two did not (Appendix 7). No exposure thresholds could be identified.

In the sensitivity analysis, studies assessed as having low/moderate risk of bias showed a pooled OR of 1.5 (95% CI 1.3–1.9), and high risk of bias studies showed a pooled OR of 1.9 (95% CI 1.5–2.4). In additional analysis, pooled OR found in cohort/case-control studies was 1.8 (95% CI 1.5–2.1) vs 1.6 (95% CI 1.2–2.0) in cross-sectional studies. Pooled OR in studies with outcome defined as total hip replacement was 1.7 (95% CI 1.3–2.2) vs 1.6 (95% CI 1.4–1.9) studies with other outcomes.

Based on the existing literature, a causal association is very likely. Statistically significant associations were found in 13 out of 15 studies (pooled OR of 1.7). It can be excluded with a reasonable degree of certainty that this association can be explained by chance, bias, or confounding (OR in moderate/low risk of bias of 1.5), though funnel plot and Egger's test indicated publication bias. Based upon this, we assessed the degree of evidence between exposure to combined exposures as strong evidence of an association (appendix 9.3).

3.5 Sex differences

Lifting/carrying loads: Five studies provided sex-specific estimates. Coggon et al (1998)[44] assessed years exposed to lifting $\geq$25 kg 10 times during a work day with OR_{men} of 2.3 and OR_{women} of 0.8, and Kaila-Kangas et al (2011)[51] assessed years exposed to lifting/carrying loads over 20 kg $\geq$10 times during a work day with OR_{men} of 2.3 and OR_{women} of 1.2. Lau et al (2007)[54] assessed lifting $\geq$10 kg 10 times during a work day with OR_{men} of 4.15 and OR_{women} of 3.24, while Rubak et al (2014)[61] assessed exposure to lifting 1 ton per day for 1 year with OR_{men} of 1.4 and OR_{women} of 1.0. Finally Solovieva et al (2018)[62] assessed exposure to heavy lifting with OR_{men} of 1.2 and OR_{women} of 1.1. Overall, four studies indicated a higher risk in men, while one study indicated no difference.

Standing: Two studies provided sex specific estimates. Coggon et al (1998)[44] assessed standing for $\geq$2 hours in an average work day with OR_{men} of 0.5 and OR_{women} of 1.3, while Cvijetic et al (199)[46] assessed exposure to 80% of work time spent in standing position with OR_{men} of 1.8 and OR_{women} of 3.2. Therefore, both studies indicated a higher risk among women.

Standing or walking: Two studies provided sex specific estimates.[61 62] Rubak et al (2014)[61] assessed exposure to standing/walking for 6 hours in an average work day for 1 year with OR_{men} of 1.0 and OR_{women} of 1.0, while Solovieva et al (2018)[62] assessed exposure to standing or moving with OR_{men} of 1.2 and OR_{women} of 1.1. Overall, no sex differences were found.

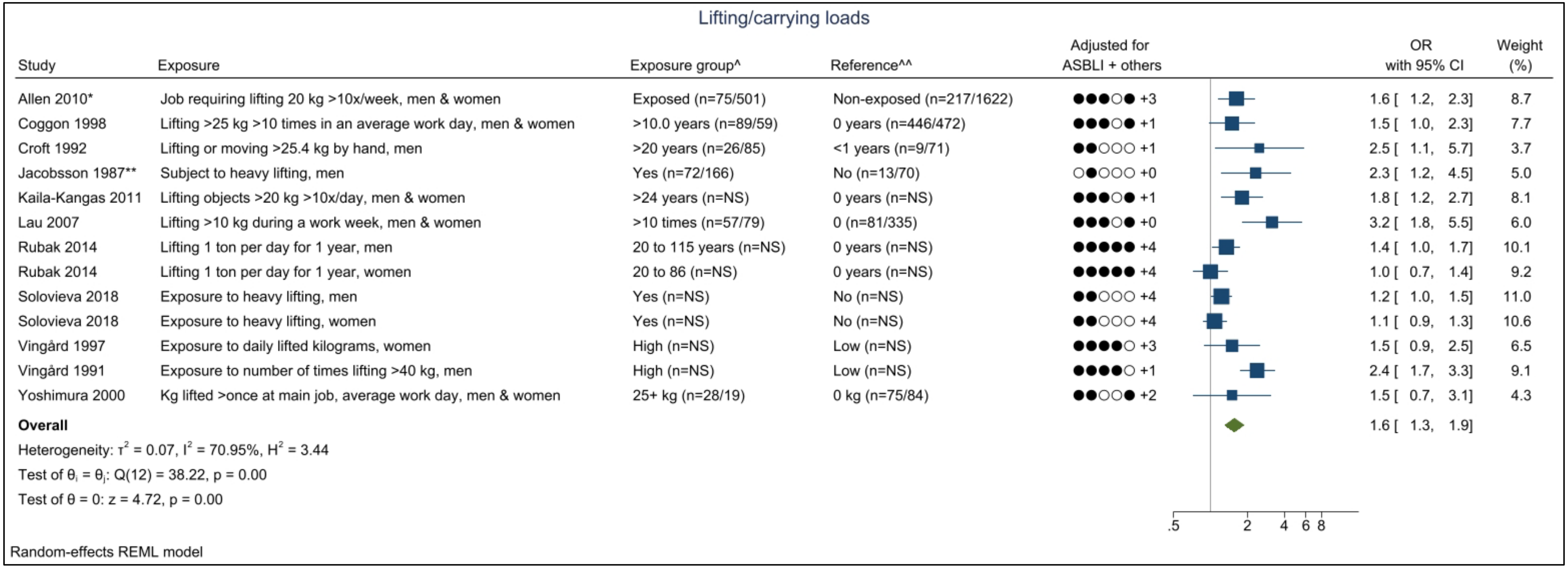
Kneeling or squatting: Solovieva et al (2018) provided sex-specific estimates.[62] The study assessed exposure to kneeling or squatting with OR_{men} of 1.2 and OR_{women} of 1.5.

Sitting: Two studies provided sex-specific estimates. Coggon et al (1998)[44] assessed years sitting for $\geq$2 hours in an average working day with OR_{men} of 1.0 and OR_{women} of 0.9, while Solovieva et al (2018)[62] assessed exposure to sitting with OR_{men} of 0.4 and OR_{women} of 0.5. Overall, no sex differences were found.

Combined exposures: Four studies provided sex-specific estimates. Cvijetic et al (1999)[46] assessed years exposed to high physical strain with OR_{men} of 1.2 and OR_{women} of 1.4. Similarly, Rubak et al (2013)[60] assessed years of physical workload with OR_{men} of 1.3 and OR_{women} of 1.0. Flugsrud et al (2002)[47] assessed the intensity of physical activity at work with OR_{men} of 2.1 and OR_{women} of 2.1. Finally, Solovieva et al (2018) assessed exposure to heavy physical work with OR_{men} of 1.3 and OR_{women} of 1.6.[62] Overall, no sex differences were found.

When comparing sex-differences among all occupational mechanical exposures, difference in risk between sex was indicated for lifting/carrying loads and standing. For lifting/carrying loads, higher risk was found among men, while higher risk was found among women for standing.

Figure 3. Forest plot of the association between lifting/carrying loads and hip osteoarthritis.



Notes: adjusted variables (ASBLI) = age, sex, body mass index, leisure time activities, and previous injuries in lower extremities. + others refer to adjusting for other confounding factors besides the ASBLI-factors.

Abbreviations: kg = kilograms; NS = not specified; x = times.

* Allen 2010 - odds ratio calculated on the basis of prevalence of distribution between groups (table 4 in the study).

** Jacobsson 1987 - odds ratio calculated on the basis of numbers of participants (table 1 in the study).

^ Numbers in brackets states numbers of exposed persons with hip OA and numbers of exposed references.

^^ Numbers in brackets states numbers of unexposed persons with hip OA and numbers of unexposed references.

Figure 4. Forest plot of the association between awkward postures and hip osteoarthritis.

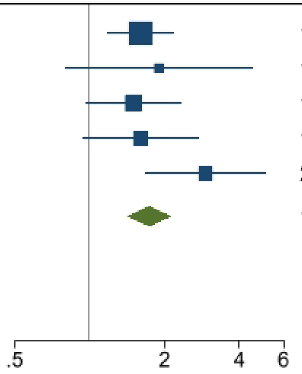
Awkward postures

Study	Exposure	Exposure group^	Reference^^	Adjusted for ASBLI + others	OR with 95% CI	Weight (%)
Allen 2010*	Bending/twisting at longest job held, men & women	Exposed (n=271/1264)	Non-exposed (n=128/843)	●●●○● +3	1.6 [1.2, 2.2]	44.7
Croft 1992	Bending for >2 hours/day, men	>20 years (n=27/100)	<1 year (n=9/58)	●●○○○ +1	1.9 [0.8, 4.5]	5.6
Rijs 2014	Perform work in an uncomfortable position, men & women	Moderate (n=NS)	Low (n=NS)	●●○○○ +0	1.5 [1.0, 2.3]	21.2
Vingård 1997	Exposure to hours working in twisted position, women	High (n=NS)	Low (n=NS)	●●●●○ +3	1.6 [0.9, 2.7]	14.7
Vingård 1991	Exposure to twisted lock position, men	High (n=NS)	Low (n=NS)	●●●●○ +1	2.9 [1.7, 5.0]	13.8
Overall					1.7 [1.4, 2.1]	

Heterogeneity: $\tau^2 = 0.00$, $I^2 = 0.00\%$, $H^2 = 1.00$

Test of $\theta_i = \theta_j$: Q(4) = 4.29, p = 0.37

Test of $\theta = 0$: z = 5.29, p = 0.00



Random-effects REML model

Notes: adjusted variables (ASBLI) = age, sex, body mass index, leisure time activities, and previous injuries in lower extremities. + others refer to adjusting for other confounding factors besides the ASBLI-factors.

Abbreviations: kg = kilograms; NS = not specified.

* Allen 2010 - odds ratio calculated on the basis of prevalence of distribution between groups (table 4 in the study).

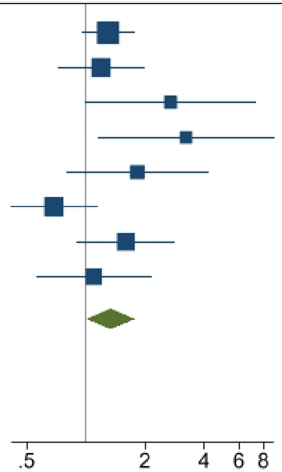
^ Numbers in brackets states numbers of exposed persons with hip OA and numbers of exposed references.

^^ Numbers in brackets states numbers of unexposed persons with hip OA and numbers of unexposed references.

Figure 5. Forest plot of the association between standing and hip osteoarthritis.

Standing

Study	Exposure	Exposure group^	Reference^^	Adjusted for ASBLI + others	OR with 95% CI	Weight (%)
Allen 2010*	Standing at longest job held, men & women	Exposed (n=187/1379)	Non-exposed (n=84/726)	●●●○● +3	1.3 [1.0, 1.7]	23.0
Coggon 1998	Standing >2 hours in an average work day, men & women	>20 years (n=363/345)	0 years (n=43/47)	●●●○● +1	1.2 [0.7, 2.0]	15.7
Croft 1992	Standing for >2 hours/day, men	>40 years (n=36/147)	<20 years (n=5/59)	●●○○○ +1	2.7 [1.0, 7.3]	6.4
Cvijetic 1999	Exposure to 80% of work time standing, women	>30 years (n=NS)	<20 years (n=NS)	●●●○○ +0	3.2 [1.2, 9.1]	6.0
Cvijetic 1999	Exposure to 80% of work time standing, men	>30 years (n=NS)	<20 years (n=NS)	●●●○○ +0	1.8 [0.8, 4.2]	8.4
Jacobsson 1987**	Subject to too much standing, men	Yes (n=43/141)	No (n=42/95)	○●○○○ +0	0.7 [0.4, 1.1]	15.7
Vingård 1997	Exposure to hours working standing, women	High (n=NS)	Low (n=NS)	●●●●○ +3	1.6 [0.9, 2.8]	13.7
Yoshimura 2000	Standing for >2 hours, men & women	Yes (n=78/76)	No (n=25/27)	●●○○● +2	1.1 [0.6, 2.2]	11.2
Overall					1.3 [1.0, 1.8]	



Heterogeneity: $\tau^2 = 0.07$, $I^2 = 44.74\%$, $H^2 = 1.81$

Test of $\theta_i = \theta_j$: Q(7) = 12.74, p = 0.08

Test of $\theta = 0$: z = 2.02, p = 0.04

Random-effects REML model

Notes: adjusted variables (ASBLI) = age, sex, body mass index, leisure time activities, and previous injuries in lower extremities. + others refer to adjusting for other confounding factors besides the ASBLI-factors.

Abbreviations: NS = not specified.

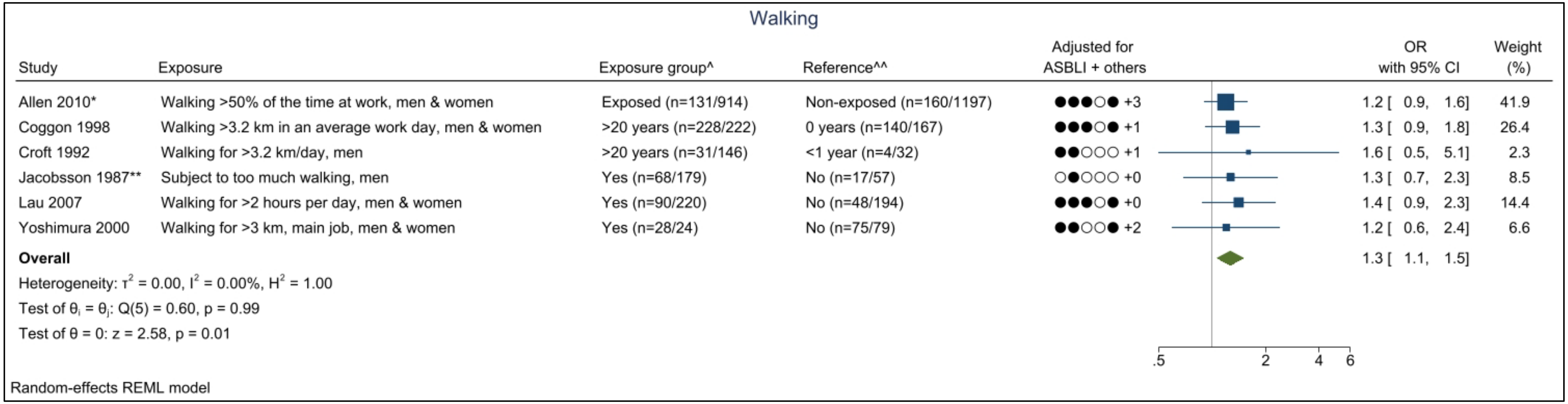
* Allen 2010 - odds ratio calculated on the basis of prevalence of distribution between groups (table 4 in the study).

** Jacobsson 1987 - odds ratio calculated on the basis of numbers of participants (table 1 in the study).

^ Numbers in brackets states numbers of exposed cases and numbers of exposed references.

^^ Numbers in brackets states numbers of unexposed cases and numbers of unexposed references.

Figure 6. Forest plot of the association between walking and hip osteoarthritis.



Notes: adjusted variables (ASBLI) = age, sex, body mass index, leisure time activities, and previous injuries in lower extremities. + others refer to adjusting for other confounding factors besides the ASBLI-factors.

Abbreviations: km = kilometres.

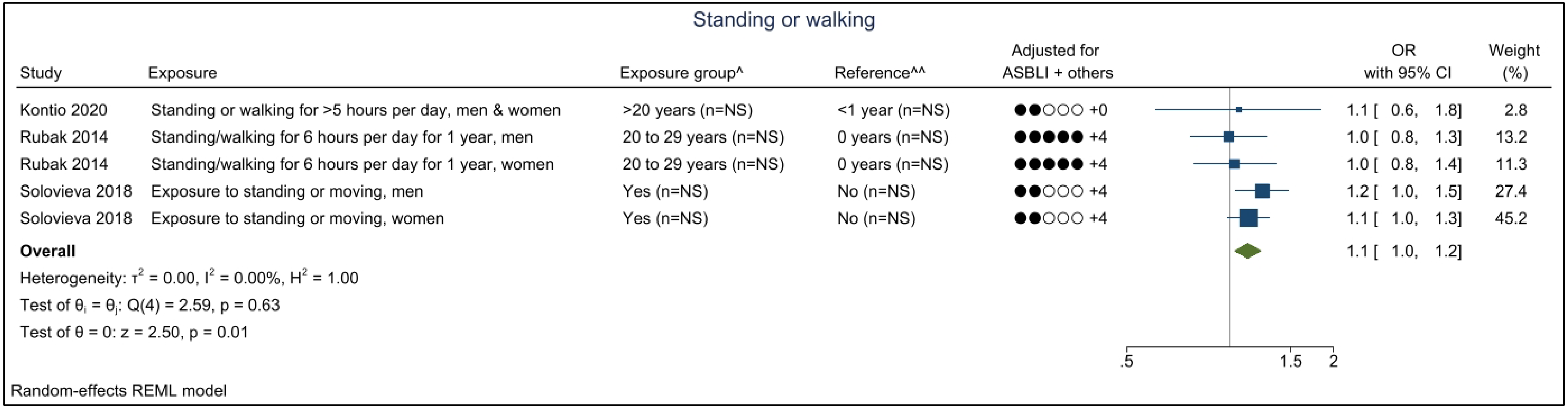
* Allen 2010 - odds ratio calculated on the basis of prevalence of distribution between groups (table 4 in the study).

** Jacobsson 1987 - odds ratio calculated on the basis of numbers of participants (table 1 in the study).

^ Numbers in brackets states numbers of exposed cases and numbers of exposed references.

^^ Numbers in brackets states numbers of unexposed cases and numbers of unexposed references.

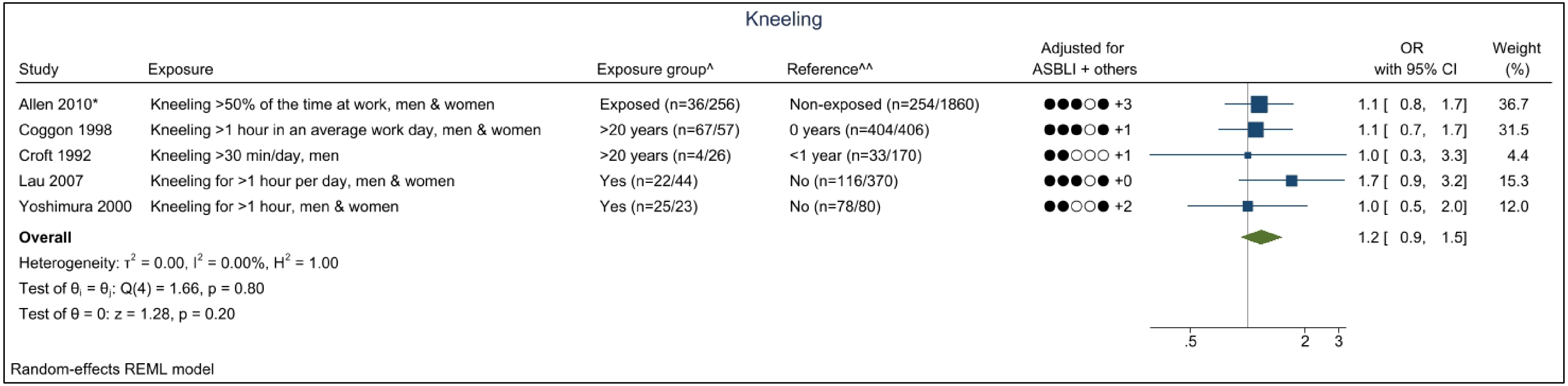
Figure 7. Forest plot of the association between standing or walking and hip osteoarthritis.



Notes: adjusted variables (ASBLI) = age, sex, body mass index, leisure time activities, and previous injuries in lower extremities. + others refer to adjusting for other confounding factors besides the ASBLI-factors.

Abbreviations: NS = not specified.

Figure 8. Forest plot of the association between kneeling and hip osteoarthritis.



Notes: adjusted variables (ASBLI) = age, sex, body mass index, leisure time activities, and previous injuries in lower extremities. + others refer to adjusting for other confounding factors besides the ASBLI-factors.

Abbreviations: min = minutes.

* Allen 2010 - odds ratio calculated on the basis of prevalence of distribution between groups (table 4 in the study).

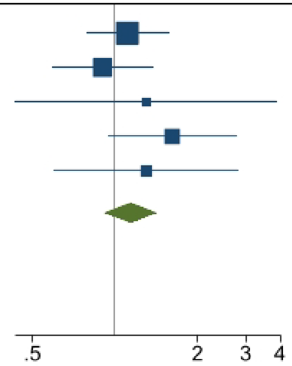
^ Numbers in brackets states numbers of exposed persons with hip OA and numbers of exposed references.

^^ Numbers in brackets states numbers of unexposed persons with hip OA and numbers of unexposed references.

Figure 9. Forest plot of the association between squatting and hip osteoarthritis.

Squatting

Study	Exposure	Exposure group^	Reference^^	Adjusted for ASBLI + others	OR with 95% CI	Weight (%)
Allen 2010*	Squatting at the longest job held, men & women	Exposed (n=48/452)	Non-exposed (n=176/1650)	●●●○● +3	1.1 [0.8, 1.6]	42.3
Coggon 1998	Squatting >1 hour in an average work day, men & women	>20 years (n=46/51)	0 years (n=470/475)	●●●○● +1	0.9 [0.6, 1.4]	27.8
Croft 1992	Squatting >30 min/day, men	>1 year (n=5/30)	<1 year (n=35/208)	●●○○○ +1	1.3 [0.4, 3.9]	4.1
Lau 2007	Squatting for >1 hour per day, men & women	Yes (n=36/78)	No (n=102/336)	●●●○● +0	1.6 [0.9, 2.8]	17.3
Yoshimura 2000	Squatting for >1 hour, men & women	Yes (n=26/21)	No (n=77/82)	●●○○● +2	1.3 [0.6, 2.8]	8.4
Overall					1.1 [0.9, 1.4]	



Heterogeneity: $\tau^2 = 0.00$, $I^2 = 0.00\%$, $H^2 = 1.00$

Test of $\theta_i = \theta_j$: $Q(4) = 3.03$, $p = 0.55$

Test of $\theta = 0$: $z = 1.15$, $p = 0.25$

Random-effects REML model

Notes: adjusted variables (ASBLI) = age, sex, body mass index, leisure time activities, and previous injuries in lower extremities. + others refer to adjusting for other confounding factors besides the ASBLI-factors.

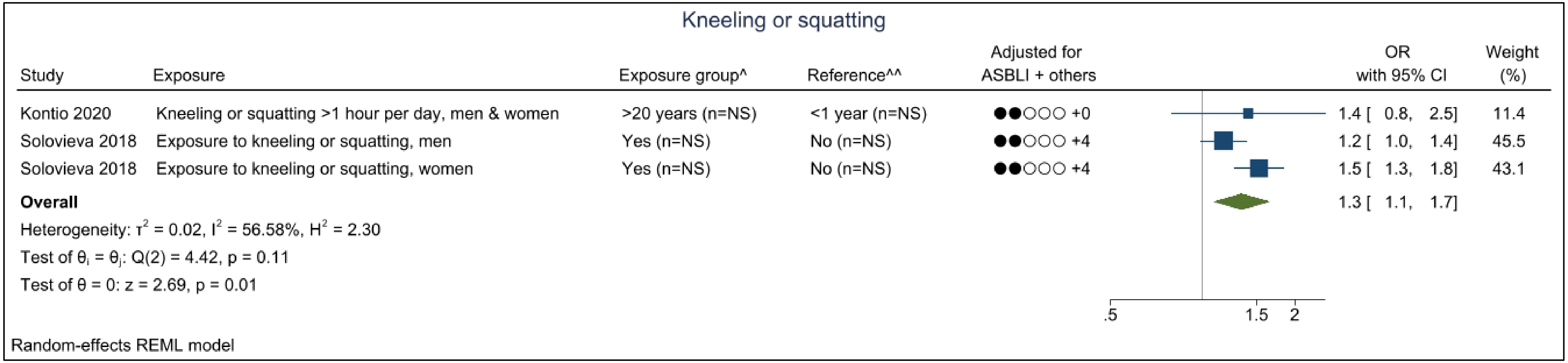
Abbreviations: min = minutes.

* Allen 2010 - odds ratio calculated on the basis of prevalence of distribution between groups (table 4 in the study).

^ Numbers in brackets states numbers of exposed persons with hip OA and numbers of exposed references.

^^ Numbers in brackets states numbers of unexposed persons with hip OA and numbers of unexposed references.

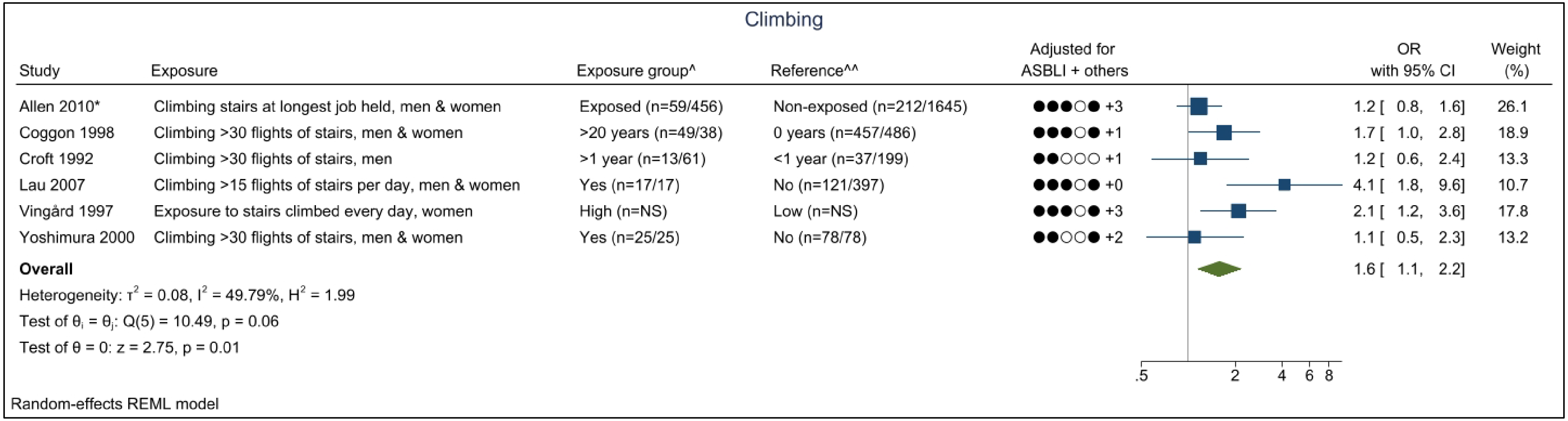
Figure 10. Forest plot of the association between kneeling or squatting and hip osteoarthritis.



