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Associations between occupational sitting and health risks: a systematic review

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ABSTRACT

Background: Emerging evidence suggests that sedentary behavior (i.e. time spent sitting) may be negatively associated with health. The aim of this study was to systematically review the evidence on associations between occupational sitting and health risks.

Methods: Studies were identified in March/April 2009 by literature searches in PubMed, PsycINFO, CENTRAL, CINAHL, EMBASE and PEDro, with subsequent related-article searches in PubMed and citation searches in Web of Science. Identified studies were categorized by health outcome. Two independent reviewers assessed methodological quality using a 15 item quality rating list (score range 0-15 points, higher score indicating better quality). Data on study design, study population, measures of occupational sitting, health risks, analyses and results were extracted.

Results: 43 papers met the inclusion criteria (21% cross sectional, 14% case control, 65% prospective); they examined the associations between occupational sitting and body mass index (BMI, N=12), cancer (N=17), cardiovascular disease (CVD, N=8), diabetes mellitus (DM, N=4) and mortality (N=6). The median study-quality score was 12 points. Half the cross-sectional studies showed a positive association between occupational sitting and BMI, but prospective studies failed to confirm a causal relationship. There was some case-control evidence for a positive association between occupational sitting and cancer; however, this was generally not supported by prospective studies. The majority of prospective studies found that occupational sitting was associated with a higher risk of DM and mortality.

Conclusions: Limited evidence was found to support a positive relationship between occupational sitting and health risks. The heterogeneity of study designs, measures, and findings makes it difficult to draw definitive conclusions at this time.

INTRODUCTION

In epidemiological studies focusing on the benefits of physical activity (PA), those who are physically-inactive have typically been described as sedentary.[1] However, the term ‘sedentary behavior’ has begun to be used to describe prolonged sitting, instead of the absence of PA. Sedentary behaviors usually have very low energy expenditure (typically less than 1.5 metabolic equivalents; multiples of the basal metabolic rate).[2] There is a rapidly-expanding body of evidence suggesting that time spent in sedentary behaviors is associated adversely with health risks, which may be independent of the protective contributions of PA.[3-9]

Prior to the 1970s, PA epidemiology studies focused on occupational activity. For example, in their landmark studies on occupational activity in 1953, Morris et al. observed higher rates of cardiovascular events in sedentary bus drivers and mail sorters than in more active bus conductors and postal workers.[10] Since then, as transport and work have become more automated, the focus of most physical activity studies, especially in the large cohort studies, has been on leisure-time PA. However, findings of recent studies have led to a renewed interest in the health effects of prolonged sitting.[11] These have demonstrated associations between sitting time and obesity[4, 6, 7], metabolic syndrome and diabetes[3, 6], markers of cardiovascular disease risk[7, 9], and premature mortality.[5, 8] The associations between sitting time and health outcomes in these studies may be independent of physical activity participation, as they remained significant after adjustment for PA.[3-9] These studies have mainly addressed sitting during leisure time rather than occupational sitting, with a particular focus on TV viewing time.

Sitting in an occupational context is also likely to be important, given that many adults in Western developed countries are in occupations that require prolonged sitting time. For example, in Australia and the USA, about two thirds of adults are employed, 83% of these in full-time work (>35 hrs/wk).[12, 13] Data from the Netherlands and Australia suggest that working adults can spend up to half their work day sitting down.[14, 15] In the USA, time-use surveys have shown that people in full-time employment spend an average of 9.2 hours working on weekdays,[16] much of which will involve sitting. In contrast, they spend an average of just over two hours per day watching TV and playing (computer) games.[16] A study of Australian workers found that those working full-time sit for an average of 4.2 hours per day at work, and spend 2.9 hours in leisure time sitting.[14] Thus, for full-time employees in physically-inactive jobs, occupational sitting is likely to be the largest contributor to overall daily sitting time.

In the context of these major contributions of occupational sitting to working adults' overall sitting time, and the high proportions of adults employed in mainly sedentary occupations, there is a need to clarify the strength of evidence on the potentially-deleterious impact of prolonged sitting at work. Thus, the aim of this systematic review was to critically review and summarize the evidence from studies which have examined associations between occupational sitting and the risk of life-style diseases, or markers thereof.