Notes: adjusted variables (ASBLI) = age, sex, body mass index, leisure time activities, and previous injuries in lower extremities. + others refer to adjusting for other confounding factors besides the ASBLI-factors.

Abbreviations: NS = not specified.

Figure 11. Forest plot of the association between climbing stairs and hip osteoarthritis.



Notes: adjusted variables (ASBLI) = age, sex, body mass index, leisure time activities, and previous injuries in lower extremities. + others refer to adjusting for other confounding factors besides the ASBLI-factors.

Abbreviations: NS = not specified.

* Allen 2010 - odds ratio calculated on the basis of prevalence of distribution between groups (table 4 in the study).

^ Numbers in brackets states numbers of exposed persons with hip OA and numbers of exposed references.

^^ Numbers in brackets states numbers of unexposed persons with hip OA and numbers of unexposed references.

Figure 12. Forest plot of the association between sitting and hip osteoarthritis.

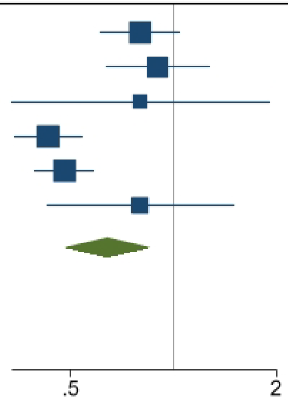
Sitting

Study	Exposure	Exposure group^	Reference^^	Adjusted for ASBLI + others	OR with 95% CI	Weight (%)
Allen 2010*	Sitting >50% of the time at work, men & women	Exposed (n=125/1007)	Non-exposed (n=166/1109)	●●●○● +3	0.8 [0.6, 1.0]	20.2
Coggon 1998	Sitting >2 hours in an average work day, men & women	>20 years (n=166/195)	0 years (n=161/159)	●●●○○ +2	0.9 [0.6, 1.3]	18.0
Croft 1992	Sitting for >2 hours/day, men	>20 years (n=18/114)	<1 year (n=14/78)	●●○○○ +1	0.8 [0.3, 1.9]	7.6
Solovieva 2018	Exposure to sitting, men	Yes (n=NS)	No (n=NS)	●●○○○ +4	0.4 [0.3, 0.5]	21.0
Solovieva 2018	Exposure to sitting, women	Yes (n=NS)	No (n=NS)	●●○○○ +4	0.5 [0.4, 0.6]	21.8
Yoshimura 2000	Sitting for >2 hours, men & women	Yes (n=47/53)	No (n=56/50)	●●○○● +2	0.8 [0.4, 1.5]	11.3
Overall					0.6 [0.5, 0.9]	

Heterogeneity: $\tau^2 = 0.09$, $I^2 = 78.17\%$, $H^2 = 4.58$

Test of $\theta_i = \theta_j$: Q(5) = 23.17, p = 0.00

Test of $\theta = 0$: z = -3.02, p = 0.00



Random-effects REML model

Notes: adjusted variables (ASBLI) = age, sex, body mass index, leisure time activities, and previous injuries in lower extremities. + others refer to adjusting for other confounding factors besides the ASBLI-factors.

Abbreviations: NS = not specified.

* Allen 2010 - odds ratio calculated on the basis of prevalence of distribution between groups (table 4 in the study).

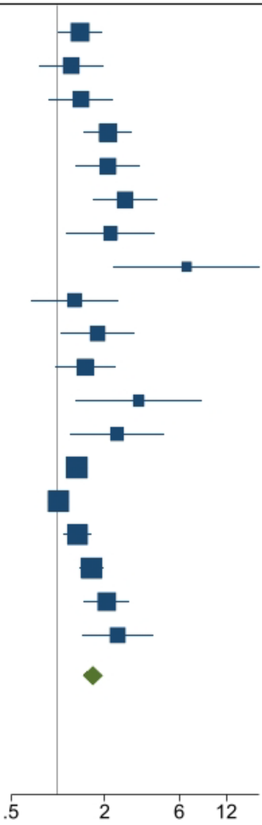
^ Numbers in brackets states numbers of exposed persons with hip OA and numbers of exposed references.

^^ Numbers in brackets states numbers of unexposed persons with hip OA and numbers of unexposed references.

Figure 13. Forest plot of the association between combined exposures and hip osteoarthritis.

Combined exposures

Study	Exposure	Exposure group^	Reference^^	Adjusted for ASBLI + others	OR with 95% CI	Weight (%)
Allen 2010*	Heavy work while standing >50% of work time, men & women	Exposed (n=65/405)	Non-exposed (n=226/1715)	●●●○● +3	1.4 [1.0, 1.9]	6.6
Cvijetic 1999	Exposure to high physical strain, men	>30 years (n=NS)	<20 years (n=NS)	●●●○○ +0	1.2 [0.8, 1.9]	5.0
Cvijetic 1999	Exposure to high physical strain, women	>30 years (n=NS)	<20 years (n=NS)	●●●○○ +0	1.4 [0.9, 2.2]	4.9
Flugsrud 2002	Physical activity at work, men	Intensive (n=97/6105)	Sedentary (n=48/6372)	●●●●○ +2	2.1 [1.5, 3.0]	6.2
Flugsrud 2002	Physical activity at work, women	Intensive (n=43/1325)	Sedentary (n=42/3381)	●●●●○ +2	2.1 [1.3, 3.3]	4.9
Heliovaara 1993	Number of occupational mechanical exposures, men & women	4 or 5 (n=27/421)	0 (n=71/2426)	●●●○● +0	2.7 [1.7, 4.3]	4.8
Jacobsson 1987**	Subject to heavy labour, men	Yes (n=71/165)	No (n=14/71)	○●○○○ +0	2.2 [1.2, 4.1]	3.4
Juhakoski 2009	Physical work load, men & women	Heavy manual (n=11/91)	Light sedentary (n=10/327)	●●●●● +3	6.7 [2.3, 19.5]	1.6
Kontio 2020	Composite cumulative work load, men & women	High (n=NS)	Low (n=NS)	●●●○● +0	1.3 [0.7, 2.4]	3.5
Ratzlaff 2011	Cumulative peak force index, men & women	Index 5 (n=NS)	Index 1 (n=NS)	●●○●● +1	1.8 [1.0, 3.1]	4.2
Rijs 2014	Physical demands, use of force, men & women	Moderate (n=NS)	Low (n=NS)	●●○○○ +0	1.5 [1.0, 2.3]	5.1
Riyazi 2008	Physically demanding jobs, men & women	Yes (n=NS)	No (n=NS)	●●●○○ +0	3.3 [1.3, 8.3]	2.1
Roach 1994	Occupational activities, men	Heavy (n=54/97)	Light (n=18/76)	○●○●○ +2	2.4 [1.2, 4.7]	3.2
Rubak 2013	Point-years of physical workload, men	35-86 years (n=2046/86085)	0 years (n=242/21165)	●●○○○ +4	1.3 [1.2, 1.5]	8.7
Rubak 2013	Point-years of physical workload, women	35-86 years (n=364/13486)	0 years (n=515/35120)	●●○○○ +4	1.0 [0.9, 1.2]	8.6
Solovieva 2018	Exposure to heavy physical work, men	Yes (n=NS)	No (n=NS)	●●○○○ +4	1.3 [1.1, 1.6]	8.0
Solovieva 2018	Exposure to heavy physical work, women	Yes (n=NS)	No (n=NS)	●●○○○ +4	1.6 [1.4, 2.0]	8.3
Thelin 1997	Heavy physical work, men	Yes (n=NS)	No (n=NS)	●●○○○ +1	2.1 [1.5, 2.9]	6.4
Vingård 1991	Exposure to twisting, walking w. burdens and climbing, men	High (n=NS)	No (n=NS)	●●●●○ +2	2.4 [1.4, 4.0]	4.5
Overall					1.7 [1.4, 2.0]	



Heterogeneity: $\tau^2 = 0.06$, $I^2 = 72.74\%$, $H^2 = 3.67$

Test of $\theta_i = \theta_j$: Q(18) = 67.96, p = 0.00

Test of $\theta = 0$: z = 6.81, p = 0.00

Random-effects REML model

Notes: adjusted variables (ASBLI) = age, sex, body mass index, leisure time activities, and previous injuries in lower extremities. + others refer to adjusting for other confounding factors besides the ASBLI-factors.**Abbreviations**: NS = not specified.

* Allen 2010 - odds ratio calculated on the basis of prevalence of distribution between groups (table 4 in the study).

** Jacobsson 1987 - odds ratio calculated on the basis of numbers of participants (table 1 in the study).

^ Numbers in brackets states numbers of exposed persons with hip OA and numbers of exposed references.

^^ Numbers in brackets states numbers of unexposed persons with hip OA and numbers of unexposed references.

Table 3 presents an overview of the level of evidence of the association between the included occupational mechanical exposures and hip OA.

Table 3. Overview of pooled odds ratios, publication bias, and level of evidence of an association between each occupational mechanical exposure and hip osteoarthritis based on studies included in the meta-analysis.

Mechanical exposures in meta-analysis	No. of studies	Pooled OR	Sensitivity analysis						Publication bias	Level of evidence of an association*
			Risk of bias		Study design		Outcome			
			Low/ moderate	High	Cohort/ Case-control	Cross-sectional	Hip replace.	Other outcomes		
Lifting/carrying loads	11	1.6 (95% CI 1.3–1.9)	1.3 OR (N=4)	1.8 OR (N=7)	1.6 OR (N=10)	1.6 OR (N=1)	1.6 OR (N=4)	1.7 OR (N=7)	Indication of publication bias. Egger's test of 0.014.	Moderate evidence of an association (++).
Awkward postures	5	1.7 (95% CI 1.4–2.1)	2.2 OR (N=2)	1.6 OR (N=3)	2.1 OR (N=3)	1.6 OR (N=2)	2.1 OR (N=3)	1.6 OR (N=2)	No indication of publication bias. Egger's test of 0.37.	Limited evidence of an association (+).
Standing	7	1.3 (95% CI 1.0–1.8)	1.6 OR (N=1)	1.3 OR (N=6)	1.2 OR (N=5)	1.6 OR (N=2)	1.8 OR (N=2)	1.2 OR (N=5)	Indication of publication bias. Egger's test of 0.07.	Limited evidence of an association (+).
Walking	6	1.3 (95% CI 1.1–1.5)	(N=0)	1.3 OR (N=6)	1.3 OR (N=5)	1.2 OR (N=1)	1.6 OR (N=1)	1.3 OR (N=5)	No indication of publication bias. Egger's test of 0.66.	Limited evidence of an association (+).
Standing or walking	3	1.1 (95% CI 1.0–1.2)	1.1 OR (N=3)	(N=0)	1.1 OR (N=3)	(N=0)	1.0 OR (N=1)	1.2 OR (N=2)	Difficult to interpret due to few studies. Egger's test of 0.42.	Insufficient evidence of an association (0).
Kneeling	5	1.2 (95% CI 0.9–1.5)	(N=0)	1.2 OR (N=5)	1.2 OR (N=4)	1.1 OR (N=1)	1.0 OR (N=1)	1.2 OR (N=4)	No indication of publication bias. Egger's test of 0.99.	Insufficient evidence of an association (0).
Squatting	5	1.1 (95% CI 0.9–1.4)	(N=0)	1.1 OR (N=5)	1.2 OR (N=4)	1.1 OR (N=1)	1.3 OR (N=1)	1.1 OR (N=4)	No indication of publication bias. Egger's test of 0.45.	Insufficient evidence of an association (0).
Kneeling or squatting	2	1.3 (95% CI 1.1–1.7)	1.3 OR (N=2)	(N=0)	1.3 OR (N=2)	(N=0)	(N=0)	1.3 OR (N=2)	Difficult to interpret. Egger's test of 0.84.	Insufficient evidence of an association (0).
Climbing stairs	6	1.6 (95% CI 1.1–2.2)	2.1 OR (N=1)	1.5 OR (N=5)	1.8 OR (N=5)	1.2 OR (N=1)	1.7 OR (N=2)	1.6 OR (N=4)	No indication of publication bias. Egger's test of 0.23.	Limited evidence of an association (+).
Sitting	5	0.6 (95% CI 0.5–0.9)	0.5 OR (N=1)	0.8 OR (N=4)	0.6 OR (N=4)	0.8 OR (N=1)	0.8 OR (N=1)	0.6 OR (N=4)	No indication of publication bias. Egger's test of 0.24.	Limited evidence of an association (+).
Combined exposures	15	1.7 (95% CI 1.4–2.0)	1.5 OR (N=6)	1.9 OR (N=9)	1.8 OR (N=11)	1.6 OR (N=4)	1.7 OR (N=4)	1.6 OR (N=11)	Indication of publication bias. Egger's test of 0.0001.	Strong evidence of an association (+++).

* See Appendix 3 for clarification.

4. Discussion

4.1 Main results

Twenty-four studies were included in this systematic review and meta-analysis on the association between occupational mechanical exposures and hip OA. Based on the level of evidence, we found strong evidence of an association for combined occupational mechanical exposures with a pooled OR of 1.7 (95% CI 1.4–2.0) and moderate evidence of an association for exposure to lifting/carrying loads with a pooled OR of 1.6 (95% CI 1.3–1.9). Limited evidence of an association was found for awkward postures, standing, walking, and climbing stairs with pooled OR's ranging from 1.3 to 1.7, while insufficient evidence was found for exposure to standing/walking, kneeling, squatting, and kneeling/squatting with pooled OR's ranging from 1.1 to 1.3. In addition, limited evidence indicated that sitting might prevent hip OA with a pooled OR of 0.6 (95% CI 0.5–0.9). No exposure thresholds could be identified.

Eight studies estimated the risk of hip OA between men and women. For lifting/carrying loads, higher risk was found among men, while higher risk was found among women for standing.

4.2 Methodological considerations

The evidence of an association between occupational mechanical exposures and hip OA was assessed based on several epidemiological parameters e.g., number of studies, consistency between studies, pooled OR, exposure-response relation, pooled OR in low to moderate risk of bias studies, and publication bias. We did not use GRADE as The Danish Work Environmental Fund requested specific guidelines for evaluation of evidence.

Several methodological considerations especially affecting the meta-analyses should be discussed, e.g., exposure, outcome, and study design. First in relation to exposure, meta-analysis requires similarities in exposure definition, metric, and assessment between studies, which was not observed. In general, exposure definition was highly heterogeneously defined. For example, lifting/carrying loads was defined as lifting loads above 10, 20, 25, 40, or 50 kg, repetitively lifting during a work day or week, exposed to lifting, exposed to heavy lifting with or without an indication of kilograms or repetitions. In addition, the exposure metric ranged from a dichotomous approach (yes/no), exposure duration (years being exposed), to a specification of intensity and frequency during a week or month reducing the comparability between studies. Despite large diversities, we presented pooled OR to visualise whether an association between occupational mechanical exposures and hip OA could be indicated across all studies taking account of study weight. In addition, the meta-analyses for some exposure variables (e.g., standing/walking and kneeling/squatting) and several of the sensitivity analyses were conducted with few studies. Therefore, the pooled ORs should be interpreted with caution.

In the meta-analysis, the measure of association comparing the highest vs. lowest exposure groups was chosen to ensure exposure contrast. However, the highest exposure groups often contained fewer participants, affecting the standard error of a given estimate, resulting in broader confidence intervals with an increased risk of type 2 error. Even though, among the 11 occupational mechanical exposures included in the meta-analyses, statistically significant pooled ORs were found for eight occupational mechanical exposures (i.e., lifting/carrying loads, awkward postures, standing, walking, standing/walking, "kneeling/squatting", climbing stairs, sitting, and combined mechanical exposures).

The exposure assessment was often based on self-reports, i.e., a questionnaire or interview. Such assessment methods can be affected by recall bias, especially when information on the exposure is gathered over decades of work, potentially contributing to exposure misclassification.[67] Five studies used JEMs/expert ratings, typically combining self-reported job titles or register-based ISCO codes (International Classification of Occupations) with the JEM. JEMs typically assigned exposures at a qualitative or semi-quantitative level based on expert ratings, and any misclassification is expected to be non-differential with respect to the outcome. By design, a JEM allocates the same exposure estimates to all workers with the same job title or ISCO code (group-based). Exposure-response relations have been shown to be essentially unbiased with group-based exposures, while individual-based models, where each individual is assigned to his/her exposure under a classical error structure, lead to attenuated slopes unless each individual is measured extensively.[68 69] This advantage of the group-based strategy comes, however, at the price of an increased uncertainty of the regression coefficient and thus reduced power, i.e. reduced ability of a study design to detect a true effect of exposure on outcome.[68 69]

Overall, the heterogeneity in exposure definition, metrics, and assessment, indicated by the generally high I^2 values in the meta-analyses, reduced the possibility to compare studies. In addition, we did not identify exposure thresholds for any exposure variable or metric (i.e., intensity, frequency, and duration).

Second, criteria for hip OA described in the included studies varied from cases of total hip replacements, radiographic data assessing joint space, registers gathering information on OA based on ICD-codes to clinical examinations. Based on few studies, we generally found higher pooled ORs in studies with outcome defined as total hip replacements. This could be due to an increased risk of total hip replacements or an increased risk of surgery given hip OA, or both. For non-surgery treated hip OA, a combination of radiographic and clinical examination are considered best for discriminating between hip OA and hip pain due to other causes.[70] Misclassification of the outcome might however occur especially for participants with less severe hip OA. A study from 2015 found that most patients with frequent hip pain did not have radiographic hip OA, and most patients with radiographic-confirmed hip OA did not have frequent hip pain.[71]

Third, heterogeneity was also observed according to the number of confounders adjusted for in each of the included studies. Overall, the number of controlling confounders varied from 0 to 9, with a mean number of 4.7 confounders, potentially explaining some of the dispersion observed. Most studies controlled for age (94%) and sex (75%), followed by BMI (55%) and previous hip injury (47%). Few studies controlled for other occupational mechanical exposures.[62] Occupational mechanical exposures often co-occur, which might confound and over-estimate measure of association when not controlled for. In the study of Solovieva et al.,[62] we chose to extract data adjusted for other occupational mechanical exposures with a higher risk of over-adjustment. If we had included the age-adjusted estimates, higher pooled OR would have been found for lifting/carrying loads, "standing/walking", "kneeling/squatting", and combined mechanical exposures, while lower pooled OR would have been found for sitting (more protective effect). For lifting/carrying loads and combined mechanical exposure, a doubling of risk could have been found.

Finally, heterogeneity also occurred according to study design, study population, number of included participants, and risk of bias assessment. Among the 24 studies, only four studies were cross-sectional studies where temporality between exposure and outcome cannot be ensured. The study population varied and consisted of e.g., farmers, community-dwelling members, veterans as well as diverse representative populations. Several of the studies included in the review comprised representative populations, while few studies specifically selected highly exposed workers such as scaffolders or carpenters. Studies with highly exposed workers are warranted to evaluate the maximum strength of association.

Based upon, comparing the results between studies was indeed difficult. To evaluate the effect of the heterogeneity, several additional sensitivity analyses were conducted investigating differences in study design, risk of bias, and outcome measures. Based on few studies, generally higher pooled ORs were found in cohort/case-control studies, studies with outcome defined as total hip replacement, while no clear trend for measure of association was found for low/moderate vs. high risk of bias studies.

4.3 Comparing results

Pooled OR from the meta-analyses were generally in favour of an association for most occupational mechanical exposures with varying strength of association and level of evidence. For lifting loads[23-28] and combined exposures,[24 27] our results align with those found in other systematic reviews which all found an association. For lifting loads, meta-analyses were only conducted in four reviews.[24-26 28] Bergman et al. (2017)[24] found a pooled OR of 2.09 among men (N=7 studies) and 1.41 among women (N=6 studies), while Canetti et al. (2020)[28] found a pooled OR of 1.51 for men and women combined (N=3). Based in 11 studies, we found a pooled OR of 1.6 for both sexes. Two systematic reviews with meta-analysis reported the doubling risk dose. In the systematic review of Seidler et al. (2018)[25] including six studies for men, the risk of developing hip OA was increased by an OR of 1.98 (95% CI 1.20–3.29) per 10,000 tons of weights ≥20 kg handled, 2.08 (95% CI 1.22–3.53) per 10,000 tons handled >10 times per day and 8.64 (95% CI 1.87–39.91) per 106 operations. These estimations resulted in doubling dosages of 10,100 tons (between 6100 and 14,000 tons) of weights ≥20 kg handled, 9500 tons (between 6000 and 10,500 tons) ≥20 kg handled >10 times per day and 321,400 operations (between 218,000 and 514,000 operations) of weights ≥20 kg. In women, there was no linear association between manual handling of weights at work and risk to develop hip OA based on five studies. In the systematic review of Sun et al. (2019),[26] the estimated doubling risk doses of heavy lifting for hip OA based on two studies was somewhat higher lying between 14,761 and 18,550 tons among men. No association was found in women. When comparing ORs for lifting/carrying loads, we generally found higher ORs in men compared to women. Due to the aim of our systematic review, we did not evaluate the doubling risk, which in some countries is the recognition of compensation of occupational diseases.[25]

For combined occupational mechanical exposures, two previous systematic reviews both found an association.[24 27] A meta-analysis was only conducted in the review by Bergman et al. (2017).[24] They found a pooled OR of 2.46 in men (N=5 studies) and 1.38 in women (N=3 studies), while we found a pooled OR of 1.7 for men and women combined based on 15 studies. We found no difference between sex.

For awkward postures and climbing stairs, we found limited evidence of an association with pooled OR between 1.6 and 1.7, which supports results found in other systematic reviews for awkward postures (N=1 study)[27] and climbing stairs (N=2 studies)[23] where no meta-analyses were conducted.[23] For standing, we found a pooled OR of 1.3 (N=7 studies), while two previous reviews (N=1 and 3 studies) found conflicting results with no meta-analysis.[23 28] Finally, our results support a protective effect of sitting (N=5 studies), which have been found in one previous review (N=2 studies).[23] No previous systematic reviews have evaluated walking.

Several of the exiting systematic reviews did not perform meta-analyses due to few studies or large heterogeneity between studies. We consider it a strength that our systematic review included several studies compared to previous reviews.

4.4 Compensation claim

In Denmark, hip OA developed due to occupational lifting/carrying loads is recognised as an occupational disease. Current demands are based upon a daily lifting load of 8–10 tons over at least 15 years of exposure in order to receive a compensation claim.

Two meta-analyses from Germany investigated the exposure-response relations and doubling risk doses based on observational studies. Seidler et al (2018)[25] included six studies and found a positive exposure-response relation for lifting for male populations. The doubling dose was estimated to be between 6000 and 14,000 cumulative tons of weights >20 kg handled, this correspond to 1.82–4.24 tons/day for 15 years assuming 220 work days per year. Furthermore, the doubling dose was between 6000 and 10,500 cumulative tons of weights >20 kg handled >10 times/day corresponding to 1.82–3.18 tons/day for 15 years.

Sun et al (2019)[26] included two studies and found a positive exposure-response relation for heavy lifting for male populations. The doubling dose was estimated to be between 14,761 and 18,522 tons corresponding to 4.47–5.61 tons/day for 15 years.

The current Danish demands for compensations claims are therefore higher compared to the doubling dose found in the systematic reviews of Seidler et al (2018)[25] and Sun et al (2019).[26]

4.5 Other risk factors

Other risk factors associated with hip OA include e.g., Body Mass Index (BMI),[13] waist-to-hip ratio,[14] obesity,[15 16] age,[16 17] sex,[18] genetic,[16 17 19] high-impact sports/long-distance running,[17 20 21] previous trauma,[17] and arthritis of other joints.[16 22]

Some considerations of high-impact sports/long-distance running vs obesity should be considered. Overload of joints has been studied for many years, from leisure-time activities to professional athletes. In a systematic review, Felson et al (2004) reviewed the scientific evidence of avocational joint overload as a risk factor for OA.[72] Conflicting evidence was found for the association between running and hip OA. This was underpinned by a systematic review by Alentorn-Gel et al (2017) who concluded that recreational runners had a lower occurrence of OA compared to competitive runners. Moreover, they found that running at a recreation level was associated with lower risk of hip OA.[21] Another study conducted by Williams (2013) found that running reduced the risk of developing hip OA possibly due to runners association with a lower BMI.[73]

Obesity increases the load in weight-bearing joints. In a systematic review, Jiang et al (2011)[13] found a 5-unit increase in BMI was associated with an 11% increase in the risk of hip OA, while a similar unit increase in BMI showed an increased risk of knee OA of 33%.[13] Badley et al (2022)[74] examined the relationship between BMI and OA in 6330 participants diagnosed with self-reported OA and 11949 controls, and found a positive association between BMI and hip OA; overweight: OR = 1.54, Obesity I: OR = 2.13, and Obesity II: OR = 3.16 when adjusting for age and sex.

Due to comprehensive work synthesising the association between occupational mechanical exposure and hip OA and due the time frame of this project, we were not able to further explore the association between other risk factors and hip OA. An overview of systematic reviews of non-occupational risk factors for hip OA is highly warranted.

4.6 Suggestions for future research and practical implications

Research on chronic diseases developing over time requires studies accounting for time lag between possible symptoms and the onset of disease. We suggest that future research utilises already large established cohorts with a prolonged longitudinal approach (e.g., DOC*X cohort), eventually incorporating register-based information. Registers can provide reliable information on essential confounding factors and possibly provide knowledge on job rotations/work participation.

There is a strong correlation between hip OA and age, and therefore newer statistical methods to study the effect of occupational mechanical exposures on hip OA is recommended. Risk and rate advancement periods (RAP) measure the impact of an exposure on the relation of age to disease. Specifically, they quantify the time by which the risk or rate of a disease is advanced among exposed subjects conditional on disease-free survival to a certain baseline age, thereby studying if workers with physically demanding work attract their hip OA at an earlier age than workers with less physically demanding work.[75]

Our reference document revealed heterogeneity in exposure definition, metric, and assessment. For example, the metric of lifting/carrying loads used different levels of duration, frequency, and intensity. These three main exposure dimensions should, if possible, be considered simultaneously when collecting data on the exposure. In addition, quantitative and technical measurements of the exposure are highly warranted. If exposure data is to be somewhat representative of each individual, repeated measures over time or group-based estimate are essential.

Difference between sex was found for both lifting/carrying loads and standing. The difference could be explained by difference exposure levels among men and women in the same exposure group e.g., men being more exposed to heavy lifting. Further studies are warranted.

5. Conclusion

In this reference document conducted as a systematic review and meta-analysis, we found strong evidence of an association for combined mechanical exposures and hip OA, and moderate evidence for lifting/carrying loads. Limited evidence of an association was found for awkward postures, standing, walking, and climbing stairs, while insufficient evidence was found for "standing/walking", kneeling, squatting, and kneeling/squatting. Finally, we found limited evidence for sitting and hip OA with sitting being a protective factor against the developing hip OA. No exposure thresholds could be identified.

6. English summary

Introduction

Osteoarthritis (OA) is a chronic disease, causing erosion in the articular cartilage and alterations in the subchondral bone, capsule, and ligaments. Almost any joint can be affected by OA, but the condition most often causes problems in the knees, hips, and small joints of the hands. Cardinal symptoms of hip OA consist of pain in or near the hip joint, stiffness, weakness, and audible clicking sounds when moving the hip.

Predisposing factors associated with hip OA include e.g., Body Mass Index (BMI), waist-to-hip ratio, age, genetic, high-impact sports/long-distance running, and occupational mechanical exposures. Six systematic reviews of the association between occupational mechanical exposures and hip OA have been published since 2010. Among the systematic reviews, lifting/carrying loads was the most often examined occupational mechanical exposure with all six systematic reviews indicating an association. For other occupational mechanical exposures, only 1-2 systematic reviews exist. Indication of an association was found for awkward postures, climbing stairs, and combined occupational mechanical exposures, while conflicting results were found for standing. A protective effect was found for sitting. Meta-analyses have only been conducted for lifting loads and combined occupational mechanical exposures with OR between 1.38 and 2.46.

In Denmark, hip OA as a result of occupational mechanical exposures is considered an occupational disease. Due to new national and international scientific studies, the Danish Labour Market Insurance and the Occupational Diseases Committee have requested a reference document to re-evaluate the existing guidelines of the exposure requirements. The aim of this systematic review and meta-analysis was to summarise the existing epidemiological evidence of the association between occupational mechanical exposures and the development of hip OA.

Materials and methods

The reference document was conducted as a systematic review and meta-analysis. Study population included persons in or above working age. The occupational mechanical exposures comprised 12 exposure variables i.e., lifting/carrying loads, awkward postures, standing, walking, standing/walking, kneeling, squatting, kneeling/squatting, climbing stairs, the combination of different mechanical exposures, and "other occupational mechanical exposures". Outcome was defined as hip OA with diagnostic evaluations including hip pain, radiographic-defined joint space narrowing, or clinical examination. Study design included observational studies, i.e., cohort, case-control, and cross-sectional studies.

For articles published before 16th of June 2022, a systematic literature search was conducted in Cochrane, PubMed, Web of Science, PsycINFO, Embase, and Cinahl. The selection of relevant articles was performed independently by two of the authors. Using predefined tables, information on author, study design, study population, outcome, outcome assessment, exposure, exposure assessment, confounders, and study results was extracted from each article by one author and quality checked by another author. To critically appraise the risk of bias of each included article, we used a modified risk of bias tool used in research on chronic diseases in several systematic reviews. Each included article could be rated as having low, moderate, or high risk of bias. The methodological quality assessment was performed independently by two of the authors.

Meta-analysis was conducted for 11 out of the 12 exposure variables to visualise whether an association between occupational mechanical exposures and hip OA across studies could be indicated. We did not include "other occupational mechanical exposures" due to large exposure heterogeneity. The meta-analysis was conducted using random-effects model with weighted odds ratios (OR) and 95% confidence intervals and heterogeneity was assessed using I-squared statistics. Publication bias was evaluated using funnel plots, and we tested the asymmetry of the funnel plots by Egger's test. Sensitivity analysis was conducted based on study quality (low/moderate vs high risk of bias), study design (cohort/case-control vs cross-sectional studies), and according to outcome (total hip replacement vs other outcomes).

Across studies, the level of evidence of an association was assessed according to guidelines provided by The Danish Work Environmental Fund. The evidence of an association was assessed based on several epidemiological parameters i.e., number of studies, consistency between studies, pooled OR, exposure-response relation, pooled OR in low to moderate risk of bias studies, and publication bias. The quality of evidence could be rated "strong" (+++), "moderate" (++), "limited" (+), "insufficient" (0) evidence of an association, or evidence suggesting lack of a causal association (-).

Results

Twenty-four articles were included in this reference document comprising six cohort studies, 14 case-control studies, and four cross-sectional studies. Two studies were assessed as having low risk of bias, six studies as having moderate risk of bias, and 16 studies were assessed as having high risk of bias.

Lifting/carrying loads: Among the 13 studies on lifting/carrying loads, 11 studies were included in the meta-analysis. We found a pooled OR of 1.6 (95% CI 1.3–1.9) with a pooled OR of 1.3 (95% CI 1.0–1.7) in low/moderate risk of bias studies (N=4 studies).
Awkward postures: Among the five studies on awkward postures, all five studies were included in the meta-analysis providing a pooled OR of 1.7 (95% CI 1.4–2.1); pooled OR was 2.2 (95% CI 1.2–3.9) in low/moderate risk of bias studies (N=2 studies).
Standing, walking, and "standing/walking": For standing (N=7 studies), walking (N=6 studies), and "standing/walking" (N=3 studies) pooled OR was 1.3 (95% CI 1.0–1.8), 1.3 (95% CI 1.1–1.5), and 1.1 (95% CI 1.0–1.2), respectively. In low/moderate risk of bias studies, ORs of 1.6 (95% CI 0.9–2.8) and 1.1 (95% CI 1.0–1.2) were found for standing (N=1) and "standing/walking" (N=3), while no low/moderate risk of bias studies existed for walking.
Kneeling, squatting, and "kneeling/squatting": For kneeling (N=5 studies), squatting (N=5 studies), and "kneeling/squatting" (N=2 studies) pooled OR was 1.2 (95% CI 0.9–1.5), 1.1 (95% CI 0.9–1.4), and 1.3 (95% CI 1.1–1.7), respectively. Only high risk of bias studies existed for kneeling and squatting, while two low/moderate risk of bias studies occurred for kneeling/squatting with a pooled OR of 1.3 (95% CI 1.1–1.7).
Climbing stairs: For climbing stairs (N=6 studies), pooled OR of 1.6 (95% CI 1.1–2.2) was found, with corresponding OR of 2.1 (95% CI 1.2–3.6) based on one low/moderate risk of bias study.
Sitting: For sitting (N=5 studies), pooled OR 0.6 (95% CI 0.5–0.9) was found, with a corresponding OR of 0.5 (95% CI 0.4–0.5) based on one low/moderate risk of bias study.
Combined mechanical exposures: Finally, for combined mechanical exposures (N=15 studies), a pooled OR of 1.7 (95% CI 1.4–2.0) was found with a pooled OR of 1.5 (95% CI 1.3–1.9) in low/moderate risk of bias studies (N=6 studies).

The meta-analysis generally indicated high heterogeneity, and we also found large differences with respect to the definition and assessment of exposure, outcome, and number of included confounders. Therefore, no exposure thresholds could be identified. In sensitivity analysis, no clear trend for measure of association was found for low/moderate vs high risk of bias studies, however higher risks were generally found for cohort/case-control vs cross-sectional studies, and outcome defined as total hip replacement vs other outcomes.

Eight studies estimated the risk of hip OA between men and women. Overall, difference in risk between sex was indicated for both lifting/carrying loads and standing. For lifting/carrying loads, higher risk was found among men, while higher risk was found among women for standing.

Conclusion

In this reference document conducted as a systematic review and meta-analysis, we found strong evidence of an association for combined mechanical exposures and hip OA, and moderate evidence for lifting/carrying loads. Limited evidence of an association was found for awkward postures, standing, walking, and climbing stairs, while insufficient evidence was found for standing/walking, kneeling, squatting, and kneeling/squatting. Finally, we found limited evidence of an association between sitting and hip OA with occupational sitting being a protective factor against developing hip OA. No exposure thresholds could be identified.

7. Danish resume (dansk resume)

Introduktion

Artrose (OA) i hoften er en degenerativ lidelse i ledbrusk og dens underliggende knogle, der kan påvirke en eller begge hofteled. Symptomer viser sig typisk i form af lyskesmerter ofte med udstråling til forsiden af låret og indimellem helt ned i knæet. Smerterne ved hofte OA er initialt overvejende relateret til belastning, men efterhånden tilkommer hvilesmerter og søvnforstyrrende smerter. Funktionsmæssigt oplever patienterne bevægeindskrænkning, haltende gang og reduceret gangdistance. I 2018 blev der i Danmark indsat ca. 12.000 hofteproteser, hvoraf ca. 10% var re-operationer.

Risikofaktorer for hofte OA omfatter hhv. arbejdsbetinget og ikke-arbejdsbetinget faktorer. Ikke-arbejdsrelaterede risikofaktorer omfatter hhv. alder, body mass index (BMI), tidligere hoftetraume, familiær disposition og medfødte misdannelser. Siden 2010 er der publiceret seks systematiske litteraturstudier, som undersøger sammenhængen mellem arbejdsrelaterede mekaniske belastninger og udvikling af hofte OA. Den mest undersøgte arbejdsrelaterede mekaniske belastning var løftearbejde, hvor alle seks systematiske litteraturstudier konkluderede at løftearbejde øger risikoen for udvikling af hofte OA. Derudover blev der fundet sammenhænge mellem arbejde i akavet arbejdsstillinger, vibrationer, at gå på trapper samt kombinationen af flere arbejdsrelaterede mekaniske belastninger og udvikling af hofte OA i 1-2 systematiske litteraturstudier. Baseret på to systematiske litteraturstudier, foreligger der uoverensstemmelse af effekten af stående arbejde, imens to systematiske reviews fandt en beskyttende effekt af siddende arbejde.

I Danmark kan hofte OA anerkendes som en erhvervssygdom, men grundet nye nationale og internationale studier har Arbejdsmarkedets Erhvervssikring og Erhvervssygdomsudvalget vurderet at der er behov for en udredning i form af et videnskabeligt referencedokument. Formålet med dette referencedokument er på baggrund af den foreliggende litteratur at undersøge sammenhængen mellem arbejdsrelaterede mekaniske belastninger og udvikling af hofte OA.

Metode og materiale

Referencedokumentet blev udarbejdet som et systematisk review og meta-analyse. Til inklusion af relevante artikler blev der udarbejdet en PECOS (Population, Exposure, Comparison, Outcome, Study design). Populationen omfattede personer i eller over den arbejdsdygtige alder. De arbejdsrelaterede mekaniske belastninger omfattede 12 belastninger herunder løftearbejde, akavede arbejdsstillinger, stående arbejder, gående arbejde, stående/gående arbejde, knæliggende arbejde, hugsiddende arbejde, knæ/hugsiddende arbejde, gå på trapper, siddende arbejde, kombinationen af flere mekaniske eksponeringer og andre arbejdsrelaterede mekaniske belastninger. Udfaldet var hofteartrose. Studiedesign inkluderede kortestudier, case-kontrol-studier og tværsnitsstudier.

Artikler publiceret før juni 2022 blev identificeret via en systematisk litteratursøgning i følgende videnskabelige databaser: Cochrane, PubMed, Web of Science, PsycINFO, Embase og Cinahl. Identificering af relevant artikler blev udført via hhv. titel/abstract screening og gennemlæsning af hele artiklen. Dette blev foretaget uafhængigt af to af referencedokumentets forfattere. Ved uenighed blev artiklen diskuteret indtil alle var enige om den endelige afgørelse.

For alle inkluderede artikler blev relevant information herunder forfatter, studiedesign, udfald, udfaldsvurdering, eksponering, eksponeringsvurdering, confoundere og resultater udtrukket og præsenteret i tabeller. Data-udtrækningen blev foretaget af en forfatterne og kvalitetstjekket af en anden forfatter. Efterfølgende blev artiklernes epidemiologiske kvalitet vurderet ved hjælp af et modificeret kvalitetsværktøj, som blev tilpasset projektets formål. Det modificerede værktøj indeholdt otte epidemiologiske domæner herunder fem "vigtige" domæner og tre "mindre vigtige" domæner. Baseret på de otte domæner blev hver artikels epidemiologiske kvalitet vurderet til havende lav, moderat eller høj risiko for bias.

Sammenhængen mellem 11 af de 12 arbejdsrelaterede mekaniske belastninger og udvikling af hofte OA blev undersøgt via Forest plots og meta-analyser. Der blev ikke foretaget analyser af "andre arbejdsrelaterede mekaniske belastninger" pga. meget store forskelle i eksponeringen. Forest plots illustrerede de enkelte studiers risikoestimater, det vægtede risikoestimat samt et estimat (I%) som udtrykker graden i forskel/ulighed mellem studiernes risikoestimater. Eksponerings-respons sammenhænge blev undersøgt. For at undersøge risikoen for publikationsbias blev der udarbejdet Funnel plots og foretaget Egger´s test. Der blev også foretaget sensitivitetsanalyser for at undersøge effekten af studiernes kvalitet (lav/moderate vs. høj risiko for bias), studiedesign (kohorte vs. case-kontrol-studier), samt forskelle mellem hoftealloplastik og andre hofte-artrose-diagnoser.

På tværs af de inkluderede studier blev evidensgraden for en sammenhæng vurderet ud fra Arbejdsmiljøforskningsfondens retningslinjer. Evidensen blev vurderet baseret på adskillige epidemiologiske parametre herunder antallet af studier, konsistens mellem studierne, pooled OR, eksponering-respons sammenhænge, pooled OR i studier med lav/moderat risiko for bias og publikationsbias. Kvaliteten af evidensgraden for en sammenhæng blev vurderet som god (+++), nogen (++), begrænset (+), utilstrækkelig (0) evidens for årsagssammenhæng eller god evidens for manglende årsagssammenhæng (-).

Resultater

I den systematiske litteratursøgning af artikler publiceret før 16. juni 2022 blev 6172 artikler identificeret, hvoraf 1873 artikler var dubletter. Efter titel og abstract screening af 4299 artikler blev yderligere 4202 artikler ekskluderet. De resterende 97 artikler blev gennemlæst, hvoraf 24 artikler opfyldte inklusionskriterierne. To artikler blev vurderet som havende lav risiko for bias, seks blev vurderet som moderat risiko for bias og 16 blev vurderet som høj risiko for bias.

Løftearbejde: Sammenhængen mellem løftearbejde og hofte OA blev undersøgt i 13 studier. Der var generelt enighed om, at løftearbejde medfører en øget risiko for hofte OA, dog fandt de to største studier ingen eller en begrænset effekt. Resultaterne fra meta-analysen (N=11 studier) viste en odds ratio (OR) på 1,6 (95% CI 1,3–1,9). Der var indikation af publikationsbias af små studier med positiv sammenhæng (Egger´s test=0.0014%). Der var derudover store epidemiologiske forskelle mellem studierne primært vedr. eksponering (I^2=70,95%), hvorfor der ikke kunne identificeres sikre tærskelværdier. På baggrund af ovenstående vurderes der at foreligge nogen grad af evidens for en årsagssammenhæng (++).

Akavede arbejdsstillinger: Sammenhængen mellem akavede arbejdsstillinger og hofte OA blev undersøgt i 5 studier. Der var generelt enighed om, at akavede arbejdsstillinger medfører en øget risiko for hofte OA. Resultater baseret på meta-analysen (N=5 studier) viste en OR på 1,7 (95 % CI 1,4–2,1). Baseret på få studier var der ikke indikation af publikationsbias af små studier med positiv sammenhæng (Egger´s test=0.37%). Der forekom store forskelle mellem studierne, men heterogeniteten kunne statistisk set ikke undersøges. På baggrund af ovenstående vurderes der, at foreligge begrænset evidens for en årsagssammenhæng (+).

Stående arbejde: Stående arbejde blev undersøgt i 7 studier, hvoraf flere viste en øget risiko for hofte OA. Meta-analysen (N=7 studier) viste en OR på 1,3 (95% CI 1,0–1,8) med en vis grad af heterogenitet (I^2=44.74%). Der forekom en tendens til publikation bias (Egger´s test=0,07%). Graden af evidens vurderes at være begrænset (+).

Gående arbejde: Gående arbejde blev undersøgt i 7 studier, hvoraf alle viste en begrænset øget risiko for hofte OA. Meta-analysen (N=6 studier) viste en OR på 1,3 (95% CI 1,1–1,5), dog kunne heterogeniteten statistisk set ikke vurderes. Der var ikke indikation af publikationsbias (Egger´s test=0,66%). Graden af evidens vurderes at være begrænset (+).

Stående/gående arbejde: Stående/gående arbejde blev undersøgt i 3 studier. Meta-analysen (N=3 studier) viste en OR på 1,1 (95% CI 1,0–1,2). På grund af få studier var det svært at vurdere publikationsbias (Egger´s test=0,42%). Der foreligger utilstrækkelig evidens for en årsags-sammenhæng (0).

Knæliggende arbejde: Knæliggende arbejde blev undersøgt i 6 studier, som generelt viste ingen eller begrænset effekt. Meta-analysen (N=5 studier) viste en OR på 1,2 (95% CI 0,9–1,5), og der var ingen klar indikation af publikation bias (Egger´s test=0,99%). Graden af evidens vurderes at være utilstrækkelig (0).

Hugsiddende arbejde: Hugsiddende arbejde blev undersøgt i 6 studier, som generelt viste ingen eller begrænset effekt. Meta-analysen (N=5 studier) viste en OR på 1,1 (95 % CI 0,9–1,4). Der var ikke indikation af publikationsbias (Egger´s test=0,45%). Graden af evidens vurderes at være utilstrækkelig (0).

Knæliggende/hugsiddende arbejde: Knæliggende/hugsiddende arbejde blev undersøgt i 2 studier. Meta-analysen (N=2 studier) viste en OR på 1,3 (95 % CI 1,1–1,7) med en I^2=58,58%. På grund af få studier var det svært at vurdere publikationsbias (Egger´s test=0,84%). Graden af evidens vurderes at være utilstrækkelig (0).

Gå på trappe: Trappegang under arbejde blev undersøgt i 7 studier, hvor flere viste en øget risiko for hofte OA. Meta-analysen (N=6 studier) viste en OR på 1,6 (95% CI 1,1–2,2) med I^2=49,79%. Der var ikke umiddelbart indikation af publikationsbias (Egger´s test=0,23%). Graden af evidens vurderes at være begrænset (+).

Siddende arbejde: Siddende arbejde blev undersøgt i 6 studier, som generelt viste en beskyttende effekt. Meta-analysen (N=5 studier) viste en OR på 0,6 (95% CI 0,5–0,9) med I^2=78,17%. Der var ikke indikation af publikationsbias (Egger´s test=0,24%). Graden af evidens vurderes at være begrænset (+).

Kombinerede mekaniske belastninger: Kombinationen af forskellige arbejdsrelaterede mekaniske belastninger blev undersøgt i 15 studier, som generel viste enighed om en sammenhæng. Resultater baseret på meta-analysen (N=15 studier) viste en OR på 1,7 (95% CI 1,4–2,0) med I^2=72,74%. Der var indikation af publikationsbias (Egger´s test=0,0001%). Det vurderes at der foreligger god evidens for en sammenhæng (+++).

Der var store epidemiologiske forskelle mellem studierne vedrørende definition og vurdering af hhv. udfald, eksponering og antallet af confounders. Særligt forskellene i de arbejdsrelaterede mekaniske belastninger gjorde sammenligningen mellem studierne vanskelig, hvorfor det, set i forhold til antallet af studier, ikke var muligt at identificere sikre tærskelværdier. Sensitivitetsanalyser baseret på den epidemiologiske studiekvalitet viste ikke et entydigt billede. Derimod fandt vi generelt større OR i kohorte og case-kontrol studier og i studier hvor udfaldet var hoftealloplastik. Forskelle i risikoen for mænd og kvinder blev undersøgt i otte studier, som fandt en større risiko for mænd i relation til løftearbejde, imens kvinder havde større risiko i forhold til stående arbejde.

Konklusion

Baseret på dette referencedokument udarbejdet som et systematisk review og meta-analyse vurderes det, at der foreligger god evidens for en sammenhæng for kombinationen af flere arbejdsrelaterede mekaniske belastninger og nogen evidens for løftearbejde. Der foreligger begrænset evidens for en sammenhæng for akavede arbejdsstillinger, stående arbejde, gående arbejde, gå på trapper, imens der foreligger utilstrækkelig evidens for stående/gående arbejde, knæliggende arbejde, hugsiddende arbejde, og "knæliggende/hugsiddende arbejde". Der er begrænset evidens for at siddende arbejde kan have en beskyttende effekt. Der kunne ikke identificeres sikre tærskelværdier.

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72 Felson DT. Obesity and vocational and avocational overload of the joint as risk factors for osteoarthritis. *J Rheumatol Suppl* 2004;70:2-5.
73 Williams PT. Effects of running and walking on osteoarthritis and hip replacement risk. *Med Sci Sports Exerc* 2013;45:1292-7.
74 Badley EM, Zahid S, Wilfong JM, Perruccio AV. Relationship Between Body Mass Index and Osteoarthritis for Single and Multisite Osteoarthritis of the Hand, Hip, or Knee: Findings From a Canadian Longitudinal Study on Aging. *Arthritis Care Res (Hoboken)* 2022;74:1879-1887.

75 Seidler A, Euler U, Bolm-Audorff U et al. Physical workload and accelerated occurrence of lumbar spine diseases: risk and rate advancement periods in a German multicenter case-control study. *Scand J Work Environ Health* 2011;37:30-6.

9. Appendix

9.1 Literature search

Search History (75) View Saved

#	Searches	Results	Type	Actions	Annotations
1	exp Occupational Exposure/	68109	Advanced	Display More Results	
2	exp Occupational Diseases/	139813	Advanced	Display More Results	
3	Lifting/	2801	Advanced	Display More Results	
4	Workload/	23365	Advanced	Display More Results	
5	Workplace/	27615	Advanced	Display More Results	
6	"axial loading*".ab,kf,ti.	1467	Advanced	Display More Results	
7	heavy lifting.ab,kf,ti.	478	Advanced	Display More Results	
8	"job site*".ab,kf,ti.	108	Advanced	Display More Results	
9	loadbearing.ab,kf,ti.	71	Advanced	Display More Results	
10	Weight-Bearing/	21598	Advanced	Display More Results	
11	load-bearing.ab,kf,ti.	4798	Advanced	Display More Results	
12	(occupational adj2 (disease* or exposure* or illness*)).ab,kf,ti.	38935	Advanced	Display More Results	
13	(physical* adj2 (work or job)).ab,kf,ti.	5039	Advanced	Display More Results	
14	strain.ab,kf,ti.	480889	Advanced	Display More Results	
15	(weight bearing or weightbearing).ab,kf,ti.	18793	Advanced	Display More Results	
16	carrying.ab,kf,ti.	138769	Advanced	Display More	

Contract

					Results
17	lifting.ab,kf,ti.	12645	Advanced	Display More Results	
18	"work load*".ab,kf,ti.	5017	Advanced	Display More Results	
19	"work location*".ab,kf,ti.	333	Advanced	Display More Results	
20	"work place*".ab,kf,ti.	2931	Advanced	Display More Results	
21	"work site*".ab,kf,ti.	1256	Advanced	Display More Results	
22	"workload*".ab,kf,ti.	33042	Advanced	Display More Results	
23	"workplace*".ab,kf,ti.	49872	Advanced	Display More Results	
24	"Worksite*".ab,kf,ti.	3734	Advanced	Display More Results	
25	"workabilit*".ab,kf,ti.	898	Advanced	Display More Results	
26	"work abilit*".ab,kf,ti.	2200	Advanced	Display More Results	
27	repetitive work.ab,kf,ti.	341	Advanced	Display More Results	
28	lifting.ab,kf,ti.	12645	Advanced	Display More Results	
29	squatting.ab,kf,ti.	1776	Advanced	Display More Results	
30	bending.ab,kf,ti.	39044	Advanced	Display More Results	
31	kneeling.ab,kf,ti.	975	Advanced	Display More Results	
32	exp occupational groups/ or farmers/	685499	Advanced	Display More Results	
33	exp Agricultural Workers' Diseases/	6658	Advanced		

				Display More Results	
34	Construction Industry/	1931	Advanced	Display More Results	
35	exp Work/	68777	Advanced	Display More Results	
36	exp Employment/	96034	Advanced	Display More Results	
37	Industry/	31934	Advanced	Display More Results	
38	exp Commerce/	67524	Advanced	Display More Results	
39	(agricultural worker* adj2 disease*).ab,kf,ti.	296	Advanced	Display More Results	
40	(building adj1 (trade* or industr*)).ab,kf,ti.	444	Advanced	Display More Results	
41	(construction adj1 (trade* or industr*)).ab,kf,ti.	1948	Advanced	Display More Results	
42	occupation.ab,kf,ti.	35985	Advanced	Display More Results	
43	"vocation*".ab,kf,ti.	13594	Advanced	Display More Results	
44	"employee*".ab,kf,ti.	52643	Advanced	Display More Results	
45	"occupational group*".ab,kf,ti.	3903	Advanced	Display More Results	
46	personnel.ab,kf,ti.	89031	Advanced	Display More Results	
47	(worker or workers).ab,kf,ti.	211429	Advanced	Display More Results	
48	employment.ab,kf,ti.	67058	Advanced	Display More Results	
49	(labor force* or labour force*).ab,kf,ti.	6196	Advanced	Display More Results	

50	(labor market or labour market).ab,kf,ti.	5305	Advanced	Display More Results
51	occupational status.ab,kf,ti.	2544	Advanced	Display More Results
52	underemployment.ab,kf,ti.	290	Advanced	Display More Results
53	"business*".ab,kf,ti.	36607	Advanced	Display More Results
54	"commerc*".ab,kf,ti.	306441	Advanced	Display More Results
55	"vendor*".ab,kf,ti.	8404	Advanced	Display More Results
56	cold temperature/ or hot temperature/	170168	Advanced	Display More Results
57	Osteoarthritis, Hip/	9429	Advanced	Display More Results
58	"coxarthr*".ab,kf,ti.	1861	Advanced	Display More Results
59	(osteoarthr* adj2 (hip or hips)).ab,kf,ti.	3691	Advanced	Display More Results
60	or/57-59	12006	Advanced	Display More Results
61	Hip Injuries/ or Hip/	14388	Advanced	Display More Results
62	(hip or hips or coxa*).ab,kf,ti.	166454	Advanced	Display More Results
63	or/61-62	168952	Advanced	Display More Results
64	Osteoarthritis/	41336	Advanced	Display More Results
65	(osteoarthr* or degenerative arthr* or osteo-arthr*).ab,kf,ti.	88503	Advanced	Display More Results
66	or/64-65	100427	Advanced	Display More Results

67	and/63,66	16857	Advanced	Display More Results
68	or/60,67	21302	Advanced	Display More Results
69	Animals/	7121048	Advanced	Display More Results
70	Humans/	20518164	Advanced	Display More Results
71	69 not 70	4979354	Advanced	Display More Results
72	or/1-56	2469214	Advanced	Display More Results
73	and/68,72	1645	Advanced	Display More Results
74	73 not 71	1594	Advanced	Display More Results
75	limit 74 to (danish or english or norwegian or swedish)	1398	Advanced	Display More Results

Save Remove Combine with: AND OR

Save All Edit Create RSS Create Auto-Alert View Saved Email All Search History Copy Search History Link Copy Search History

Basic Search | Find Citation | Search Tools | Search Fields | **Advanced Search** | Multi-Field Search 1 Resource selected | Hide | Change

Ovid MEDLINE(R) ALL 1946 to May 31, 2022

9.2 Risk of bias assessment

Case-Control Study	Yes	No	Unclear
Major domain 1 – study design and selection			
Were the cases recruited in an acceptable way? Consider the following: ● Are the cases representative of a population, clearly defined and differentiated from controls? ● Was there an established reliable system for selecting all the cases? ● Were inclusion and exclusion criteria explicit and applied similarly to all eligible cases?			
Were the controls selected in an acceptable way? Consider the following: ● Are the controls representative of a population and clearly defined? ● Are the same inclusion and exclusion criteria for cases used to select controls (equally applied) and matched appropriately? ● Is it clearly established that controls are non-cases?			
Is the participation rate satisfactory? Consider the following: ● Are there large differences between the two groups? ● Is the participation rate low?			
Major domain 2 – Exposure			
Was the exposure accurately measured to minimise bias? Consider the following: ● Is the exposure clearly defined? ● Do measurements truly reflect what it is supposed to measure (have they been validated?). ● Is the method of assessment reliable?			
Major domain 3 – Outcome			
Was the outcome accurately measured to minimise bias? Consider the following: ● Is the outcome clearly defined? ● Do measurements truly reflect what it is supposed to measure (have they been validated?). ● Is the method of assessment reliable?			
Major domain 4 – Non-participants			
Is comparison made between participants and non-participants? Consider the following: ● Is similarities or differences established?			
Major domain 5 – Analysis method			
Was the analysis method adequate? Consider the following: ● Are the main potential confounders identified and taken into account in the analysis? ● Were adequate statistical models used to reduce bias?			
Minor domain 1 – Funding			
Was the source of funding provided? Consider the following: ● Was the study affected by sponsors? ● Did sponsoring organization participate in the analysis?			
Minor domain 2 – Chronology			
Could chronology be established? Consider the following: ● Was the timeframe sufficient to see an association between the exposure and outcome?			
Minor domain 3 – Conflict of interest			
Was the study without any conflict of interest? Consider the following: ● Was the study affected by the authors affiliations or interests?			