METHODS

Literature search

The databases PubMed, PsycINFO, CENTRAL (The Cochrane Central Register of Controlled Trials), CINAHL, EMBASE and PEDro, were searched for relevant studies in March/April

2009 by Ingrid Riphagen, medical librarian (full search for all databases, except for the EMBASE, which was searched from 1980). Groups of thesaurus terms as well as free terms were used to search the databases. Terms for *'adults'* were used in AND-combination with terms for *'workplace setting'*, *'sitting'*, and search terms representing study designs and languages (Complete search profiles are available on request from Ingrid Riphagen). Subsequently, the librarian performed a related articles search in PubMed and a citation search in Web of Science for selected papers. Furthermore, additional articles were identified by manually checking the reference lists of included papers and searching the authors' own literature databases.

Inclusion criteria and selection process

In order to be included in the review, studies were required to: 1) focus on adults; 2) be undertaken in a workplace setting or in a general setting in a working population; 3) use a specific measure of occupational sitting (categorical or continuous; self-report or objective), or of occupational activities below 1.5 metabolic equivalents; 4) examine the association between occupational sitting and the risk of life style diseases, or markers thereof (e.g. weight, cholesterol, blood pressure) or mortality. Only full-text peer reviewed articles were considered for inclusion. Papers written in Chinese, Dutch, English, French, German, Italian, Norwegian and Spanish, were checked for eligibility. Titles and abstracts of the identified references were reviewed to exclude articles out of scope. Subsequently, two reviewers independently reviewed the full text of all potentially relevant references for eligibility. Disagreements between these reviewers were discussed with two more reviewers and a consensus decision was made.

Data extraction and quality assessment

Data on the study population, measure of occupational sitting, health risks, analyses and results were extracted for each paper. Papers describing multiple health risks[6, 17-19] were included in each of the relevant tables. The studies describing the associations between occupational sitting and all-cause, cardiovascular and cancer mortality were clustered in one table. Methodological quality of the included studies was independently determined by two reviewers using a quality rating list based on checklists for the reporting of observational studies and a list used for quality rating.[20-22] This quality rating list consists of 15 criteria assessing different methodological aspects (Table 1). Criteria had a 'yes' (1 point), 'no' (0 points) or 'unclear' (0 points) answer format. All criteria had the same weight and a quality score ranging from 0 to 15 points was calculated for each study.

Terminology used in the review

In this review, the term *'occupational sitting'* is used as an umbrella term in the abstract, introduction, and discussion. However, in the results section, the term *'occupational activity'* is used if papers used a categorical measure of activity with '*sitting'* or *'sedentary'* as the reference category. In contrast, if a paper used the highest level of occupational activity as the reference category (often *'heavy labour'*), or compared categories of sitting time, then the term *'occupational sitting'* is used. For consistency, the term *'occupational sitting'* is used in the beginning and concluding sentences for each health risk in the results.

RESULTS

Study selection

The literature searches yielded 3202 unique potentially relevant articles (Figure 1). After excluding the records out of scope, the full-text of 355 records was checked. Three-hundred and twelve of these articles did not meet the inclusion criteria; the most common reason for exclusion was that there was no measure of occupational sitting (number of studies [N]=232, 70%). Finally, 43 papers examining the associations between occupational sitting and the following health risks were included in this review: BMI (N=12), cancer (N=17), CVD (N=8), DM (N=4) and mortality (N=6).

Quality assessment

The criteria for quality assessment and the number and proportion of studies scoring a point for each quality criterion are reported in Table 1. The agreement between the quality raters ranged from 10/15 to 15/15 and the mean percentage agreement was 87 (SD=9). The median quality score for the included papers was 12 (25^{th}-75^{th} percentiles=10-12) points out of 15. Hypotheses and study design were reported for all studies and more than 90% of the included studies scored a point for identifying the target population, the source of the data, variables included in the analyses and for the use of appropriate statistical methods. Very few studies reported the validity (10 studies) or reliability (4 studies) of the measure used for occupational sitting. See Appendix table A for the quality assessment of each paper included in this review.