Cohort Study	Yes	No	Unclear
Major domain 1 – study design and selection			
Was the cohort recruited in an acceptable way? Consider the following: ● Is it representative of a defined population and clearly specified? ● Are groups comparable in all respects other than the factor under investigation? ● Was everybody included who should have been?			
Was the follow-up of subjects acceptable? Consider the following: ● Conventionally, a 20% drop out rate is acceptable, but observational studies conducted over longer periods, a higher drop-out rate is to be expected. ● Were losses to follow-up taken into account in the analysis (sensitivity analysis, described etc.)?			
Major domain 2 – Exposure			
Was the exposure accurately measured to minimise bias? Consider the following: ● Is the exposure clearly defined? ● Do measurements truly reflect what it is supposed to measure (have they been validated?). ● Is the method of assessment reliable? ● Were all the subjects classified into exposure groups using the same procedure?			
Major domain 3 – Outcome			
Was the outcome accurately measured to minimise bias? Consider the following: ● Is the outcome clearly defined? ● Do measurements truly reflect what it is supposed to measure (have they been validated?). ● Is the method of assessment reliable? ● Were the measurement methods similar in the different groups? ● If blinding is not possible, is there some recognition that knowledge of exposure status could influence the assessment of the outcome?			
Major domain 4 – Enrolment			
Was the outcome taken into account at enrolment? Consider the following: ● Some participants might have the outcome at the time of enrolment. Is it assessed at baseline in the analysis?			
Major domain 5 – Analysis method			
Was the analysis method adequate? Consider the following: ● Are the main potential confounders identified and taken into account in the analysis? ● Were adequate statistical models used to reduce bias?			
Minor domain 1 – Funding			
Was the source of funding provided? Consider the following: ● Was the study affected by sponsors? ● Did sponsoring organization participate in the analysis?			
Minor domain 2 – Chronology			
Could chronology be established? Consider the following: ● Was the timeframe sufficient to see an association between the exposure and outcome? ● Was the follow-up long enough for the outcome to occur?			
Minor domain 3 – Conflict of interest			
Was the study without any conflict of interest? Consider the following: ● Was the study affected by the authors affiliations or interests?			

Cross-sectional studies	Yes	No	Unclear
Major domain 1 – study design and selection			
Were the subjects recruited in an acceptable way? Consider the following: ● Are subjects representative of a population, clearly defined and differentiated from controls? ● Was the method of selection of the subjects clearly described? ● Could the way the sample was obtained introduce bias?			
Is the participation rate satisfactory? Consider the following: ● Was the sample size based on pre-study considerations of statistical power? ● Was a satisfactory response rate achieved or was the sample size justified?			
Major domain 2 – Exposure			
Was the exposure accurately measured to minimise bias? Consider the following: ● Is the exposure clearly defined? ● Do measurements truly reflect what it is supposed to measure (have they been validated?). ● Is the method of assessment reliable?			
Major domain 3 – Outcome			
Was the outcome accurately measured to minimise bias? Consider the following: ● Is the outcome clearly defined? ● Do measurements truly reflect what it is supposed to measure (have they been validated?). ● Is the method of assessment reliable?			
Major domain 4 – Non-participants			
Is comparison made between participants and non-participants? Consider the following: ● Is similarities or differences established?			
Major domain 5 – Analysis method			
Was the analysis method adequate? Consider the following: ● Are the main potential confounders identified and taken into account in the analysis? ● Were adequate statistical models used to reduce bias?			
Minor domain 1 – Funding			
Was the source of funding provided? Consider the following: ● Was the study affected by sponsors? ● Did sponsoring organization participate in the analysis?			
Minor domain 2 – Chronology			
Could chronology be established? Consider the following: ● Was the timeframe sufficient to see an association between the exposure and outcome? ● Was the follow-up long enough for the outcome to occur?			
Minor domain 3 – Conflict of interest			
Was the study without any conflict of interest? Consider the following: ● Was the study affected by the authors affiliations or interests?			

9.3 Evidence of association

Danish Labour Market Insurance and Occupational Diseases Committee

Degree of evidence for a causal association between exposure to a specific risk factor and a specific outcome.

The following categories are applied:

+++	Strong evidence of a causal association
++	Moderate evidence of a causal association
+	Limited evidence of a causal association
0	Insufficient evidence of a causal association
-	Evidence suggesting lack of a causal association

Description of categories:

Strong evidence of a causal association (+++): A causal association is very likely. A positive relation between exposure to a risk factor and outcome has been observed in several epidemiological studies. It can be excluded with a reasonable degree of certainty that this association can be explained by chance, bias or confounding.

Moderate evidence of a causal association (++): A causal association is likely. A positive relation between exposure to a risk factor and outcome has been observed in several epidemiological studies. It cannot be excluded with a reasonable degree of certainty that this association can be explained by chance, bias or confounding, although this is not a very probable explanation.

Limited evidence of a causal association (+): A causal association is possible. A positive relation between exposure to a risk factor and outcome has been observed in several epidemiological studies. It is not unlikely that this association can be explained by chance, bias or confounding.

*Insufficient evidence of a causal association (0): A*vailable studies are of insufficient quality, consistency, or statistical weight to allow a conclusion on the presence or absence of a causal association.

Evidence suggesting lack of a causal association (-): Several studies of sufficient quality, consistency and statistical weight suggest that the specific risk factor is not causally related to the specific outcome.

Comments: The classification does not include a category for which a causal association is considered to be established without any doubt. The key criterion is the epidemiological evidence. The probability that chance, bias and confounding can explain observed associations are criteria that includes criteria such as consistency, number of 'high quality' studies, types of design etc. Biological plausibility and contributory information can support the evidence of a causal association.

9.4 Excluded articles from full-text reading

	References	Reason for exlcusion
1	Ageberg E, Engstrom G, Gerhardsson De Verdier M, Rollof J, Roos EM, Lohmander LS. Effect of leisure time physical activity on severe knee or hip osteoarthritis leading to total joint replacement: A population-based prospective cohort study. BMC Musculoskelet Disord. 2012;13.	Other reasons (e.g., abstract, books).
2	Andersen S, Thygesen LC, Davidsen M, Helweg-Larsen K. Cumulative years in occupation and the risk of hip or knee osteoarthritis in men and women: a register-based follow-up study. Occup Environ Med. 2012;69(5):325-30.	Exposure criteria not fulfilled.
3	Andersen S, Thygesen LC, Davidsen M, Helweg-Larsen K. Cumulative years in occupation and the risk of hip or knee osteoarthritis in men and women: a register-based follow-up study. Occupational and Environmental Medicine. 2011;11.	Exposure criteria not fulfilled.
4	Andersson S, Nilsson B, Hessel T, Saraste M, Noren A, Stevens-Andersson A, et al. Degenerative joint disease in ballet dancers. Clinical Orthopaedics and Related Research. 1989;238:233-6.	Exposure criteria not fulfilled.
5	Axmacher B, Lindberg H. Coxarthrosis in farmers. Clin Orthop. 1993(287):82-6.	Exposure criteria not fulfilled.
6	Bullough P, Goodfellow J, O'Conner J. The relationship between degenerative changes and load-bearing in the human hip. J Bone Joint Surg Br. 1973;55(4):746-58.	Exposure criteria not fulfilled.
7	Cimmino MA, Parodi M. Risk factors for osteoarthritis. Seminars in Arthritis and Rheumatism. 2004;34(2 SUPPL.):29-34.	Other reasons (e.g., abstract, books).
8	Cimmino MA, Sarzi-Puttini P, Scarpa R, Caporali R, Parazzini F, Zaninelli A, et al. Clinical presentation of osteoarthritis in general practice: determinants of pain in Italian patients in the AMICA study. Semin Arthritis Rheum. 2005;35(1 Suppl 1):17-23.	Outcome criteria not fulfilled.
9	Cleveland RJ, Schwartz TA, Prizer LP, Randolph R, Schoster B, Renner JB, et al. Associations of educational attainment, occupation, and community poverty with hip osteoarthritis. Arthritis care & research. 2013;65(6):954-61.	Exposure criteria not fulfilled.
10	Cooper C, Campbell L, Byng P, Croft P, Coggon D. Occupational activity and the risk of hip osteoarthritis. Ann Rheum Dis. 1996;55(9):680-2.	Other reasons (e.g., abstract, books).
11	Cooper DJ, Scammell BE, Batt ME, Palmer D. Factors associated with pain and osteoarthritis at the hip and knee in Great Britain's Olympians: a cross-sectional study. British Journal of Sports Medicine. 2018;52(17):9.	Exposure criteria not fulfilled.
12	Croft P, Coggon D, Cruddas M, Cooper C. Osteoarthritis of the hip: An occupational disease in farmers. Br Med J. 1992;304(6837):1269-72.	Exposure criteria not fulfilled.
13	Cunningham RJ. Farmer's hip. Bmj. 1992;305(6845):118-9.	Other reasons (e.g., abstract, books).
14	Felson DT. Relation of obesity and of vocational and avocational risk factors to osteoarthritis. J Rheumatol. 2005;32(6):1133-5.	Other reasons (e.g., abstract, books).
15	Felson DT. Obesity and vocational and avocational overload of the joint as risk factors for osteoarthritis. J Rheumatol Suppl. 2004;70:2-5.	Other reasons (e.g., abstract, books).
16	Felson DT. Do occupation-related physical factors contribute to arthritis? Bailliere's Clinical Rheumatology. 1994;8(1):63-77.	Other reasons (e.g., abstract, books).
17	Franklin J, Ingvarsson T, Englund M, Lohmander S. Association between occupation and knee and hip replacement due to osteoarthritis: a case-control study. Arthritis Res Ther. 2010;12(3):R102.	Exposure criteria not fulfilled.
18	Fransen M, Agaliotis M, Bridgett L, MacKey MG. Hip and knee pain: Role of occupational factors. Best Practice and Research: Clinical Rheumatology. 2011;25(1):81-101.	Other reasons (e.g., abstract, books).

19	Goekoop RJ, Kloppenburg M, Kroon HM, Dirkse LEV, Huizinga TWJ, Westendorp RGJ, et al. Determinants of absence of osteoarthritis in old age. Scand J Rheumatol. 2011;40(1):68-73.	No measure of an association.
20	Gokhale CN, Simon SS, Hadaye RS, Lavangare SR. A cross-sectional study to screen community health volunteers for hip/knee-osteoarthritis and osteoporosis. J. 2019;8(6):2101-5.	Exposure criteria not fulfilled.
21	Grotle M, Hagen KB, Natvig B, Dahl FA, Kvien TK. Obesity and osteoarthritis in knee, hip and/or hand: An epidemiological study in the general population with 10 years follow-up. BMC Musculoskelet Disord. 2008;9	Exposure criteria not fulfilled.
22	Harris EC, Coggon D. HIP osteoarthritis and work. Best Practice and Research: Clinical Rheumatology. 2015;29(3):462-82.	Other reasons (e.g., abstract, books).
23	Hochberg MC. Risk factors for the development and progression of hip osteoarthritis. J Rheumatol. 2005;32(6):1135-6.	Other reasons (e.g., abstract, books).
24	Holmberg S, Stiernstrom EL, Thelin A, Svardsudd K. Musculoskeletal symptoms among farmers and non-farmers: a population-based study. Int J Occup Environ Health. 2002;8(4):339-45.	Exposure criteria not fulfilled.
25	Hubertsson J, Turkiewicz A, Petersson I, Englund M. OCCUPATION AND RISK OF SICK LEAVE AND DISABILITY PENSION DUE TO KNEE AND HIP OSTEOARTHRITIS IN MEN AND WOMEN. Ann Rheum Dis. 2015;74:552-3.	Other reasons (e.g., abstract, books).
26	Hubertsson J, Turkiewicz A, Petersson IF, Englund M. Understanding Occupation, Sick Leave, and Disability Pension Due to Knee and Hip Osteoarthritis From a Sex Perspective. Arthritis care & research. 2017;69(2):226-33.	Outcome criteria not fulfilled.
27	Iosifidis MI, Tsarouhas A, Fylaktou A. Lower limb clinical and radiographic osteoarthritis in former elite male athletes. Knee Surg Sports Traumatol Arthrosc. 2015;23(9):2528-35.	Outcome criteria not fulfilled.
28	Jacobsen S, Sonne-Holm S. Hip dysplasia: A significant risk factor for the development of hip osteoarthritis. A cross-sectional survey. Rheumatology (Oxford). 2005;44(2):211-8.	Outcome criteria not fulfilled.
29	Jacobsen S, Sonne-Holm S, Soballe K, Gebuhr P, Lund B. Joint space width in dysplasia of the hip. Journal of Bone and Joint Surgery - Series B. 2005;87(4):471-7.	Exposure criteria not fulfilled.
30	Jarvholm B, From C, Lewold S, Malchau H, Vingard E. Incidence of surgically treated osteoarthritis in the hip and knee in male construction workers. Occupational and Environmental Medicine. 2008;65(4):275-8.	Exposure criteria not fulfilled.
31	Jarvholm B, Lundstrom R, Malchau H, Rehn B, Vingard E. Osteoarthritis in the hip and whole-body vibration in heavy vehicles. Int Arch Occup Environ Health. 2004;77(6):424-6.	Exposure criteria not fulfilled.
32	Johansson H, Hongslo Vala C, Oden A, Lorentzon M, McCloskey E, Kanis JA, et al. Low risk for hip fracture and high risk for hip arthroplasty due to osteoarthritis among Swedish farmers. Osteoporos Int. 2018;29(3):741-9.	Exposure criteria not fulfilled.
33	Kettunen JA, Kujala UM, Kaprio J, Koskenvuo M, Sarna S. Lower-limb function among former elite male athletes. Am J Sports Med. 2001;29(1):2-8.	Exposure criteria not fulfilled.
34	Kirkhorn S, Greenlee RT, Reeser JC. The Epidemiology of Agriculture-related Osteoarthritis and its Impact on Occupational Disability. Wis Med J. 2003;102(7):38-44.	Other reasons (e.g., abstract, books).
35	Kujala UM, Kaprio J, Sarna S. Osteoarthritis of weight bearing joints of low limbs in former elite male athletes. Br Med J. 1994;308(6923):231-4.	No measure of an association.
36	L'Hermette M, Polle G, Tourny-Chollet C, Dujardin F. Hip passive range of motion and frequency of radiographic hip osteoarthritis in former elite handball players. British Journal of Sports Medicine. 2006;40(1):45-9.	Exposure criteria not fulfilled.
37	Lanyon P, Muir K, Doherty S, Doherty M. Assessment of a genetic contribution to osteoarthritis of the hip: sibling study. Br Med J. 2000;321(7270):1179-83.	Exposure criteria not fulfilled.
38	Lee CG. Work-related musculoskeletal disorders in Korean farmers. J Korean Med Assoc. 2012;55(11):1054-62.	Other reasons (e.g., abstract, books).
39	Lindberg H. [Hereditary and mechanical factors behind arthrosis of the hip and the knee]. Lakartidningen. 1990;87(51-52):4403-4, 6.	Other reasons (e.g., abstract, books).
40	Lindberg H, Danielsson LG. The relation between labor and coxarthrosis. Clinical Orthopaedics and Related Research. 1984;191:159-61.	Exposure criteria not fulfilled.

41	Lindberg H, Roos H, Gardsell P. Prevalence of coxarthrosis in former soccer players: 286 players compared with matched controls. Acta Orthop Scand. 1993;64(2):165-7.	Exposure criteria not fulfilled.
42	Mahomed NN. Does occupational lifting cause hip osteoarthritis? J Rheumatol. 2000;27(2):292-3.	Other reasons (e.g., abstract, books).
43	Nicholls RA. Intra-articular disorders of the hip in athletes. Phys Ther Sport. 2004;5(1):17-25.	Other reasons (e.g., abstract, books).
44	Plotnikoff R, Karunamuni N, Lytvyak E, Penfold C, Schopflocher D, Imayama I, et al. Osteoarthritis prevalence and modifiable factors: a population study. BMC Public Health. 2015;15:10.	Exposure criteria not fulfilled.
45	Pope DP, Hunt IM, Birrell FN, Silman AJ, Macfarlane GJ. Hip pain onset in relation to cumulative workplace and leisure time mechanical load: A population based case-control study. Ann Rheum Dis. 2003;62(4):322-6.	Outcome criteria not fulfilled.
46	Roos H. Are there long-term sequelae from soccer? Clin Sports Med. 1998;17(4):819-31.	Other reasons (e.g., abstract, books).
47	Rossignol M. Primary osteoarthritis and occupation in the Quebec National Health and Social Survey. Occupational and Environmental Medicine. 2004;61(9):729-35.	Outcome criteria not fulfilled.
48	Rossignol M, Leclerc A, Allaert FA, Rozenberg S, Valat JP, Avouac B, et al. Primary osteoarthritis of hip, knee, and hand in relation to occupational exposure. Occupational and Environmental Medicine. 2005;62(11):772-7.	Exposure criteria not fulfilled.
49	Rossignol M, Leclerc A, Hilliquin P, Allaert FA, Rozenberg S, Valat J, et al. Primary osteoarthritis and occupations: a national cross sectional survey of 10 412 symptomatic patients. Occup Environ Med. 2003;60(11):882-6.	Exposure criteria not fulfilled.
50	Sandmark H. Musculoskeletal dysfunction in physical education teachers. Occupational and Environmental Medicine. 2000;57(10):673-7.	Exposure criteria not fulfilled.
51	Schmitt H, Brocai DRC, Lukoschek M. High prevalence of hip arthrosis in former elite javelin throwers and high jumpers: 41 Athletes examined more than 10 years after retirement from competitive sports. Acta Orthop Scand. 2004;75(1):34-9.	Exposure criteria not fulfilled.
52	Schneider S, Schmitt G, Mau H, Schmitt H, Sabo D, Richter W. Prevalence and correlates of osteoarthritis in Germany. Representative data from the First National Health Survey. Orthopade. 2005;34(8):782-90.	Other reasons (e.g., abstract, books).
53	Seok H, Choi SJ, Yoon JH, Song GG, Won JU, Kim JH, et al. The association between osteoarthritis and occupational clusters in the Korean population: A nationwide study. PLoS ONE. 2017;12(1) (no pagination).	Exposure criteria not fulfilled.
54	Spector TD, Harris PA, Hart DJ, Cicuttini FM, Nandra D, Etherington J, et al. Risk of osteoarthritis associated with long-term weight-bearing sports: a radiologic survey of the hips and knees in female ex-athletes and population controls. Arthritis Rheum. 1996;39(6):988-95.	Exposure criteria not fulfilled.
55	Steen Rubak T, Wulff Svendsen S, Frost P. 0140Risk of total hip replacement in relationship to cumulative exposures in the work environment. Occup Environ Med. 2014;71:A17-A.	Other reasons (e.g., abstract, books).
56	Tateuchi H, Koyama Y, Akiyama H, Goto K, So K, Kuroda Y, et al. Daily cumulative hip moment is associated with radiographic progression of secondary hip osteoarthritis. Osteoarthritis and Cartilage. 2017;25(8):1291-8.	Exposure criteria not fulfilled.
57	Taylor-Gjevre RM, Trask C, King N, Koehncke N, Saskatchewan Farm Injury Cohort Study T. Prevalence and occupational impact of arthritis in Saskatchewan farmers. J. 2015;20(2):205-16.	Study design criteria not fulfilled.
58	Teichtahl AJ, Smith S, Wang YY, Wluka A, O'Sullivan R, Giles GG, et al. Occupational risk factors for hip osteoarthritis are associated with early hip structural abnormalities: a 3.0 T magnetic resonance imaging study of community-based adults. Arthritis Res Ther. 2015;17:8.	Outcome criteria not fulfilled.
59	Thelin A. Hip joint arthrosis: an occupational disorder among farmers. Am J Ind Med. 1990;18(3):339-43.	Exposure criteria not fulfilled.
60	Thelin A. Arthritis of the hip joint is a common complaint amongst farmers. [Swedish]. Lakartidningen. 1985;82(46):3994-9.	Exposure criteria not fulfilled.

61	Thelin A, Holmberg S. Hip osteoarthritis in a rural male population: A prospective population-based register study. Am J Ind Med. 2007;50(8):604-7.	Exposure criteria not fulfilled.
62	Thelin A, Vingard E, Holmberg S. Osteoarthritis of the hip joint and farm work. Am J Ind Med. 2004;45(2):202-9.	Exposure criteria not fulfilled.
63	Tuchsen F, Hannerz H, Burr H, Lund T, Krause N. Risk factors predicting hip pain in a 5-year prospective cohort study. Scandinavian Journal of Work, Environment and Health. 2003;29(1):35-9.	Outcome criteria not fulfilled.
64	Tuchsen F, Hannerz H, Jensen MV, Krause N. Socioeconomic status, occupation, and risk of hospitalisation due to coxarthrosis in Denmark 1981-99. Ann Rheum Dis. 2003;62(11):1100-5.	Exposure criteria not fulfilled.
65	van Dijk CN, Lim LS, Poortman A, Strubbe EH, Marti RK. Degenerative joint disease in female ballet dancers. Am J Sports Med. 1995;23(3):295-300.	No measure of an association.
66	Vingard E, Alfredsson L, Goldie I, Hogstedt C. Sports and osteoarthrosis of the hip. An epidemiologic study. Am J Sports Med. 1993;21(2):195-200.	No measure of an association.
67	Vingard E, Alfredsson L, Goldie I, Hogstedt C. Occupation and osteoarthrosis of the hip and knee: A register-based cohort study. Int J Epidemiol. 1991;20(4):1025-31.	Exposure criteria not fulfilled.
68	Vingard E, Alfredsson L, Hogstedt C, Goldie I. [Increased risk of arthrosis of the knee and hip among workers with heavy weight on the legs]. Lakartidningen. 1990;87(51-52):4413-6.	Other reasons (e.g., abstract, books).
69	Vingard E, Alfredsson L, Malchau H. Osteoarthrosis of the hip in women and its relationship to physical load from sports activities. Am J Sports Med. 1998;26(1):78-82.	Exposure criteria not fulfilled.
70	Vingard E, Alfredsson L, Malchau H. Lifestyle factors and hip arthrosis. A case referent study of body mass index, smoking and hormone therapy in 503 Swedish women. Acta Orthop Scand. 1997;68(3):216-20.	Exposure criteria not fulfilled.
71	Vingard E, Sandmark H, Alfredsson L. Musculoskeletal disorders in former athletes. A cohort study in 114 track and field champions. Acta Orthop Scand. 1995;66(3):289-91.	Outcome criteria not fulfilled.
72	Yesil H, Hepguler S, Ozturk C, Yesil M, Capaci K. Risk Factors of Symptomatic Knee, Hand and Hip Osteoarthritis in a Suburban Area of Izmir City. Turk Fiz Tip Rehabil Derg. 2014;60(2):126-33.	Exposure criteria not fulfilled.
73	Zetterberg C, Hansson T. [Arthrosis of the hip and knee. Heredity, sports and overweight are usually more hazardous than work]. Lakartidningen. 1995;92(22):2307-10.	Other reasons (e.g., abstract, books).

9.5 Data extraction on measure of association

					Men		Women		All	
Author	**Exposure**	**Outcome**	**Confounders**	**Categories of exposure**	**Measure of association**	**95% CI**	**Measure of association**	**95% CI**	**Measure of association**	**95% CI**
Lifting/carrying loads										
Allen 2010	*Lifting*: Lifting/carrying/moving objects weighing >10 lbs. at the longest job participants held measured on a 5-point scale and dichotomised. Radiographic: no OA, exposed n=716 and OA, exposed n=367. Symptomatic: no OA, exposed n=926 and OA, exposed n=146.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - Never, seldom, sometimes - Often or always Symptomatic OA: - Never, seldom, sometimes - Often or always	- - - -	- - - -	- - - -	- - - -	1.00 OR 1.20 OR 1.00 OR 1.67 OR	- 0.98 – 1.46 - 1.26 – 2.23
	Lifting: If the participants had ever held a job requiring lifting 10 kg $\geq$10x/week. This was compared to those who did and did not. Radiographic: no OA, exposed n=670 and OA, exposed n=315. Symptomatic: no OA, exposed n=851 and OA, exposed n=132.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - No - Yes Symptomatic OA: - No - Yes	- - - -	- - - -	- - - -	- - - -	1.00 OR 1.10 OR 1.00 OR 1.71 OR	- 0.90 – 1.36 - 1.28 – 2.29
	Lifting: If the participants had ever held a job requiring lifting 20 kg $\geq$10x/week. This was compared to those who did and did not. Radiographic: no OA, exposed n=402 and OA, exposed n=177. Symptomatic: no OA, exposed n=501 and OA, exposed n=75.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - No - Yes Symptomatic OA: - No - Yes	- - - -	- - - -	- - - -	- - - -	1.00 OR 1.03 OR 1.00 OR 1.63 OR	- 0.80 – 1.32 - 1.15 – 2.30
	Lifting: If the participants had ever held a job requiring lifting 50 kg $\geq$10x/week. This was compared to those who did not. Radiographic: no OA, exposed n=148 and OA, exposed n=75. Symptomatic: no OA, exposed n=183 and OA, exposed n=38.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - No - Yes Symptomatic OA: - No - Yes	- - - -	- - - -	- - - -	- - - -	1.00 OR 1.02 OR 1.00 OR 1.88 OR	- 0.73 – 1.43 - 1.20 – 2.92

Coggon 1998	*Lifting*: heavy occupational lifting was assessed as duration of lifting ≥25 kg >10 times in an average working day up to the age of 30 years (n=611 cases, and n=611 controls).	Radiographic OA.	BMI, presence of Heberden's nodes, and history of hip injury. Matched on age, sex and general practice.	- 0 years - 0.1-4.9 years - 5.0-9.9 years - ≥10.0 years	1.0 OR 0.6 OR 1.6 OR 2.7 OR	- 0.2 – 1.3 0.7 – 3.7 1.4 – 5.1	1.0 OR 1.0 OR 0.8 OR 1.2 OR	- 0.5 – 2.0 0.4 – 1.7 0.5 – 2.6	1.0 OR 0.8 OR 1.0 OR 1.9 OR	- 0.5 – 1.3 0.6 – 1.7 1.2 – 3.0
	Lifting: heavy occupational lifting was assessed as duration of lifting ≥25 kg >10 times in an average working day up to 10 years before entry into the study, defined as the date when the case member of matched pair was interviewed (n=611 cases, and n=611 controls).	Radiographic OA.	BMI, presence of Heberden's nodes, and history of hip injury. Matched on age, sex and general practice.	- 0 years - 0.1-9.9 years - 10.0-19.9 years - ≥20.0 years	1.0 OR 0.8 OR 1.5 OR 2.3 OR	- 0.4 – 1.7 0.6 – 3.8 1.3 – 4.4	1.0 OR 1.1 OR 1.4 OR 0.8 OR	- 0.6 – 1.7 0.7 – 2.9 0.4 – 1.5	1.0 OR 0.9 OR 1.2 OR 1.5 OR	- 0.6 – 1.4 0.7 – 2.2 1.0 – 2.3
	Lifting: maximum level of lifting for at least 10 years up to the age of 30 years >10 times in an average working day (n=611 cases and n=611 controls).	Radiographic OA.	BMI, presence of Heberden's nodes, and history of hip injury. Matched on age, sex and general practice.	- <10 kg - 10-24 kg - 25-49 kg - ≥50 kg	1.0 OR 1.7 OR 3.0 OR 2.9 OR	- 0.9 – 3.4 1.5 – 6.3 1.3 – 6.4	1.0 OR 1.0 OR 0.8 OR 1.7 OR	- 0.6 – 1.8 0.3 – 2.5 0.5 – 6.1	1.0 OR 1.2 OR 1.9 OR 2.1 OR	- 0.8 – 1.9 1.1 – 3.4 1.1 – 3.9
	Lifting: maximum level of lifting for at least 10 years up to 10 years before entry into the study, defined as the date when the case member of matched pair was interviewed, >10 times in an average working day (n=611 cases and n=611 controls).	Radiographic OA.	BMI, presence of Heberden's nodes, and history of hip injury. Matched on age, sex and general practice.	- <10 kg - 10-24 kg - 25-49 kg - ≥50 kg	1.0 OR 1.4 OR 1.9 OR 3.2 OR	- 0.7 – 3.0 0.9 – 3.9 1.6 – 6.5	1.0 OR 0.9 OR 0.9 OR 1.1 OR	- 0.6 – 1.3 0.5 – 1.7 0.5 – 2.5	1.0 OR 1.0 OR 1.1 OR 1.8 OR	- 0.7 – 1.4 0.7 – 1.8 1.1 – 2.9
Croft 1992	*Lifting*: years of exposure to lifting or moving weights >56 lbs (>25.4 kg) by hand (n=262 referents, n=224 all cases, and n=49 severe cases).	Radiographic OA.	Age and hospital group.	All cases: - <1 year - 1-19 years - ≥20 years Severe cases: - <1 year - 1-19 years - ≥20 years	 1.0 OR 0.9 OR 1.2 OR 1.0 OR 1.2 OR 2.5 OR	 - 0.6 – 1.4 0.7 – 1.9 - 0.5 – 2.9 1.1 – 5.7	 - - - - - -	 - - - - - -	 - - - - - -	 - - - - - -
Jacobsson 1987	*Heavy lifting*: was assessed as if the participants had been subject to heavy lifting (n=342).	Radiographic OA.	None.	- No - Yes	1.00 OR 2.37 OR	- 1.30 – 4.32	- -	- -	- -	- -
Kaila-Kangas 2011	*Lifting*: exposure to lifting was assessed using a question on manual handling of heavy objects such as lifting, carrying, or pushing loads over 20 kg on	Clinical examination.	Age, BMI, smoking, and traumatic fractures.	- No - Yes	1.0 OR 2.0 OR	- 1.0 – 4.0	1.0 OR 1.8 OR	- 1.1 – 2.8	1.0 OR 1.8 OR	- 1.2 – 2.7

	average of at least 10 times per working day (n=6556).									
	Lifting: exposure to lifting was assessed using a question on manual handling of heavy objects such as lifting, carrying, or pushing loads over 20 kg on average of at least 10 times per working day depending on years (n=6556).	Clinical examination.	Age, BMI, smoking, and traumatic fractures.	- 0 years - 1-12 years - 13-24 years - >24 years	1.0 OR 1.1 OR 2.2 OR 2.3 OR	- 0.4 – 3.2 0.8 – 5.9 1.2 – 4.3	1.0 OR 1.6 OR 3.8 OR 1.2 OR	- 0.7 – 3.5 1.7 – 8.1 0.7 – 2.1	1.0 OR 1.4 OR 2.8 OR 1.8 OR	- 0.7 – 2.6 1.5 – 5.0 1.1 – 2.4
Lau 2000	*Lifting*: was assessed as lifting ≥10 kg during a working week (n=30 cases and n=90 controls for men and n=108 cases and n=324 controls for women).	Radiographic OA.	Men: adjusted for history of joint injury. Matched on age. Women: adjusted for height, weight, history of joint injury, regular sports activities. Matched on age.	- No - 1-10 times - >10 times	1.0 OR 1.8 OR 3.1 OR	- 0.4 – 8.1 0.7 – 14.3	1.0 OR 0.7 OR 2.4 OR	- 0.3 – 1.7 1.1 – 5.3	- - -	- - -
	Lifting: was assessed as lifting ≥50 kg during a working week (n=30 cases and n= 90 controls).	Radiographic OA.	None. Matched on age.	- No - 1-10 times - >10 times	1.0 OR 8.5 OR 9.6 OR	- 1.6 – 45.3 2.2 – 42.2	1.0 OR 2.0 OR 2.9 OR	- 0.9 – 4.6 1.5 – 5.6	- - -	- - -
Lau 2007	*Lifting*: was assessed as lifting 10 kg or more during a working week (n=30 cases and 90 controls for men and n=108 cases and n=324 controls for women).	Radiographic OA.	BMI and injury. Matched on age	- No - 1-10 times - >10 times	1.00 OR 2.13 OR 4.15 OR	- 0.59 – 7.72 1.23 – 14.01	1.00 OR 0.74 OR 3.24 OR	- 0.32 – 1.74 1.71 – 6.14	1.00 OR 1.01 OR 3.17 OR	- 0.51 – 2.00 1.83 – 5.52
	Lifting: was assessed as lifting 50 kg or more during a working week (n=30 cases and 90 controls).	Radiographic OA.	BMI and injury. Matched on age	- No - 1-10 times - >10 times	1.00 OR 14.00 OR 9.40 OR	- 1.96 – 100.01 1.26 – 70.42	1.00 OR 3.53 OR 2.71 OR	- 1.33 – 9.40 1.21 – 6.10	1.00 OR 4.60 OR 3.39 OR	- 2.00 – 10.57 1.63 – 7.04
Olsen 1994	*Tons lifted*: was assessed by asking how many kilograms were lifted per week and was collected from the start of the occupational career to the year of diagnosis, aggregated for men's work life up to 49th year of age. It was then defined into three exposure groups (n=239 cases and n=302 controls).	Register information on first-time prosthesis.	Age, BMI, smoking, and sports activities.	- Low - Medium - High	1.00 OR 1.58 OR 1.84 OR	- NS NS	- - -	- - -	- - -	- - -
	number of lifts >40 kg: was assessed by asking how many kilograms were lifted per week	Register information on first-time prosthesis.	Age, BMI, smoking, and sports activities.	- Low - Medium - High	1.00 OR 1.38 OR 2.48 OR	- NS NS	- - -	- - -	- - -	- - -

	and was collected from the start of the occupational career to the year of diagnosis, aggregated for men's work life up to 49th year of age. It was then defined into three exposure groups (n=239 cases and n=302 controls).									
Rubak 2014	*Lifting*: was assessed as ton-years calculating lifting 1 ton per day for 1 year (n=1776 case-control sets including at least 1 case and 1 control, divided in 861 sets for women and 915 sets for men).	Register information on total hip replacement due to OA.	One occupational exposure at a time adjusted for body mass index at age 25, change in body mass index, pack-years of smoking, previous fracture of a lower extremity, familial predisposition, endurance and contact sport at age 25, and region of residence. Matched on age.	Men: - 0 years - >0 to <10 years - 10 to <20 years - 20 to 115 Women: - 0 years - >0 to >10 years - 10 to <20 years - 20 to 86	 1.00 OR 0.99 OR 0.89 OR 1.35 OR - - - -	 - 0.75 – 1.30 0.67 – 1.17 1.05 – 1.74 - - - -	 - - - - 1.00 OR 1.15 OR 0.81 OR 1.00 OR	 - - - - - 0.87 – 1.53 0.61 – 1.09 0.72 – 1.35	 - - - - - - - -	 - - - - - - - -
Solovieva 2018	*Heavy lifting*: was assessed from a job-exposure matrix dichotomising heavy lifting (n=574,617 men and n=561,037 women).	Register information on disability retirement due to hip OA.	Age, heavy physical work, kneeling or squatting, sitting, and standing or moving.	- No - Yes	1.00 HR 1.23 HR	- 1.02 – 1.48	1.00 HR 1.08 HR	- 0.87 – 1.34	- -	- -
Vingård 1997	*Lifting*: was assessed based on how many kilos the participant lifted each day and divided into three subclasses on the basis of the exposure distribution (n=230 cases and n= 273 controls).	Total hip replacement due to OA.	Age, BMI, smoking, sports activities, number of children, and hormone therapy.	- Low - Medium - High exposure	- - -	- - -	1.0 RR 1.1 RR 1.5 RR	- 0.7 – 1.7 0.9 – 2.5	- - -	- - -
Vingård 1991	*Lifted tons*: was assessed as the number of lifted kilograms and divided into three subclasses on the basis of the exposure distribution (n=233 cases and n=302 controls).	Total hip replacement due to OA.	Age, BMI, smoking, and sport activities up to the age of 29 years.	- Low - Medium - High	1.00 RR 1.58 RR 1.84 RR	- 0.93 – 2.66 1.12 – 3.03	- - -	- - -	- - -	- - -
	Number of lifts: was assessed as the number of times a person lifted heavy burdens (>40 kg) and divided into three subclasses on the basis of the exposure distribution (n=233 cases and n=302 controls).	Total hip replacement due to OA.	Age, BMI, smoking, and sport activities up to the age of 29 years.	- Low - Medium - High	1.00 RR 1.38 RR 2.40 RR	- 0.81 – 2.36 1.50 – 2.83	- - -	- - -	- - -	- - -

Yoshimura 2000	*Lifting*: assessed as weights lifted more than once (kg) during an average working week at the first job (n= 103 cases and n=103 controls).	Radiographic OA.	History of knee pain and age left school. Matched on age, sex, and district of residence.	First job: - Lifting 0 kg - Lifting ≥10 kg - Lifting ≥25 kg - Lifting ≥50 kg	 - - - -	 - - - -	 - - - -	 - - - -	 1.0 OR 1.2 OR 3.5 OR -	 - 0.6 – 2.4 1.3 – 9.7 -
	Lifting: assessed as weights lifted more than once (kg) during an average working week at the main job (n= 103 cases and n=103 controls).	Radiographic OA.	History of knee pain and age left school. Matched on age, sex, and district of residence.	Main job: - Lifting 0 kg - Lifting ≥10 kg - Lifting ≥25 kg - Lifting ≥50 kg	 - - - -	 - - - -	 - - - -	 - - - -	 1.0 OR 1.2 OR 1.5 OR 4.1 OR	 - 0.6 – 2.1 0.7 – 3.0 1.1 – 15.2
Awkward posture										
Allen 2010	*Posture*: bending/twisting/reaching at the longest job participants held, measured on a 5-point scale and dichotomised. Radiographic: no OA, exposed n=980 and OA, exposed n=480. Symptomatic: no OA, exposed n=1264 and OA, exposed n=271.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - Never, seldom, sometimes - Often or always Symptomatic OA: - Never, seldom, sometimes - Often or always	 - - - -	 - - - -	 - - - -	 - - - -	 1.00 OR 1.21 OR 1.00 OR 1.60 OR	 - 0.98 – 1.48 - 1.18 – 2.17
Croft 1992	*Bending*: years of exposure to bending for >2 hours a day (n=259 referents, n=212 all cases, and n=46 severe cases).	Radiographic OA.	Age and hospital group.	All cases: - <1 year - 1–19 years - ≥20 years Severe cases: - <1 year - 1–19 years - ≥20 years	 1.0 OR 0.7 OR 1.2 OR 1.0 OR 0.8 OR 1.9 OR	 - 0.4 – 1.1 0.7 – 1.9 - 0.3 – 2.0 0.8 – 4.5	 - - - - - -	 - - - - - -	 - - - - - -	 - - - - - -
Rijs 2014	*Positions*: was assessed with a job-exposure matrix measuring work performed in uncomfortable positions (n=271 for current job and n=971 for longest job held).	Self-report and general practitioner data on hip OA.	Age and sex.	Current job: - Low - Moderate Longest job: - Low - Moderate	 - - - -	 - - - -	 - - - -	 - - - -	 1.0 OR 2.5 OR 1.0 OR 1.5 OR	 - 0.9 – 7.5 - 0.99 – 2.4
Vingård 1997	*Twisted position*: was assessed based on hours working in a twisted position and divided into three subclasses on the basis of the exposure distribution (n=230 cases and n= 273 controls).	Total hip replacement due to OA.	Age, BMI, smoking, sports activities, number of children, and hormone therapy.	- Low - Medium - High	- - -	- - -	1.0 RR 1.1 RR 1.6 RR	- 0.7 – 1.8 0.9 – 2.6	- - -	- - -
Vingård 1991	*Static*: was assessed as working in a twisted locked position and divided into three subclasses based on the exposure	Total hip replacement due to OA.	Age, BMI, smoking, and sport activities up to the age of 29 years.	- Low - Medium - High	1.00 RR 1.21 RR 2.92 RR	- 0.64 – 2.31 1.69 – 5.05	- - -	- - -	- - -	- - -

	distribution (n=233 cases and n=302 controls).									
Standing										
Allen 2010	*Stand*: standing at the longest job participants held, measured on a 5-point scale. Radiographic: no OA, exposed n=1051 and OA, exposed n=524. Symptomatic: no OA, exposed n=1379 and OA, exposed n=187.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - Never, seldom, sometimes - Often or always Symptomatic OA: - Never, seldom, sometimes - Often or always	- - - -	- - - -	- - - -	- - - -	1.00 OR 1.15 OR 1.00 OR 1.30 OR	- 0.94 – 1.42 - 0.97 – 1.75
Coggon 1998	*Standing*: standing for >2 hours in an average working day for up to 10 years before entry into the study (n=611 cases and n=611 controls).	Radiographic OA.	BMI, Heberden's nodes, and history of hip injury. Matched on age, sex and general practice.	- 0 years - 0.1-9.9 years - 10.0-19.9 years - ≥20.0 years	1.0 OR 0.2 OR 0.4 OR 0.5 OR	- 0.0 – 1.4 0.1 – 2.4 0.1 – 2.3	1.0 OR 1.1 OR 1.1 OR 1.3 OR	- 0.6 – 2.0 0.6 – 1.9 0.7 – 2.1	1.0 OR 1.0 OR 1.0 OR 1.2 OR	- 0.6 – 1.7 0.6 – 1.7 0.7 – 1.9
Croft 1992	*Standing*: years of exposure to standing for >2 hours a day (n=284, n= 232 all cases, and n=51 severe cases).	Radiographic OA.	Age and hospital group.	All cases: - <20 year - 20–39 years - ≥40 years Severe cases: - <20 year - 20–39 years - ≥40 years	1.0 OR 1.8 OR 1.7 OR 1.0 OR 1.5 OR 2.7 OR	- 1.0 – 3.1 1.0 – 2.8 - 0.5 – 4.8 1.0 – 7.3	- - - - - -	- - - - - -	- - - - - -	- - - - - -
Jacobsson 1987	*Standing*: was assessed as if the participants had been subject to too much standing (n=342).	Radiographic OA.	None.	- No - Yes	1.00 OR 0.78 OR	- 0.49 – 1.24	- -	- -	- -	- -
Vingård 1997	*Standing*: was assessed based on hours working in standing position and divided into three subclasses based on the exposure distribution (n=230 cases and n= 273 controls).	Total hip replacement due to OA.	Age, BMI, smoking, sports activities, number of children, and hormone therapy.	- Low - Medium - High	- - -	- - -	1.0 RR 1.4 RR 1.6 RR	- 0.8 – 2.2 0.9 – 2.8	- - -	- - -
Yoshimura 2000	*Standing*: was assessed as standing ≥2 hours (n=103 cases and n=103 controls).	Radiographic OA.	History of knee pain and age left school. Matched on age, sex, and district of residence.	First job: - No - Yes Main job: - No - Yes	- - - -	- - - -	- - - -	- - - -	1.0 OR 1.4 OR 1.0 OR 1.1 OR	- 0.7 – 2.8 - 0.6 – 2.3
Walking										
Allen 2010	*Walking*: ever held a job requiring walking >50 % of their time.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior	Radiographic OA: - <50 % - >50 %	- -	- -	- -	- -	1.00 OR 1.15 OR	- 0.95 – 1.40

	Radiographic: no OA, exposed n=703 and OA, exposed n=344. Symptomatic: no OA, exposed n=914 and OA, exposed n=131.		knee injury, and household tasks.	Symptomatic OA: - <50 % - >50 %	- -	- -	- -	- -	1.00 OR 1.19 OR	- 0.90 – 1.56
	Walk: walking at the longest job the participants held measured on a 5-point scale and dichotomised. Radiographic: no OA, exposed n=1174 and OA, exposed n=568. Symptomatic: no OA, exposed n=1525 and OA, exposed n=203.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - Never, seldom, sometimes - Often or always Symptomatic OA: - Never, seldom, sometimes - Often or always	- - - -	- - - -	- - - -	- - - -	1.00 OR 1.15 OR 1.00 OR 1.38 OR	- 0.92 – 1.43 - 1.00 – 1.91
Coggon 1998	*Walking*: walking for >2 miles (3.2 km) in an average working day for up to 10 years before entry into the study (n=611 cases and n=611 controls).	Radiographic OA.	BMI, Heberden's nodes, and history of hip injury. Matched on age, sex and general practice.	- 0 years - 0.1-9.9 years - 10.0-19.9 years - ≥20.0 years	1.0 OR 0.8 OR 1.1 OR 1.2 OR	- 0.4 – 1.9 0.4 – 2.5 0.6 – 2.5	1.0 OR 1.5 OR 1.5 OR 1.3 OR	- 1.0 – 2.3 1.0 – 2.3 0.8 – 2.0	1.0 OR 1.3 OR 1.4 OR 1.3 OR	- 0.9 – 1.9 0.9 – 2.0 0.9 – 1.8
Croft 1992	*Walking*: years of exposure to walking >2 miles (3.2 km) a day (n=275 referents, n=229 all cases, and n=51 severe cases).	Radiographic OA.	Age and hospital group.	All cases: - <1 year - 1–19 years - ≥20 years Severe cases: - <1 year - 1–19 years - ≥20 years	1.0 OR 0.8 OR 0.8 OR 1.0 OR 1.4 OR 1.6 OR	- 0.5 – 1.5 0.5 – 1.5 - 0.4 – 4.6 0.5 – 5.1	- - - - - -	- - - - - -	- - - - - -	- - - - - -
	Walking on rough ground: years of exposure to walking >2 miles (3.2 km) over rough ground (n=264 referents, n=218 all cases, and n=49 severe cases).	Radiographic OA.	Age and hospital group.	All cases: - <1 year - 1–19 years - ≥20 years Severe cases: - <1 year - 1–19 years - ≥20 years	1.0 OR 1.2 OR 1.0 OR 1.0 OR 2.0 OR 1.9 OR	- 0.7 – 1.8 0.6 – 1.6 - 0.9 – 4.3 0.9 – 4.1	- - - - - -	- - - - - -	- - - - - -	- - - - - -
Jacobsson 1987	*Walking*: was assessed as if the participants had been subject to too much walking (n=342).	Radiographic OA.	None.	- No - Yes	1.00 OR 1.56 OR	- 0.86 – 2.80	- -	- -	- -	- -
Lau 2000	*Walking*: was assessed as walking for ≥2 hours on an average working day (n=30 cases and n=90 controls).	Radiographic OA.	History of joint injury. Matched on age.	- No - Yes	1.0 OR 1.3 OR	- 0.3 – 6.7	- -	- -	- -	- -
	Walking: was assesses as walking for ≥2 hours on an average	Radiographic OA.	None. Matched on age.	- No -Yes	- -	- -	1.0 OR 1.4 OR	- 0.9 – 2.3	- -	- -

	working day (n=108 cases and n=324 controls).									
Lau 2007	*Walking*: was assesses as walking for ≥2 hours on an average working day (n=30 cases and n=90 controls for men and n=108 cases and n=324 controls for women).	Radiographic OA.	BMI and injury. Matched on age.	- No - Yes	1.00 OR 4.02 OR	- 1.04 – 15.56	1.00 OR 1.16 OR	- 0.69 – 1.96	1.00 OR 1.41 OR	- 0.88 – 2.25
Yoshimura 2000	*Walking*: was assessed as walking ≥3 km (n=103 cases and n=103 controls).	Radiographic OA.	History of knee pain and age left school. Matched on age, sex, and district of residence.	First job: - No - Yes Main job: - No - Yes	 - - - -	 - - - -	 - - - -	 - - - -	 1.0 OR 1.0 OR 1.0 OR 1.2 OR	 - 0.4 – 2.2 - 0.6 – 2.4
Standing or walking										
Kontio 2020	*Standing or walking*: was assessed as cumulative exposure to standing or walking for ≥5 hours per day (n=4405 with no OA and n=87 for hip OA).	Hospitalisation due to hip OA.	Age and sex.	- <1 year - 1-10 years - 11-20 years - >20 years	- - - -	- - - -	- - - -	- - - -	1.00 HR 0.90 HR 1.39 HR 1.06 HR	- 0.48 – 1.72 0.75 – 2.58 0.61 – 1.84
Solovieva 2018	*Standing or moving*: was assessed from a job-exposure matrix dichotomising standing or moving (n=574,617 men and n=561,037 women).	Disability retirement due to OA.	Age, heavy physical work, kneeling or squatting, heavy lifting, standing or moving.	- No - Yes	1.00 HR 1.24 HR	- 1.04 – 1.48	1.00 HR 1.13 HR	- 0.98 – 1.29	- -	- -
Rubak 2014	*Standing*: was assessed as exposure to standing/walking 6 hours per working day for 1 year (n=1776 case-control sets including at least 1 case and 1 control, divided in 861 sets for women and 915 sets for men).	Total hip replacement due to OA.	One occupational exposure at a time adjusted for body mass index at age 25, change in body mass index, pack-years of smoking, previous fracture of a lower extremity, familial predisposition, endurance and contact sport at age 25, and region of residence. Matched on age.	- 0 years - >0 to <10 years - 10 to <20 years - 20 to 29 years	1.00 OR 1.13 OR 1.14 OR 0.99 OR	- 0.85 – 1.50 0.87 – 1.48 0.77 – 1.28	1.00 OR 0.91 OR 0.99 OR 1.03 OR	- 0.56 – 1.48 0.74 – 1.25 0.78 – 1.35	- - - -	- - - -
Kneeling										
Allen 2010	*Kneeling*: ever held a job requiring kneeling >50 % of their time. Radiographic: no OA, exposed n=209 and OA, exposed n=85.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - <50 % - >50 % Symptomatic OA:	 - -	 - -	 - -	 - -	 1.00 OR 0.84 OR	 - 0.62 – 1.14