General findings

For each outcome, an overview of study designs, findings, quality scores, adjustment for physical activity and sample sizes is presented in Figure 2. There were several study designs, including cross-sectional, case-control and prospective studies. There were no evident differences in quality scores of studies finding: 1) that occupational sitting was associated with an increased health risk (n=22, of which 12 adjusted for PA); 2) that there was no association (n=20, 4 adjusted for PA); or 3) that sitting was associated with a decreased health risk (n=5, 3 adjusted for PA). Samples sizes in included studies were large, generally thousands of people. Only seven studies included less than 1000 participants, of which three included less than 500 participants.

Associations between occupational sitting and BMI, waist circumference or waist hip ratio

Twelve studies examined the association between occupational sitting and BMI (see Figure 2 for overview). Details of study designs, study populations, measures for occupational sitting and BMI, and analyses are shown in Appendix Table B. Nine studies used a cross-sectional design[19, 24-30, 32], two were prospective,[6, 17] and one study reported both cross-sectional and prospective data.[31] Participant numbers ranged from 158[25] to more than 250,000[32] and the median number of participants was 6,575 (25^{th}–75^{th} percentiles=1,695–12,675). One study included men only[31] and two studies included women only.[6, 25] The percentage of women in the other studies ranged from 36% to 87%. All studies used self-report measures of occupational sitting. Three studies, two with a cross-sectional design [26, 27] and one prospective,[6] used a continuous measure for occupational sitting time and then categorized data for the analyses. The other studies used a categorical measure of occupational sitting with descriptive categories (e.g., *'most of the time'* vs *'hardly ever'*)[25], or a categorical measure of occupational activity with *'sitting'* or *'sedentary'* as one of the response options.[17, 19, 24, 28-32] Six studies used a dichotomized outcome for BMI with cut-offs of 25 kg/m^2, [27] 30 kg/m^2, [6, 29-31] or 27 kg/m^2; [32] three studies used multiple BMI categories[19, 24, 28] and four analyzed BMI as a continuous outcome.[17, 25, 26, 30] In addition to BMI, one study also examined the association between occupational sitting and waist circumference [28] and another study examined waist-to-hip ratio.[26]

Five of the ten cross-sectional studies reported a significant positive association between occupational sitting and BMI; one for BMI≥25 (in men, but not in woman)[27], one for BMI as a continuous outcome (in men, but not in women)[26] and one in a study only including women.[25] The other two studies reported that men with a higher BMI were more likely to have a sedentary job.[19, 24] The results of these five cross-sectional studies were adjusted for at least sociodemographic variables, such as age and education, except for one study that reported only unadjusted results.[25]

One cross-sectional study found that Norwegians who reported being active at work (‘*walking, walking and lifting, or heavy activity in the last year’*) had higher odds of having a BMI≥27 kg/m^2 than participants who were *‘mostly sitting’* during work.[32] This was for both men and women, but the association was stronger for women than for men. Gutierrez-Fisac[30] et al. also found that a higher level of occupational activity was associated with higher BMI (men and women) and increased odds of having a BMI ≥30 kg/m^2 (women). However, this association did not remain significant after adjustment for sociodemographic and lifestyle factors and health. In other cross-sectional studies, occupational activity was not associated with obesity, [29, 31] or with waist circumference[28] but sedentary hours per working day were positively associated with waist-to-hip ratio, although only in women.[26]

Two of the three prospective studies[17, 31] reported no significant positive associations between sitting and the maintenance or development of obesity[31] or between sitting and BMI.[17] Hu et al. found a significant trend for increased obesity risk across categories of sitting time, however, the difference was only statistically significant for women who sat more than 40 hours/week compared with women who sat <1 hour/week.[6]

In summary, five of the ten cross-sectional studies showed a positive association between occupational sitting and BMI, but four studies found no association and one study found a negative association. Of the three prospective studies, one found a positive association, but the other two found no association.

Associations between occupational sitting and cancer

Seventeen studies described the association between occupational sitting and various cancers (see Figure 2 for overview).[33-49] Details of these studies are provided in Appendix Table C; the studies are arranged according to the type of cancer, including breast cancer (N=3)[33, 37, 45]; endometrial and ovarian cancer (N=3)[35, 36, 47]; colon and rectal cancer (N=4)[34, 38, 42, 44]; renal and pancreatic cancer (N=3)[39, 40, 46]; prostate and testicular cancer[41]; and lung cancer (N=3).[43, 48, 49]

Four of the 17 studies were case control studies[33-36] and the other 13 were prospective studies. The number of participants was less than 1000 in three of the case-control studies and 1,198 in the fourth study.[36] Participant numbers in the prospective studies ranged from 16,477[38] to 416,227[49]; the median number of participants was 53,242 (25^{th}–75^{th} percentiles=27,379 – 149,843). The mean follow-up duration for the prospective studies was 12.0 (SD=5.0) years and ranged between 5-10 years [44, 45, 47-49]; 10-15 years[37-39, 46]; 15-20 years[41-43] and one study had a follow-up duration of 22.6 years.[40] All studies, except one, used a categorical measure of occupational activity, with *'mostly sedentary/mainly sitting'* as one of the response options. The case-control study that directly assessed sitting time as a continuous measure (hours/day) then categorized it for the analyses.[35]

Three case-control studies[33, 35, 36] and three prospective studies[37, 45, 47] included only women. These examined breast cancer,[33, 37, 45] ovarian cancer,[35, 36] and endometrial cancer.[47] Compared with breast cancer risk in *'sedentary/mainly sitting'* workers, one study found no association between *'standing'* and *'manual and heavy manual'* and breast cancer risk [45] and two found that more occupational activity was associated with lower breast cancer risk.[33, 37] However, in the Norwegian study[37] this was only the case for premenopausal women. The studies examining ovarian cancer found that *'light'*, *'moderate'*, or *'strenuous'* occupational activity was associated with lower cancer risk, compared with *'sitting'* [36] and that more sitting was associated with increased cancer risk.[35] There was no association between occupational sitting for more than half of working time and endometrial cancer.[47]

Three prospective studies[38, 42, 44] and one case-control study[34] examined the association between occupational activity and colon and rectal cancer in men and women. There was no statistically significant association between categories of occupational activity and risk of cancer in the prospective studies. However, in the case-control study, *'standing'* or *'tiring'* occupational activity was associated with a lower risk of colon or rectal cancer (compared with *'mainly sitting')*.[34]

Two prospective studies, one in men and women[40] and one in men only[46], found that there was no association between occupational activity and risk of renal cell cancer. Other studies in men only found that this was also the case for pancreatic cancer,[39] as well as prostate and testicular cancer.[41]

The association between occupational sitting and lung cancer was also examined in three prospective studies.[43, 48, 49] Two of these studies found a higher lung cancer risk for '*standing'* versus *'sitting during work/sedentary'* [48, 49], although in one study this was true for men only.[49] The third study concluded that occupational activity was not associated with lung cancer risk.[43]

In summary, of the 17 studies, only five found that occupational sitting was associated with higher risk of breast cancer[33, 37], ovarian cancer [35, 36] or colorectal cancer.[34] Four of these studies were case-control studies,[33-36] with one prospective study.[37] Ten prospective studies found no evidence of an association,[38-47] and two studies observed an increased lung cancer risk in people who were more active at work, compared with those in sedentary jobs.[48, 49]

Associations between occupational sitting and cardiovascular disease

Eight papers described the association between occupational sitting and cardiovascular outcomes (see Figure 2 for overview, details in Appendix Table D), of which three examined risk of infarction,[18, 50, 52] two examined risk of coronary heart disease,[54] and one examined both.[53] Six were prospective cohort studies[18, 52-56] and two were case-control studies.[50, 51] All studies used a self-report, categorical measure of occupational activity with *'sedentary' or 'mainly sitting'* or *'physically very easy sitting office work'* as one of the response options, except for one that used a categorical measure with combinations of total occupational sitting time and *'time without getting up'*.[51]

Compared with having a sedentary occupation, more PA at work was associated with a lower risk of infarction[50, 52, 53] or CVD[54] in four studies. However, two of these studies included overlapping data,[53, 54] and in another, a significant association was seen only in the 1960s and early 1970s.[52] In contrast, other papers reported that being more active at work was associated with higher cardiovascular disease risk[56], or that there was no association.[18] The remaining studies concluded that there was no clear association between prolonged sitting and thromboembolism,[51] and between occupational activity and stroke,[55]compared with *'physically very easy sitting office work'*. The latter study, however, observed a lower risk of stroke in people with *'high'* occupational activity in men and women together, but this association was not present for genders separately.