	Symptomatic: no OA, exposed n=256 and OA, exposed n=36.			- <50 % - >50 %	- -	- -	- -	- -	1.00 OR 1.15 OR	- 0.76 – 1.73
	Crouch or kneel: crouching or kneeling at the longest job participants held, measured on a 5-point scale and dichotomised. Radiographic: no OA, exposed n=193 and OA, exposed n=88. Symptomatic: no OA, exposed n=243 and OA, exposed n=37.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - Never, seldom, sometimes - Often or always Symptomatic OA: - Never, seldom, sometimes - Often or always	- - - -	- - - -	- - - -	- - - -	1.00 OR 1.15 OR 1.00 OR 1.45 OR	- 0.84 – 1.56 - 0.95 – 2.21
Coggon 1998	*Kneeling*: kneeling for >1 hour in an average working day for up to 10 years before entry into the study (n=611 cases and n=611 controls).	Radiographic OA.	BMI, Heberden's nodes, and history of hip injury. Matched on age, sex and general practice.	- 0 years - 0.1-9.9 years - 10.0-19.9 years - ≥20.0 years	1.0 OR 0.8 OR 2.0 OR 1.0 OR	- 0.4 – 1.4 0.6 – 4.7 0.6 – 1.7	1.0 OR 0.9 OR 0.7 OR 1.2 OR	- 0.6 – 1.4 0.4 – 1.3 0.5 – 3.0	1.0 OR 0.9 OR 1.0 OR 1.1 OR	- 0.6 – 1.2 0.6 – 1.7 0.7 – 1.7
Croft 1992	*Kneeling*: years of exposure to kneeling for >30 min a day (n=244 referents, n=197 all cases, and n=41).	Radiographic OA.	Age and hospital group.	All cases: - <1 year - 1–19 years - ≥20 years Severe cases: - <1 year - 1–19 years - ≥20 years	1.0 OR 0.6 OR 0.7 OR 1.0 OR 0.5 OR 1.0 OR	- 0.4 – 1.0 0.4 – 1.3 - 0.2 – 1.4 0.3 – 3.2	- - - - - -	- - - - - -	- - - - - -	- - - - - -
Lau 2000	*Kneeling*: was assessed as kneeling for ≥ 1 hour on an average working day (n=30 cases and n=90 controls).	Radiographic OA.	History of joint injury. Matched on age.	- No - Yes	1.0 OR 7.4 OR	- 0.7 – 76.9	- -	- -	- -	- -
	Kneeling: was assessed as kneeling for ≥ 1 hour on an average working day (n=108 cases and n=324 controls).	Radiographic OA.	None. Matched on age.	- No - Yes	- -	- -	1.0 OR 1.3 OR	- 0.7 – 2.5	- -	- -
Lau 2007	*Kneeling*: was assessed as kneeling for ≥ 1 hour on an average working day (n=30 cases and n=90 controls for men and n=108 cases and n=324 controls for women).	Radiographic OA.	BMI and injury. Matched on age.	- No - Yes	1.00 OR 5.22 OR	- 0.82 – 33.30	1.00 OR 1.52 OR	- 0.76 – 3.05	1.00 OR 1.70 OR	- 0.90 – 3.21
Yoshimura 2000	*Kneeling*: was assessed as kneeling ≥1 hour (n=103 cases and n=103 controls).	Radiographic OA.	History of knee pain and age left school. Matched on age, sex, and district of residence.	First job: - No - Yes Main job: - No - Yes	- - - -	- - - -	- - - -	- - - -	1.0 OR 0.7 OR 1.0 OR 1.0 OR	- 0.4 – 1.4 - 0.5 – 2.1

Squatting										
Allen 2010	*Squat*: squatting at the longest job participants held, measured on a 5-point scale and dichotomised. Radiographic: no OA, exposed n=350 and OA, exposed n=164. Symptomatic: no OA, exposed n=452 and OA, exposed n=48.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - Never, seldom, sometimes - Often or always Symptomatic OA: - Never, seldom, sometimes - Often or always	- - - -	- - - -	- - - -	- - - -	1.00 OR 1.03 OR 1.00 OR 1.11 OR	- 0.81 – 1.30 - 0.79 – 1.57
Coggon 1998	*Squatting*: squatting for >1 hour in an average working day for up to 10 years before entry into the study (n=611 cases and n=611 controls).	Radiographic OA.	BMI, Heberden's nodes, and history of hip injury. Matched on age, sex and general practice.	- 0 years - 0.1-9.9 years - 10.0-19.9 years - ≥20.0 years	1.0 OR 0.9 OR 1.4 OR 0.9 OR	- 0.5 – 1.6 0.5 – 3.6 0.5 – 1.6	1.0 OR 1.1 OR 1.5 OR 0.7 OR	- 0.6 – 1.9 0.6 – 3.4 0.3 – 1.8	1.0 OR 1.0 OR 1.5 OR 0.9 OR	- 0.7 – 1.5 0.8 – 2.7 0.6 – 1.4
Croft 1992	*Squatting*: years of exposure to squatting for >30 min a day (n=238 referents, n=190 all cases, and n=40 severe cases).	Radiographic OA.	Age and hospital group.	All cases: - <1 year - ≥1 year Severe cases: - <1 year - ≥1 year	1.0 OR 0.7 OR 1.0 OR 1.3 OR	- 0.4 – 1.4 - 0.4 – 3.6	- - - -	- - - -	- - - -	- - - -
Lau 2000	*Squatting*: was assessed as squatting for ≥1 hour on an average working day (n=30 cases and 90 controls).	Radiographic OA.	None. Matched on age.	- No - Yes	1.0 OR 1.3 OR	- 0.5 – 3.2	- -	- -	- -	- -
	Squatting: was assessed as squatting for ≥1 hour on an average working day (n=108 cases and 324 controls).	Radiographic OA.	Height, weight, history of joint injury, and regular sports activity. Matched on age.	- No - Yes	- -	- -	1.0 OR 1.2 OR	- 0.5 – 3.0	- -	- -
Lau 2007	*Squatting*: was assessed as squatting for ≥1 hour on an average working day (n=30 cases and 90 controls for men and n=108 cases and 324 controls for women).	Radiographic OA.	BMI and injury. Matched on age.	- No - Yes	1.00 OR 0.87 OR	- 0.29 – 2.65	1.00 OR 1.99 OR	- 1.07 – 3.71	1.00 OR 1.62 OR	- 0.95 – 2.78
Yoshimura 2000	*Squatting*: was assessed as squatting ≥1 hour (n=103 cases and n=103 controls).	Radiographic OA.	History of knee pain and age left school. Matched on age, sex, and district of residence.	First job: - No - Yes Main job: - No - Yes	- - - -	- - - -	- - - -	- - - -	1.0 OR 1.0 OR 1.0 OR 1.3 OR	- 0.5 – 2.2 - 0.6 – 2.8
Kneeling or squatting										

Kontio 2020	*Kneeling or squatting*: was assessed as cumulative exposure to kneeling or squatting for ≥1 hour per day (n=4405 with no OA and n=87 for hip OA).	Hospitalisation due to hip OA.	Age and sex.	- <1 year - 1-10 years - 11-20 years - >20 years	- - - -	- - - -	- - - -	- - - -	1.00 HR 1.68 HR 1.50 HR 1.41 HR	- 0.96 – 2.95 0.75 – 2.98 0.79 – 2.50
Solovieva 2018	*Kneeling or squatting*: was assessed from a job-exposure matrix dichotomising kneeling or squatting (n=574,617 men and n=561,037 women).	Disability retirement due to OA.	Age, heavy physical work, heavy lifting, sitting, standing or moving.	- No - Yes	1.00 HR 1.17 HR	- 0.99 – 1.39	1.00 HR 1.53 HR	- 1.27 – 1.84	- -	- -
Climbing stairs										
Allen 2010	*Climb stairs*: climbing stairs at the longest job participants held, measured on a 5-point scale and dichotomised. Radiographic: no OA, exposed n=351 and OA, exposed n=167. Symptomatic: no OA, exposed n=456 and OA, exposed n=59.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - Never, seldom, sometimes - Often or always Symptomatic OA: - Never, seldom, sometimes - Often or always	- - - -	- - - -	- - - -	- - - -	1.00 OR 1.01 OR 1.00 OR 1.17 OR	- 0.80 – 1.28 - 0.84 – 1.62
Coggon 1998	*Climbing*: climbing >30 flights of stairs in an average working day for up to 10 years before entry into the study (n=611 cases and n=611 controls).	Radiographic OA.	BMI, Heberden’s nodes, and history of hip injury. Matched on age, sex and general practice.	- 0 years - 0.1-9.9 years - 10.0-19.9 years - ≥20.0 years	1.0 OR 1.3 OR 2.3 OR 1.8 OR	- 0.7 – 2.5 1.1 – 4.9 0.9 – 3.4	1.0 OR 1.4 OR 1.3 OR 2.3 OR	- 0.8 – 2.2 0.4 – 4.0 0.8 – 6.3	1.0 OR 1.3 OR 1.7 OR 1.7 OR	- 0.9 – 1.9 1.0 – 3.1 1.0 – 2.8
Croft 1992	*Climbing ladders*: years of exposure to climbing ladders (n=264 referents, n=226 all cases, and n=47 severe cases).	Radiographic OA.	Age and hospital group.	All cases: - <1 year - 1–19 years - ≥20 years Severe cases: - <1 year - 1–19 years - ≥20 years	1.0 OR 0.9 OR 0.8 OR 1.0 OR 0.8 OR 1.6 OR	- 0.6 – 1.4 0.5 – 1.5 - 0.3 – 1.8 0.7 – 3.8	- - - - - -	- - - - - -	- - - - - -	- - - - - -
	Climbing: years of exposure to climbing >30 flights of stairs a day (n=260 referents, n=225 all cases, and n=50 severe cases).	Radiographic OA.	Age and hospital group.	All cases: - <1 year - ≥1 year Severe cases: - <1 year - ≥1 year	1.0 OR 1.0 OR 1.0 OR 1.2 OR	- 0.6 – 1.5 - 0.6 – 2.5	- - - -	- - - -	- - - -	- - - -
Lau 2000	*Climbing stairs*: was assessed as climbing ≥15 flights of stairs on an average working day (n=30 cases and n=90 controls for men	Radiographic OA.	Men: adjusted for history of joint injury. Matched on age.	- No - Yes	1.0 OR 12.5 OR	- 1.5 – 104.3	1.0 OR 2.3 OR	- 0.6 – 8.1	- -	- -

	and n=108 cases and n=324 controls for women).		Women: adjusted for height, weight, history of joint injury, and regular sports activities. Matched on age.							
Lau 2007	*Climbing*: was assessed as climbing ≥15 flights of stairs on an average working day (n=30 cases and n=90 controls for men and n=108 cases and n=324 controls for women).	Radiographic OA.	BMI and injury. Matched on age.	- Yes	15.90 OR	2.30 – 109.9	2.60 OR	0.97 – 7.08	4.13 OR	1.78 – 9.60
Vingård 1997	*Climbing*: was assessed based on how many stairs climbed every day on work and divided into three subclasses on the basis of the exposure distribution (n=230 cases and n= 273 controls).	Total hip replacement due to OA.	Age, BMI, smoking, sports activities, number of children, and hormone therapy.	- Low - Medium - High	- - -	- - -	1.0 RR 1.3 RR 2.1 RR	- 0.8 – 2.2 1.2 – 3.6	- - -	- - -
Yoshimura 2000	*Climbing*: was assessed as climbing ≥30 flights of stairs (n=103 cases and n=103 controls).	Radiographic OA.	History of knee pain and age left school. Matched on age, sex, and district of residence.	First job: - No - Yes Main job: - No - Yes	 - - - -	 - - - -	 - - - -	 - - - -	 1.0 OR 0.9 OR 1.0 OR 1.1 OR	 - 0.4 – 2.0 - 0.5 – 2.1
Sitting										
Allen 2010	*Sitting*: ever held a job requiring sitting >50 % of their time. Radiographic: no OA, exposed n=776 and OA, exposed n=356. Symptomatic: no OA, exposed n=1007 and OA, exposed n=125.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - <50 % - >50 % Symptomatic OA: - <50 % - >50 %	 - - - -	 - - - -	 - - - -	 - - - -	 1.00 OR 0.96 OR 1.00 OR 0.80 OR	 - 0.79 – 1.16 - 0.61 – 1.04
	Sitting: sitting at the longest job participants held, measured on a 5-point scale and dichotomised. Radiographic: no OA, exposed n=669 and OA, exposed n=314. Symptomatic: no OA, exposed n=875 and OA, exposed n=103.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - Never, seldom, sometimes - Often or always Symptomatic OA: - Never, seldom, sometimes - Often or always	 - - - -	 - - - -	 - - - -	 - - - -	 1.00 OR 0.94 OR 1.00 OR 0.81 OR	 - 0.77 – 1.14 - 0.61 – 1.07
Coggon 1998	*Sitting*: sitting for >2 hours an average working day for up to 10 years before entry into the study	Radiographic OA.	BMI, Heberden's nodes, and history of hip injury. Matched on age, sex and general practice.	- 0 years - 0.1-9.9 years - 10.0-19.9 years - ≥20.0 years	1.0 OR 1.8 OR 1.7 OR 1.0 OR	- 0.9 – 3.7 0.7 – 3.9 0.6 – 1.7	1.0 OR 0.9 OR 1.2 OR 0.9 OR	- 0.6 – 1.3 0.8 – 1.8 0.6 – 1.3	1.0 OR 1.0 OR 1.2 OR 0.9 OR	- 0.7 – 1.4 0.9 – 1.8 0.6 – 1.2

	(n=611 cases and n=611 controls).									
Croft 1992	*Sitting*: years of exposure to sitting for >2 hours a day (n=283 referents, n=229 all cases, and n=48 severe cases).	Radiographic OA.	Age and hospital group.	All cases: - <1 year - 1 – 19 years - ≥20 years Severe cases: - <1 year - 1 – 19 years - ≥20 years	 1.0 OR 1.1 OR 1.2 OR 1.0 OR 1.0 OR 0.8 OR	 - 0.7 – 1.7 0.8 – 1.8 - 0.4 – 2.2 0.3 – 1.7	 - - - - - -	 - - - - - -	 - - - - - -	 - - - - - -
Solovieva 2018	*Sitting*: was assessed from a job-exposure matrix dichotomising sitting (n=574,617 men and n=561,037 women).	Disability retirement due to OA.	Age, heavy physical work, kneeling or squatting, heavy lifting, and standing or moving.	- No - Yes	1.00 HR 0.43 HR	- 0.34 – 0.54	1.00 HR 0.48 HR	- 0.39 – 0.58	- -	- -
Vingård 1997	*Sitting*: was assessed based on hours working in sitting position and divided into three subclasses based on the exposure distribution (n=230 cases and n= 273 controls).	Total hip replacement due to OA.	Age, BMI, smoking, sports activities, number of children, and hormone therapy.	- Low - Medium - High	- - -	- - -	1.0 RR 0.8 RR 0.8 RR	- 0.5 – 1.2 0.4 – 1.3	- - -	- - -
Yoshimura 2000	*Sitting*: was assessed as sitting for ≥2 hours (n=103 cases and n=103 controls).	Radiographic OA.	History of knee pain and age left school. Matched on age, sex, and district of residence.	First job: - No - Yes Main job: - No - Yes	 - - - -	 - - - -	 - - - -	 - - - -	 1.0 OR 0.6 OR 1.0 OR 0.8 OR	 - 0.3 – 1.0 - 0.4 – 1.4
Combined mechanical exposures										
Allen 2010	*Light work*: ever held a job requiring light work while standing >50% of their time Radiographic: no OA, exposed n=422 and OA, exposed n=202. Symptomatic: no OA, exposed n=560 and OA, exposed n=63.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - <50 % - >50 % Symptomatic OA: - <50 % - >50 %	 - - - -	 - - - -	 - - - -	 - - - -	 1.00 OR 1.05 OR 1.00 OR 0.74 OR	 - 0.85 – 1.29 - 0.54 – 1.01
	Heavy work: ever held a job requiring heavy work while standing >50% of their time. Radiographic: no OA, exposed n=328 and OA, exposed n=144. Symptomatic: no OA, exposed n=405 and OA, exposed n=65.	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - <50 % - >50 % Symptomatic OA: - <50 % - >50 %	 - - - -	 - - - -	 - - - -	 - - - -	 1.00 OR 1.04 OR 1.00 OR 1.39 OR	 - 0.82 – 1.32 - 1.01 – 1.91
	Heavy work: doing heavy work while standing at the longest job	Radiographic and symptomatic OA.	Age, sex, race, BMI, smoking (ever and	Radiographic OA: - Never, seldom,	 -	 -	 -	 -	 1.00 OR	 -

	participants held, measured on a 5-point scale and dichotomised. Radiographic: no OA, exposed n=180 and OA, exposed n=84. Symptomatic: no OA, exposed n=222 and OA, exposed n=41.		current vs. never), prior knee injury, and household tasks.	sometimes - Often or always Symptomatic OA: - Never, seldom, sometimes - Often or always	 - - -	 - - -	 - - -	 - - -	 1.20 OR 1.00 OR 1.75 OR	 0.88 – 1.63 - 1.17 – 2.61
Cvijetic 1999	*Physical demands at work*: was divided into 4 categories depending of the physical demands pertinent to participants' occupation. Category 1, n=119 men and 96 women Category 2, n=34 men and 38 women Category 3, n=92 men and 115 women Category 4, n=50 men and 49 women.	Radiographic OA.	Age and BMI.	Radiological signs: - Category 1 - Category 2 - Category 3 - Category 4 Clinical signs: - Category 1 - Category 2 - Category 3 - Category 4	 1.00 OR 1.50 OR 1.16 OR 1.15 OR 1.00 OR 2.20 OR 1.40 OR 2.19 OR	 - 0.60 – 3.21 0.58 – 2.30 0.52 – 2.52 - 0.30 – 13.1 0.50 – 4.00 0.44 – 10.8	 1.00 OR 1.45 OR 1.19 OR 1.34 OR 1.00 OR 3.00 OR 1.37 OR 1.77 OR	 - 0.49 – 3.58 0.65 – 2.32 0.52 – 3.04 - 1.00 – 8.92 0.50 – 3.79 0.36 – 8.63	 - - - - - - - -	 - - - - - - - -
	Physical demands at work: years exposed to physical demands at work within occupation groups (n=NS in exposure groups).	Radiographic OA.	Age and BMI.	Category 1: - <20 years - 20-29.9 years - >30 years Category 2: - <20 years - 20-29.9 years - >30 years Category 3: - <20 years - 20-29.9 years - >30 years Category 4: - <20 years - 20-29.9 years - >30 years	 1.00 OR 1.38 OR 1.49 OR 1.00 OR 2.09 OR 1.83 OR 1.00 OR 2.45 OR 2.46 OR 1.00 OR 1.57 OR 1.22 OR	 - 0.94 – 2.79 0.79 – 3.20 - 0.98 – 3.17 0.68 – 3.56 - 0.53 – 3.32 0.51 – 4.54 - 0.64 – 2.85 0.98 – 2.46	 1.00 OR 1.07 OR 3.89 OR 1.00 OR 1.94 OR 3.24 OR 1.00 OR 1.51 OR 2.34 OR 1.00 OR 1.23 OR 1.41 OR	 - 1.03 – 1.29 0.42 – 4.64 - 0.64 – 2.14 0.51 – 4.02 - 0.68 – 1.92 0.66 – 2.93 - 0.97 – 1.54 0.78 – 1.97	 - - - - - - - - - - - -	 - - - - - - - - - - - -
Flugsrud 2002	*Physical activity at work*: was divided into categories of from sedentary work to heavy physical labour (n= 24884 men and n=24874 women).	Register data on total hip replacements.	Age at screening, height, BMI, physical activity in leisure, marital status, and smoking habits.	- Sedentary - Moderate - Intermediate - Intensive	1.0 RR 1.5 RR 1.7 RR 2.1 RR	- 1.0 – 2.2 1.1 – 2.4 1.5 – 3.0	1.0 RR 1.1 RR 1.4 RR 2.1 RR	- 0.8 – 1.6 0.9 – 2.0 1.3 – 3.3	- - - -	- - - -
Heliovaara 1993	*Physical stress at work*: a sum index of 5 occupational mechanical exposures (lifting/carrying, twisted/awkward posture, whole body vibration, repeated	Clinical diagnosis.	BMI, injury to lower limb, sex, and age.	Unilateral OA: - 0 - 1 - 2 - 3 - 4–5	 - - - - -	 - - - - -	 - - - - -	 - - - - -	 1.0 OR 1.1 OR 1.5 OR 2.4 OR 2.3 OR	 - 0.7 – 1.8 1.0 – 2.3 1.4 – 3.8 1.2 – 4.3

	movement, and working speed) (n=7217)			Bilateral OA:						
				- 0	-	-	-	-	1.0 OR	-
				- 1	-	-	-	-	1.4 OR	0.8 – 2.3
				- 2	-	-	-	-	2.2 OR	1.5 – 3.4
				- 3	-	-	-	-	2.8 OR	1.6 – 4.7
				- 4–5	-	-	-	-	2.9 OR	1.5 – 5.8
				Uni or bilateral OA:						
				- 0	-	-	-	-	1.0 OR	-
				- 1	-	-	-	-	1.2 OR	0.9 – 1.8
				- 2	-	-	-	-	1.9 OR	1.4 – 2.6
				- 3	-	-	-	-	2.7 OR	1.8 – 3.9
				- 4–5	-	-	-	-	2.7 OR	1.7 – 4.4
Jacobsson 1987	*Heavy labour*: was assessed as subject to heavy labour, particularly to farming, forestry, industrial work or heavy lifting, or to much walking, standing or tractor driving (n=342)	Radiographic OA.	None.	- No - Yes	1.00 OR 2.42 OR	- 1.33 – 4.41	- -	- -	- -	- -
Juhakoski 2009	*Physical work load*: were assessed as categories of physical workload ranking the exposure from least to heaviest (n=840).	Clinical examination.	Age, sex, education, BMI, smoking, alcohol intake, leisure time physical activity, and injury.	- Light sedentary - Other sedentary - Light standing - Medium heavy - Heavy manual	1.0 OR 1.1 OR 1.2 OR 3.1 OR 6.7 OR	- 0.1 – 10.0 0.4 – 3.4 1.2 – 8.0 2.3 – 19.5	- - - - -	- - - - -	- - - - -	- - - - -
Kontio 2020	*Manual handling of heavy loads*: was assessed as cumulative exposure to lifting, carrying or pushing ≥20 kg for ≥10 times a day (n=4405 with no OA and n=87 for hip OA).	Register information on hip OA.	Age and sex.	- <1 year - 1-10 years - 11-20 years - >20 years	- - - -	- - - -	- - - -	- - - -	1.00 HR 1.34 HR 0.41 HR 0.64 HR	- 0.77 – 2.34 0.13 – 1.30 0.31 – 1.30
	Composite cumulative work load: was calculated using k-means cluster analysis to capture duration and pattern of co-occurrence of physically heavy work, manual handling, kneeling or squatting, and standing or walking (n=4405 with no OA and n=87 for hip OA).	Register information on hip OA.	Age, sex, prior injury, and BMI.	- Low - Intermediate - High	- - -	- - -	- - -	- - -	1.00 HR 1.19 HR 1.28 HR	- 0.74 – 1.93 0.68 – 2.39
	Physically heavy work: was assessed as cumulative exposure to work involving lifting and carrying heavy loads, excavating, shovelling or hammering (n=4405 with no OA and n=87 for hip OA).	Register information on hip OA.	Age and sex.	- <1 year - 1-10 years - 11-20 years - >20 years	- - - -	- - - -	- - - -	- - - -	1.00 HR 1.01 HR 1.40 HR 1.06 HR	- 0.53 – 1.92 0.75 – 2.61 0.61 – 1.84

	Cumulative exposure to physical workload: was calculated as the total number of years having been exposed during the entire work career for each workload factor (n=4405 with no OA and n=87 for hip OA).	Register information on hip OA.	Age and sex.	- Low - Intermediate - High	- - -	- - -	- - -	- - -	1.00 HR 1.18 HR 1.34 HR	- 0.74 – 1.88 0.72 – 2.48
Ratzlaff 2011	*Cumulative peak force index*: was measured using time spend in specific occupational activities, bodyweight, and the peak hip joint force for each activity (%bodyweight), and divided into quintiles (n= 2918)	Self-reporting hip OA.	Sex, previous injury, age, sport/recreation, and household.	- Index 1 - Index 2 - Index 3 - Index 4 - Index 5	- - - - -	- - - - -	- - - - -	- - - - -	1.00 HR 1.11 HR 1.30 HR 1.58 HR 1.80 HR	- 0.63 – 1.83 0.72 – 2.11 0.86 – 2.52 0.95 – 2.82
Rijs 2014	*Use of force*: was assessed using a job-exposure matrix measuring use of force from lifting, pushing, pulling, carrying or use of tools (n=272 for current job and n= 972 for longest job held).	Self-reporting and general practitioner data.	Age and sex.	Current job: - Low - Moderate Longest job: - Low - Moderate	 - - - -	 - - - -	 - - - -	 - - - -	 1.0 OR 2.5 OR 1.0 OR 1.5 OR	 - 0.9 – 7.5 - 0.99 – 2.4
Riyazi 2008	*Physically demanding jobs*: was based on expert judgments of job titles containing demanding work characterised by lifting of heavy objects, handling of heavy tools, stooping, frequently in combination with standing or walking (n=382 cases and n=345 controls).	Radiographic OA.	Age, sex, and BMI.	- No - Yes	- -	- -	- -	- -	1.0 OR 3.3 OR	- 1.3 - 8.2
Roach 1994	*Workload*: was assessed as number of years exposed to mechanical exposures classified into three categories (n=99 cases and n=233 controls).	Radiographic and register data.	None.	- Light - Intermediate - Heavy	1.0 OR 1.9 OR 2.4 OR	- 1.0 – 3.8 1.3 – 4.3	- - -	- - -	- - -	- - -
	Workload: was assessed as number of years exposed to mechanical exposures classified into three categories (n=99 cases and n=233 controls).	Radiographic and register data.	Cancer, obesity at age 40, and football.	- Light - Heavy	1.0 OR 2.4 OR	- 1.2 – 4.7	- -	- -	- -	- -
Rubak 2013**	*Physical workloads*: was assessed as exposure to overall physical workload to the hip, calculated as number of employment years, based on total lifts per working day, frequency	Register information on total hip replacement.	Age, cumulative physical workload, calendar year, county of residence, and socioeconomic status.	- 0 - >0 - <5 point-years - 5 - <15 point-years - 15-<25 point-years - 25-<35 point-years - 35 - 86 point-years	1.00 OR 1.13 OR 1.14 OR 1.19 OR 1.27 OR 1.33 OR	- 0.98 – 1.31 1.00 – 1.31 1.04 – 1.36 1.11 – 1.48 1.17 – 1.53	1.00 OR 0.96 OR 0.96 OR 0.94 OR 0.99 OR 1.01 OR	- 0.8 – 1.06 0.87 – 1.05 0.85 – 1.04 0.88 – 1.10 0.88 – 1.16	- - - - - -	- - - - - -

	of lifting ≥20 kg, whole-body vibration, and standing/walking the majority of the day (n= 1010944 men and 899549 women).									
Solovieva 2018	*Heavy physical work*: was assessed from a job-exposure matrix dichotomising heavy physical work (n=574,617 men and n=561,037 women).	Register information on disability retirement due to OA.	Age, kneeling or squatting, heavy lifting, sitting, and standing or moving.	- No - Yes	1.00 HR 1.34 HR	- 1.10 – 1.64	1.00 HR 1.65 HR	- 1.39 – 1.95	- -	- -
Thelin 1997	*Heavy physical work*: was assessed as subjective heavy physical work for more than half a year before participants were 16 years of age (n=216 cases and n=479 controls).	Radiographic OA.	None. Matched on age and place of residence.	- No - Yes	1.00 OR 2.06 OR	- 1.48 – 2.86	- -	- -	- -	- -
Vingård 1991	*Dynamic*: was assessed as exposure to walking with burdens and stair climbing and divided into three subclasses on the basis of the exposure distribution (n=233 cases and n=302 controls).	Total hip replacement due to OA.	Age, BMI, smoking, and sport activities up to the age of 29 years.	- Low - Medium - High	1.00 RR 1.92 RR 2.17 RR	- 1.11 – 3.32 1.27 – 3.73	- - -	- - -	- - -	- - -
	Static + dynamic: was assessed as exposure to working in a twisted locked position, walking with burdens, and stair climbing and divided into three subclasses based on the exposure distribution (n=233 cases and n=302 controls).	Total hip replacement due to OA.	Age, BMI, smoking, and sport activities up to the age of 29 years.	- Low - Medium - High	1.00 RR 1.82 RR 2.42 RR	- 1.02 – 3.24 1.45 – 4.04	- - -	- - -	- - -	- - -
Other occupational mechanical exposures										
Allen 2010	*Crawl*: crawling on knees at the longest job participants held, measured on a 5-point scale. Radiographic: no OA, exposed n=107 and OA, exposed n=60. Symptomatic: no OA, exposed n=137 and OA, exposed n=30.	Hip OA.	Age, sex, race, BMI, smoking (ever and current vs. never), prior knee injury, and household tasks.	Radiographic OA: - Never, seldom, sometimes - Often or always Symptomatic OA: - Never, seldom, sometimes - Often or always	 - - - -	 - - - -	 - - - -	 - - - -	 1.00 OR 1.35 OR 1.00 OR 2.28 OR	 - 0.93 – 2.00 - 1.43 – 3.65
Coggon 1998	*Driving*: driving for >4 hours in an average working day for up to 10 years before entry into the	Radiographic OA.	BMI, Heberden's nodes, and history of hip injury.	- 0 years - 0.1-9.9 years - 10.0-19.9 years	1.0 OR 1.3 OR 0.5 OR	- 0.7 – 2.6 0.2 – 1.3	1.0 OR 4.0 OR 2.7 OR	- 1.2 – 13.7 0.3 – 28.5	1.0 OR 1.8 OR 0.7 OR	- 1.0 – 3.1 0.3 – 1.5

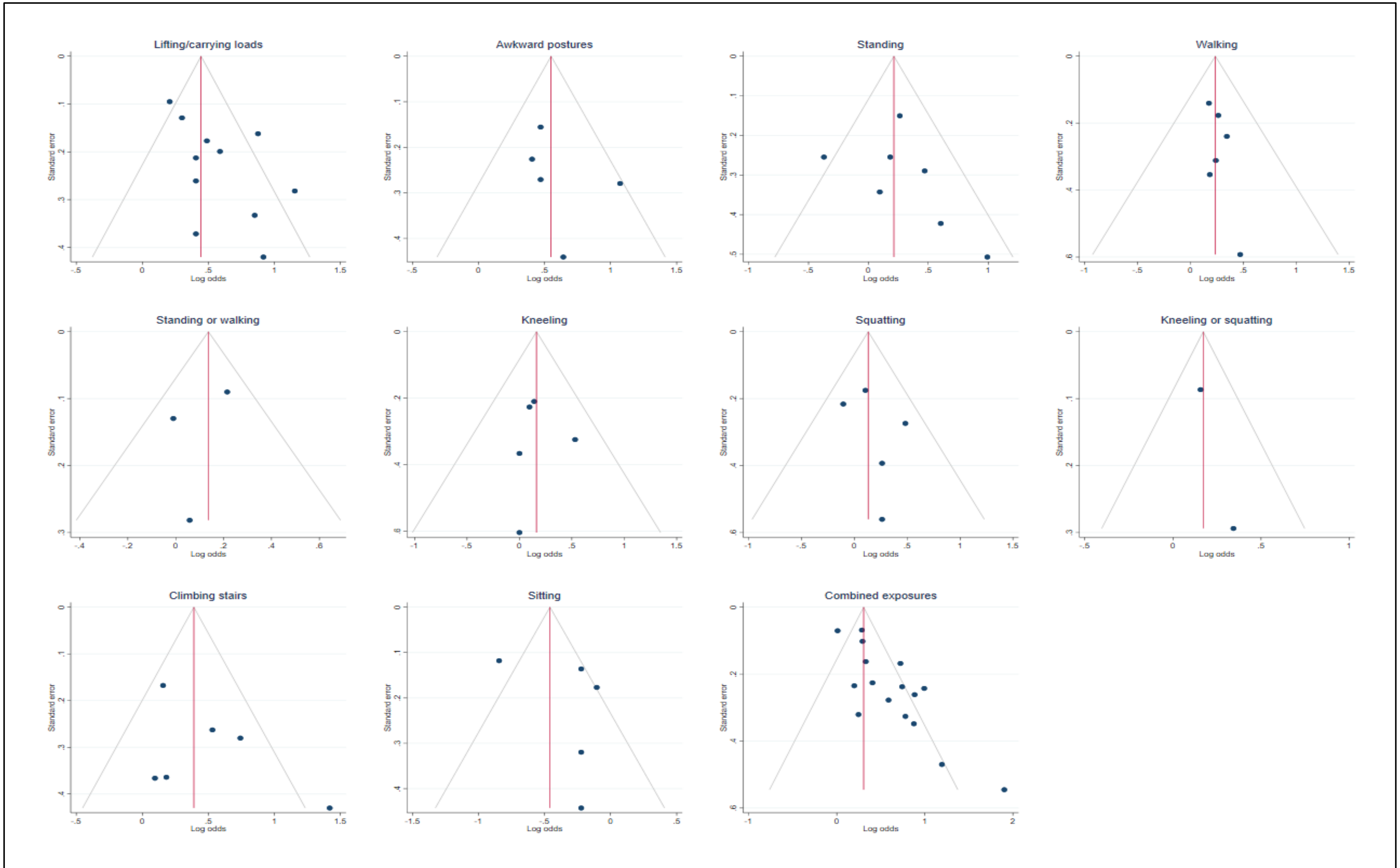
	study (n=611 cases and n=611 controls).		Matched on age, sex, and general practice.	- ≥20.0 years	0.9 OR	0.4 – 1.8	-		1.0 OR	0.5 – 1.9
Croft 1992	*Driving*: years of exposure to driving for >4 hours a day (n=274 referents, n=228 all cases, and n=47 severe cases).	Radiographic OA.	Age and hospital group.	All cases: - <1 year - ≥1 year Severe cases: - <1 year - ≥1 year	 1.0 OR 0.8 OR 1.0 OR 0.9 OR	 - 0.5 – 1.2 - 0.4 – 1.8	 - - - -	 - - - -	 - - - -	 - - - -
	Running: years of running for >1 hour a day (n=269 referents, n=228 all cases, and n=47 severe cases).	Radiographic OA.	Age and hospital group.	All cases: - <1 year - ≥1 year Severe cases: - <1 year - ≥1 year	 1.0 OR 1.3 OR 1.0 OR 0.5 OR	 - 0.5 – 3.3 - 0.1 – 4.2	 - - - -	 - - - -	 - - - -	 - - - -
Lau 2000	*Digging*: was assessed as digging for ≥1 hour on an average working day (n=30 cases and n=90 controls for men and n=108 cases and n=324 controls for women).	Radiographic OA.	Men: none. Matched on age. Women: adjusted for height, weight, history of joint injury, and regular sports activities. Matched on age.	- No - Yes	1.0 OR 2.0 OR	- 0.3 – 12.0	1.0 OR 2.2 OR	- 0.8 – 6.5	- -	- -
	Driving: was assessed as driving for ≥4 hour on an average working day (n=30 cases and n=90 controls for men and n=108 cases and n=324 controls for women).	Radiographic OA.	Men and women: None. Matched on age.	- No - Yes	1.0 OR 0.4 OR	- 0.04 – 3.0	- -	- -	- -	- -
	Vibrations: was assessed as use of vibration tools for ≥1 hour each day (n=108 cases and n=324 controls).	Radiographic OA.	Height, weight, history of joint injury, and regular sports activity. Matched on age.	- No - Yes	- -	- -	1.0 OR 7.9 OR	- 0.8 – 77.8	- -	- -
	Vibrations: was assessed as use of vibration tools for ≥1 hour each day (n=30 cases and n=90 controls)	Radiographic OA.	None. Matched on age.	- No - Yes	1.0 OR 0.7 OR	- 0.2 – 2.3	- -	- -	- -	- -
Lau 2007	*Digging*: was assessed as digging for ≥1 hour on an average working day (n=30 cases and n=90 controls for men and n=108 cases and n=324 controls for women).	Radiographic OA.	BMI and injury. Matched on age.	- No - Yes	1.00 OR 1.98 OR	- 0.21 -19.07	1.00 OR 3.25 OR	- 1.47 – 7.20	1.00 OR 2.92 OR	- 1.40 – 6.11
	Driving: was assessed as driving for ≥4 hour on an average	Radiographic OA.	BMI and injury. Matched on age.	- No - Yes	1.00 OR 0.30 OR	- 0.03 – 3.09	- -	- -	- -	- -

	working day (n=30 cases and n=90 controls for men and n=108 cases and n=324 controls for women).									
	Vibrations: was assessed as use of vibration tools for an hour each day (n=30 cases and n=90 controls for men and n=108 cases and n=324 controls for women)	Radiographic OA.	BMI and injury. Matched on age.	- No - Yes	1.00 OR 2.15 OR	- 0.36 – 12.73	1.00 OR 7.68 OR	- 1.32 – 44.80	1.00 OR 3.94 OR	- 1.18 – 13.12
Olsen 1994	*Jumping*: No information on the collection was provided, but the exposure was aggregated for men's work life up to 49th year of age. It was then defined into three exposure groups (n=239 cases and n=302 controls).	First-time prosthesis.	Age, BMI, smoking and sports activities.	- Low - Medium - High	1.00 OR 1.83 OR 1.52 OR		- - -	- - -	- - -	- - -
Rijs 2014	*Repetitive movements*: was assessed with a job-exposure matrix measuring repetitive movements at work (n=268 for current job and n=820 for longest job held).	Hip OA.	Age and sex.	Current job: - Low - Moderate - High Longest job: - Low - Moderate - High	 - - - - - -	 - - - - - -	 - - - - - -	 - - - - - -	 1.0 OR 5.7 OR 6.2 OR 1.0 OR 2.1 OR 2.5 OR	 - 0.7 – 45.6 0.7 – 56.4 - 0.99 – 4.6 1.2 – 5.6
Rubak 2014	*Whole-body vibrations*: was assessed as ever or never exposure to whole-body vibrations (n=1776 case-control sets including at least 1 case and 1 control, divided in 861 sets for women and 915 sets for men).	Total hip replacement due to OA.	One occupational exposure at a time adjusted for body mass index at age 25, change in body mass index, pack-years of smoking, previous fracture of a lower extremity, familial predisposition, endurance and contact sport at age 25, and region of residence. Matched on age.	- Never - Ever	1.00 OR 1.26 OR	- 0.97 – 1.64	1.00 OR 0.64 OR	- 0.35 – 1.15	- -	- -
Vingård 1997	*Jumps*: was assessed based on numbers of jumps or movements between different levels on work and divided into three subclasses based on the exposure distribution (n=503).	Total hip replacement due to OA.	Age, BMI, smoking, sports activities, number of children, and hormone therapy.	- Low - Medium - High	- - -	- - -	1.0 RR 1.0 RR 2.1 RR	- 0.5 – 2.0 1.1 – 4.2	- - -	- - -

Yoshimura 2000	*Driving*: was assessed as driving for ≥4 hours (n=103 cases and n=103 controls).	Radiographic OA.	History of knee pain and age left school. Matched on age, sex, and district of residence.	First job: - No - Yes Main job: - No - Yes	 - - - -	 - - - -	 - - - -	 - - - -	 1.0 OR 1.1 OR 1.0 OR 1.4 OR	 - 0.1 – 7.6 - 0.4 – 5.4

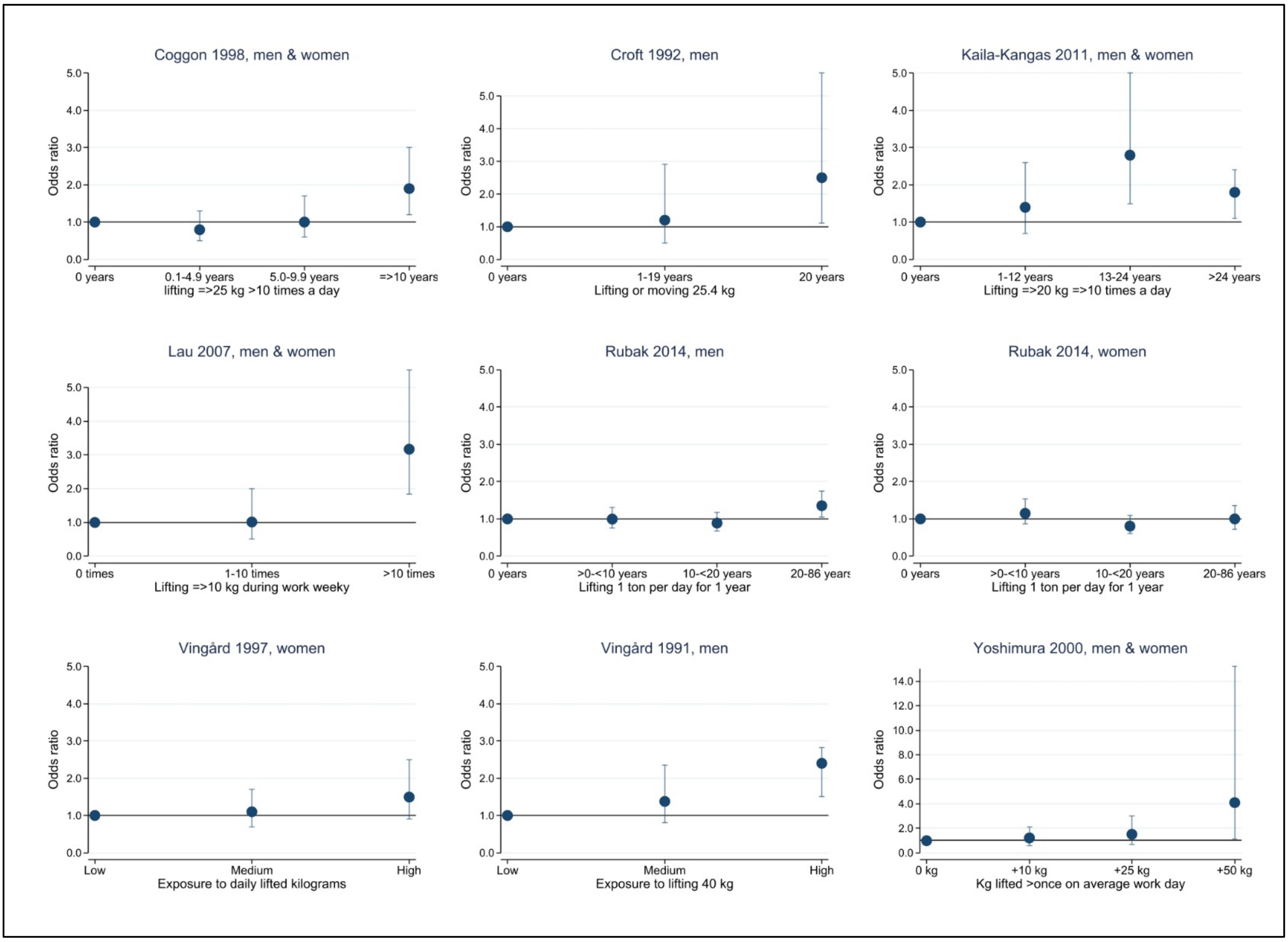
Abbreviations: BMI = body mass index; HR = hazard ratio; n = numbers; OA = osteoarthritis; OR = odds ratio; RR = relative risk;
** In Rubak 2013, numbers in table 2 are not consistent with numbers provided in flow chart (a total of 9 women). We have extracted numbers of participants from table 2 used in the forest plot.

9.6 Funnel plots

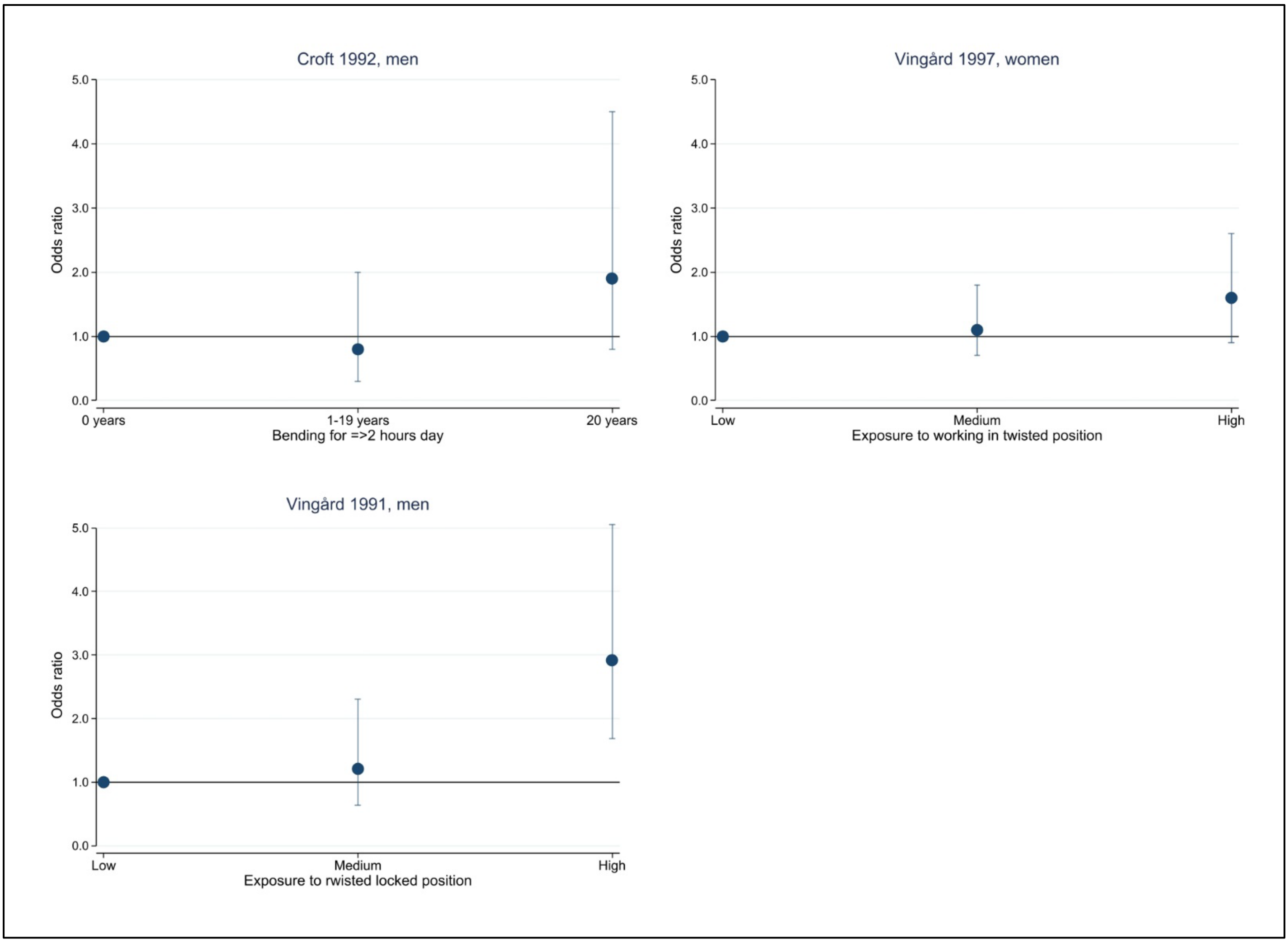


9.7 Scatterplots of exposure-response relation

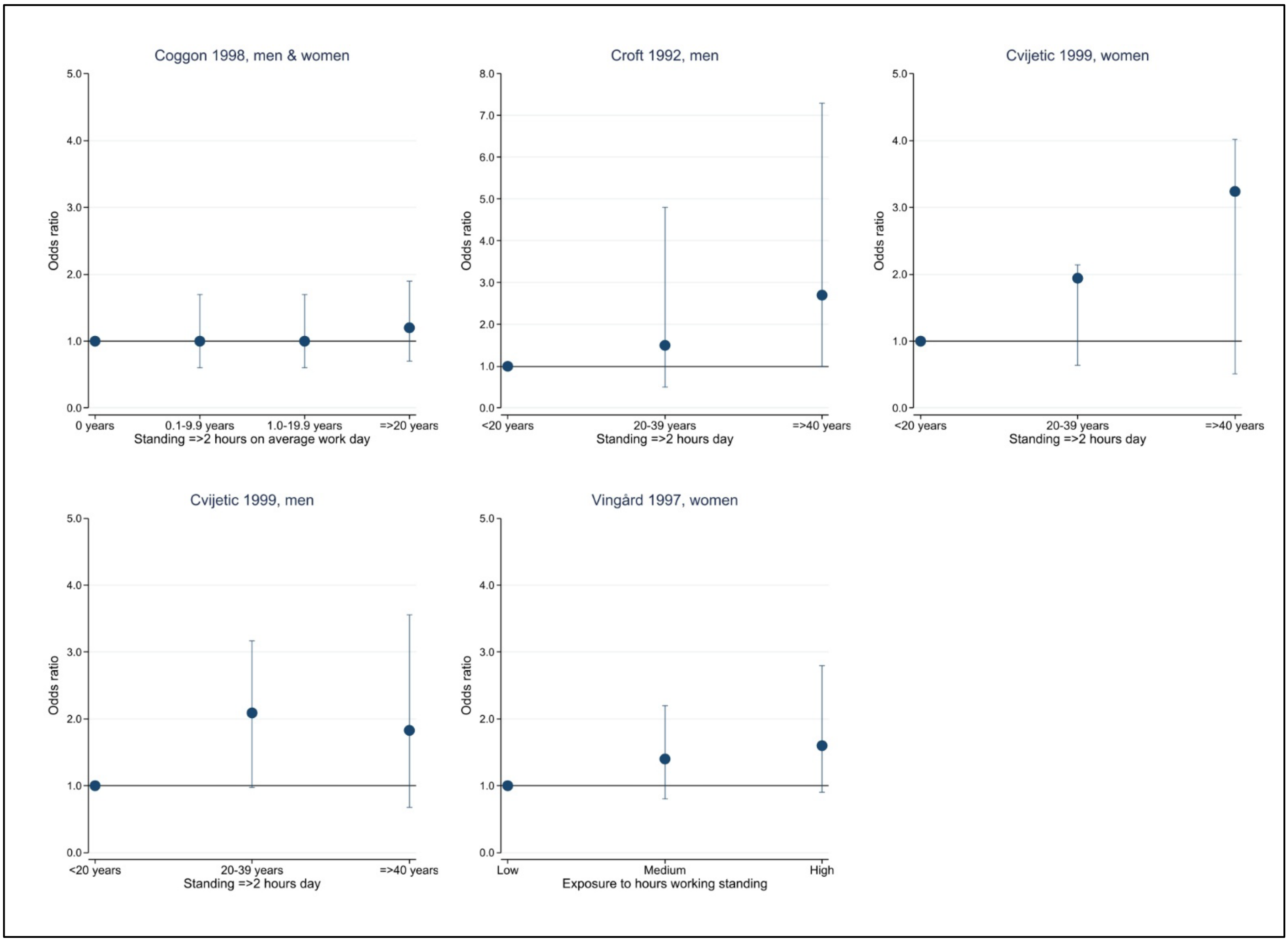
9.7.1 Lifting/carrying loads



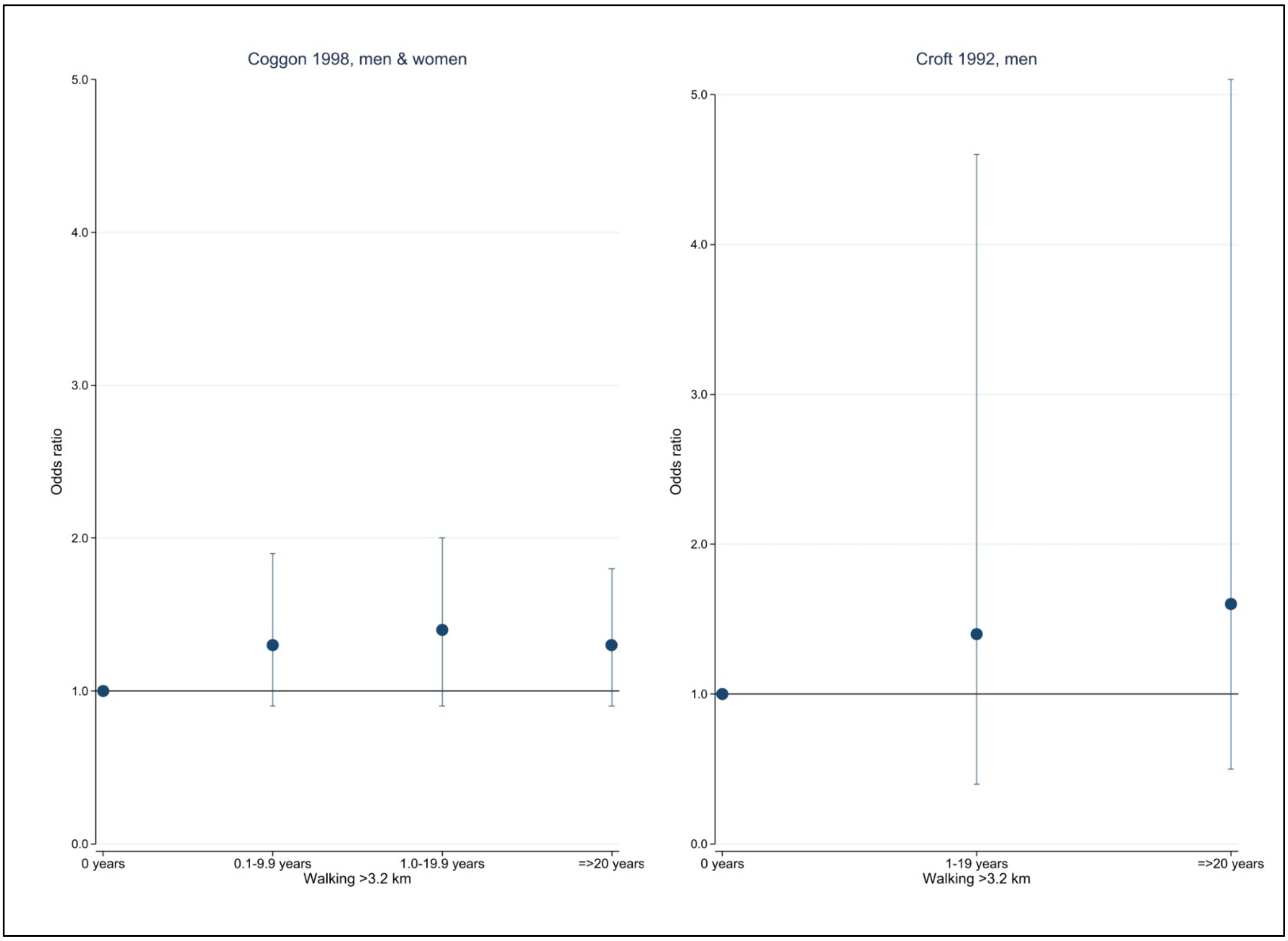
9.7.2 Awkward postures



9.7.3 Standing

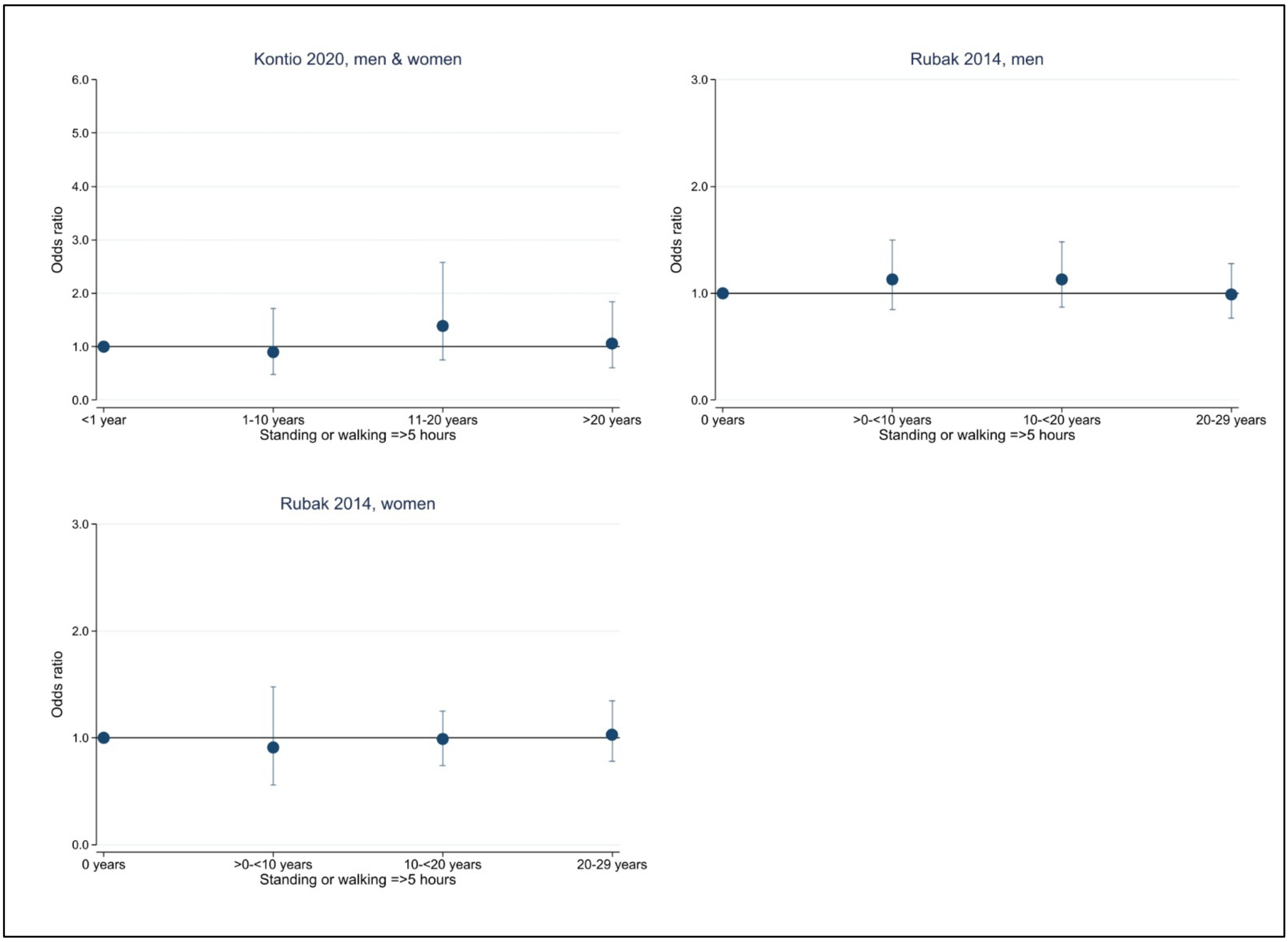


9.7.4 Walking

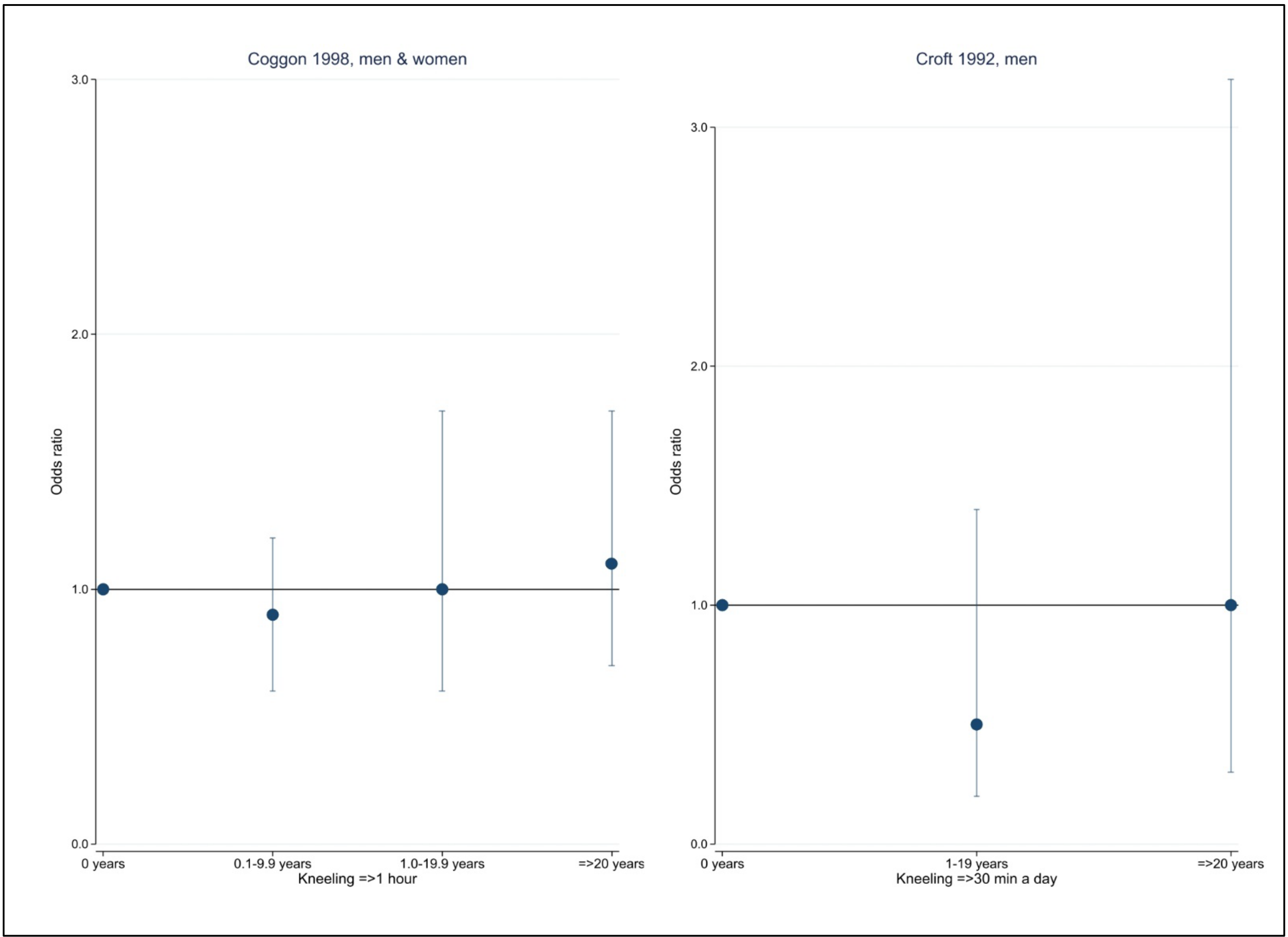


Coggon 1998, men & women
Odds ratio
5.0
4.0
3.0
2.0
1.0
0.0
0 years
0.1-9.9 years
1.0-19.9 years
=>20 years
Walking >3.2 km
Croft 1992, men
Odds ratio
5.0
4.0
3.0
2.0
1.0
0.0
0 years
1-19 years
=>20 years
Walking >3.2 km

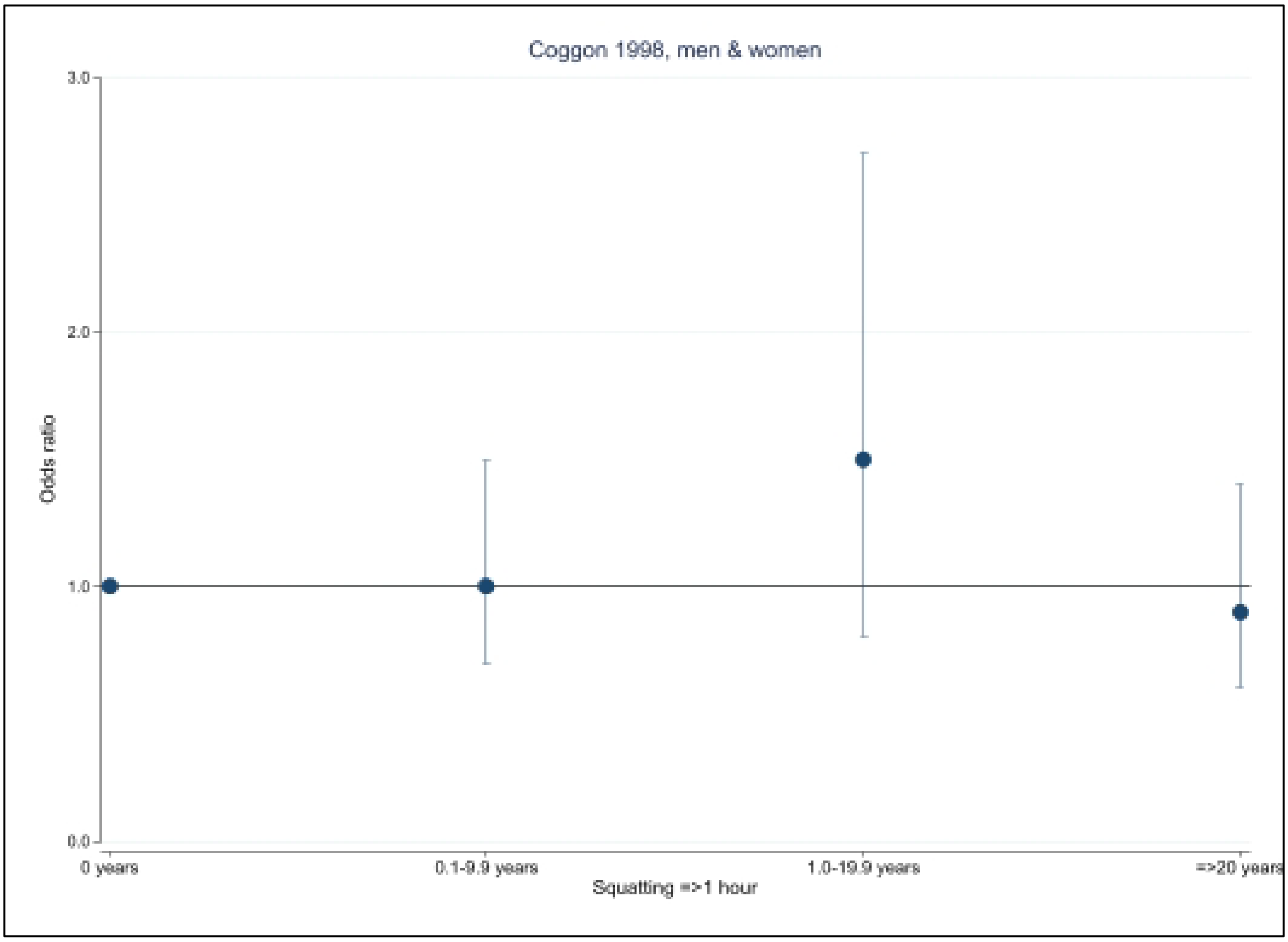
9.7.5 Standing or walking



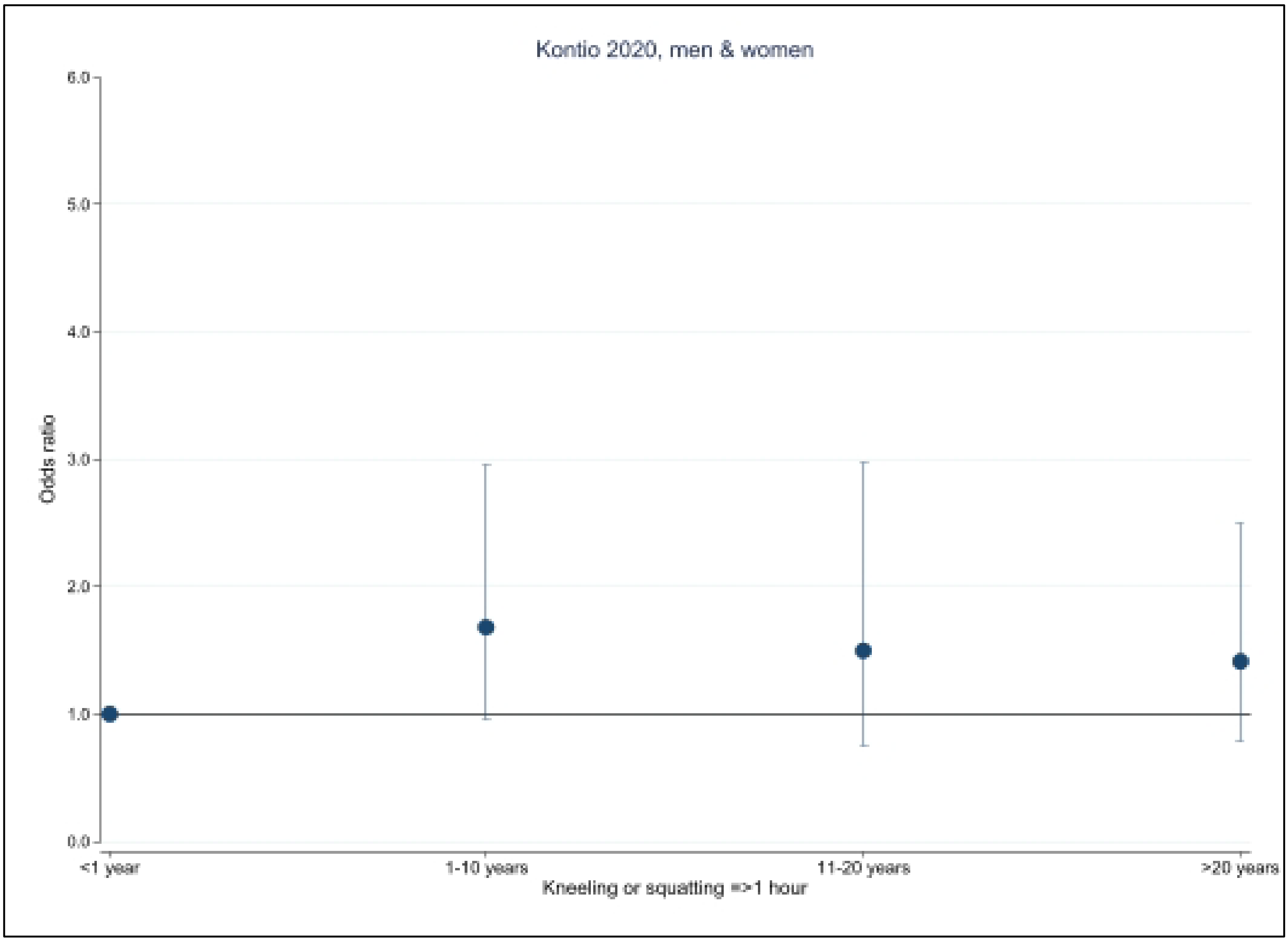
9.7.6 Kneeling



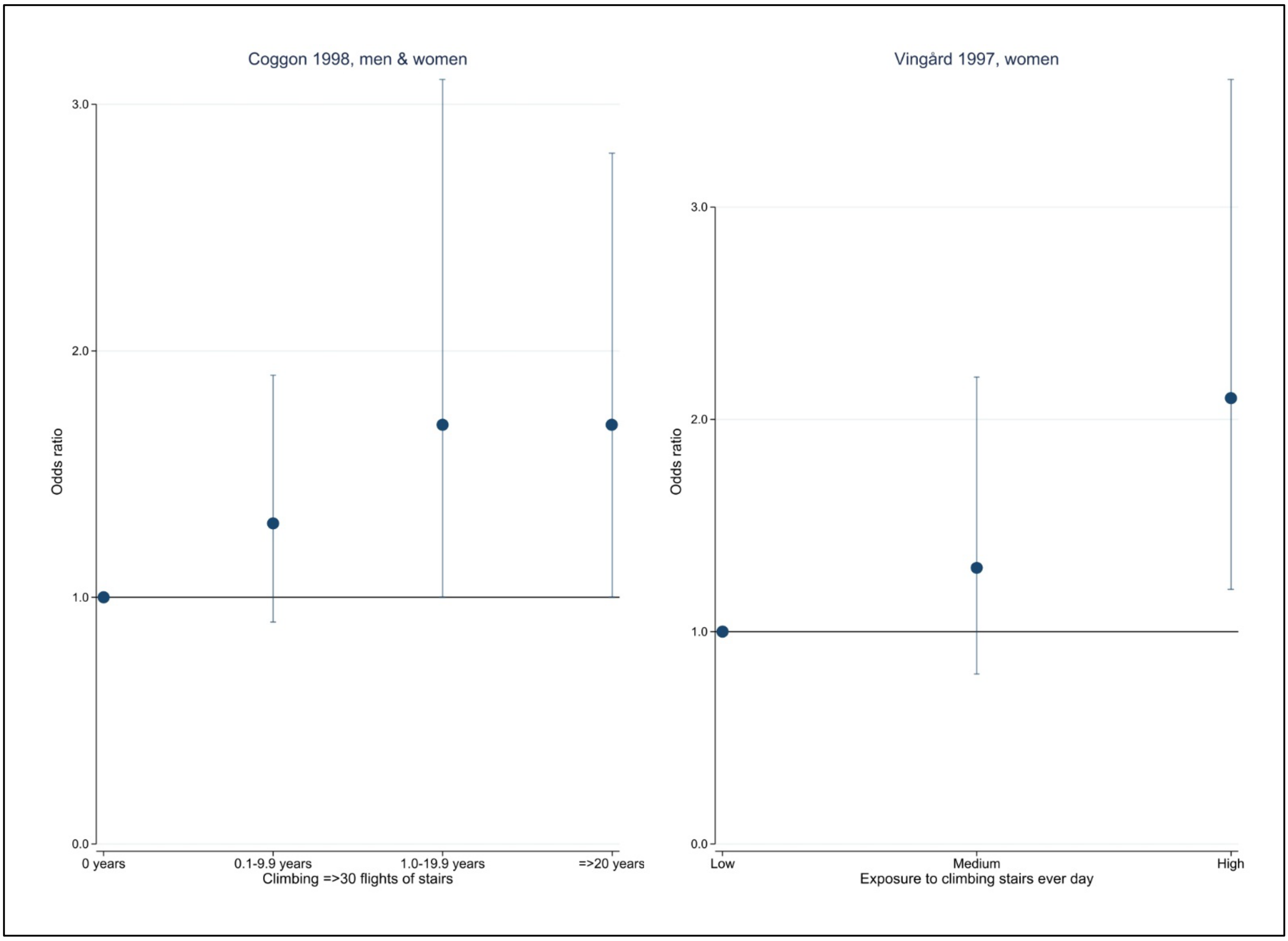
9.7.7 Squatting



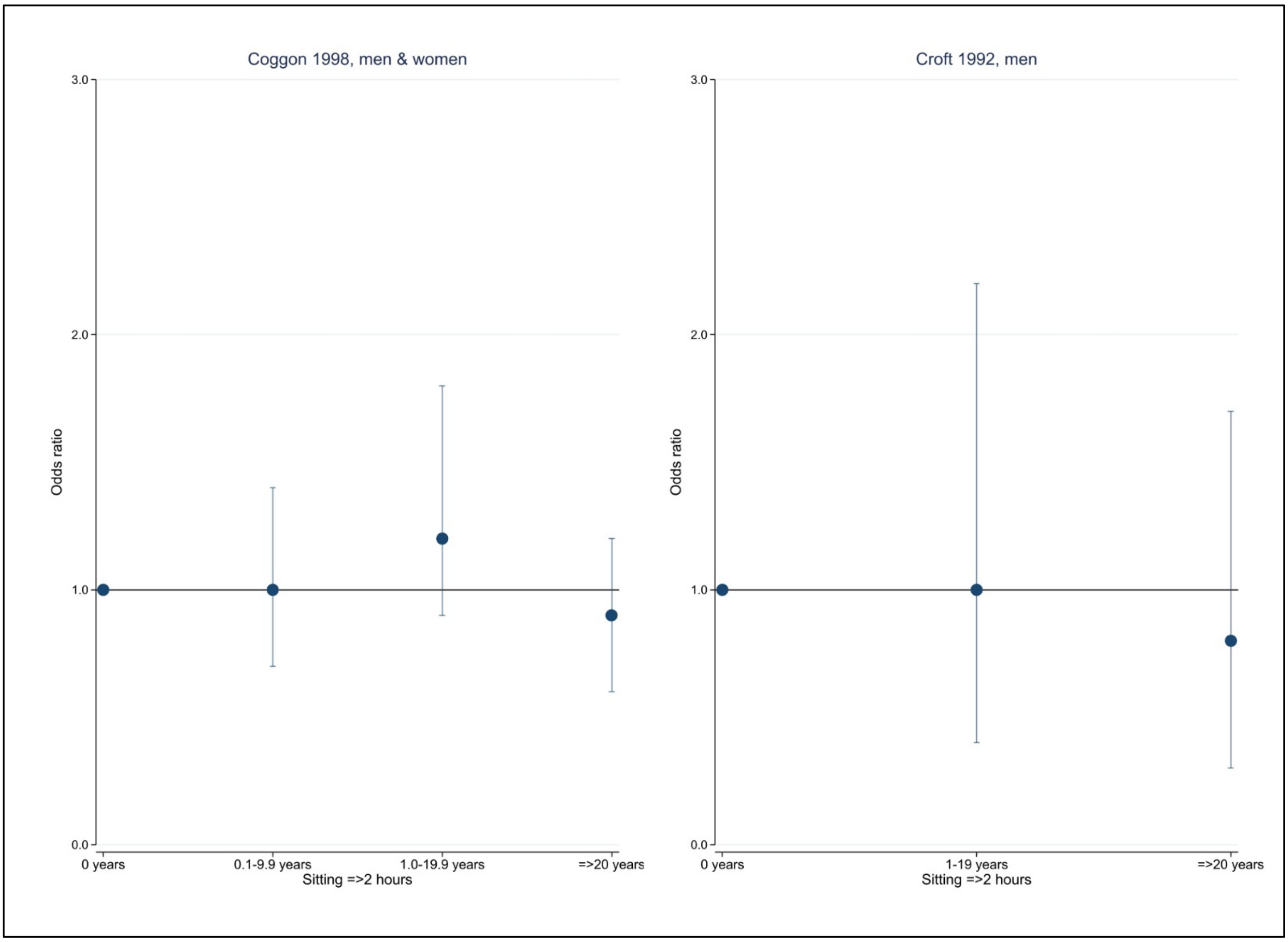
9.7.8 Kneeling and squatting



9.7.9 Climbing stairs



9.7.10 Sitting



9.7.11 Combined exposures