In summary, the CVD papers showed conflicting results, with four showing an increased risk of CVD outcomes with occupational sitting (compared with more PA at work), three showing no association and one showing the opposite effect of increased CVD risk with increasing occupational activity.

Associations between occupational sitting and diabetes mellitus

Four studies examined the association between occupational sitting and DM, of which one was a cross-sectional study[19] and three were prospective studies (see Figure 2 for overview, details in Appendix Table E).[6, 17, 57] The studies were conducted with general population samples, except for the Nurses Health Study, which included only registered female nurses.[6] All studies used self-report measures; three used a categorical variable for occupational activity with *'sedentary' or 'physically very easy sitting office work'* as a response option[17, 19, 57] and one used a continuous measure of sitting time that was categorized for the analyses.[6] Two studies used self-reported DM as the outcome[6, 17] while the remainder derived data on DM from national registers[57], or used DM as diagnosed by a doctor or blood sample.[19]

The cross-sectional study of data from 6,473 adults aged 45+ years found a decrease in DM risk across categories of increasing occupational activity, compared with *'sedentary'*.[19] Two of the prospective studies also found a positive association between occupational sitting and

DM risk; compared with occupational sitting of *'less than one hour'*, more sitting was associated with a higher risk of DM.[6] In another study, more occupational activity was associated with a lower risk of DM, compared with *'physically very easy sitting office work'*.[57] The third prospective study did not find a significant association across categories of occupational activity and DM.[17]

In summary, for DM, two prospective and one cross-sectional study found that sitting was associated with increased risk of DM, while one prospective study found no association.

Associations between occupational sitting and mortality

Six prospective studies[18, 58-62] examined the association between occupational sitting and all-cause mortality[18, 58, 59, 62], cardiovascular mortality[18, 59-62] and cancer mortality [62] (see Figure 2 for overview, details in Appendix Table F). Follow-up duration was 10-20 years, except for two studies with a follow-up of less than 10 years.[60, 62] Two studies examined men only[18, 62] and the others included about 50 percent women. All six studies used a categorical measure for occupational activity, with *'mainly/primarily sitting'* or *'sedentary work'* or *'physically very easy sitting office work'*, as one of the response options.

Compared with a job that involved mainly *'physically very easy sitting office work/primarily sitting'*, more PA during work was associated with lower all-cause mortality in men and women[59] or in women only[58] and lower CVD mortality in samples including both men and women[59, 61] and in a sample with unknown gender distribution.[60] One study in middle-aged men found that more occupational activity was associated with higher all-cause mortality, but there was no association with CVD mortality.[18] Kristal Boneh et al. (2000) found no association between prevalent working posture (i.e sitting, standing, walking) and cancer, CVD, or all-cause mortality.[18, 62]

In summary, for mortality, four prospective studies found that sitting was associated with an increased mortality risk, one study found no association and one study found that sitting was associated with a decreased mortality risk.

DISCUSSION

In this systematic review of the relationships between occupational sitting and health risks, we identified 43 papers that met our inclusion criteria. In those papers, we found 22 studies with: 1) cross-sectional and prospective evidence for a positive association between occupational sitting and BMI and DM; and 2) case-control and prospective evidence for a positive association between occupational sitting and cancer, CVD and mortality. However, we also found 20 studies which did not find any association and five studies found that sitting was associated with a decreased risk of various health conditions.

The World Cancer Research Fund/ American Institute for Cancer Research (WCRF/AICR) uses a continuum of five grades ranging from ‘*convincing evidence*’ to ‘*substantial effect on risk unlikely*’, to judge the evidence on causal relationships between behaviors and health risks.[63] The first two WCRF/AICR criteria that must be met for the evidence of a causal relationship to be ‘convincing’ are that there must be: 1) *‘evidence from more than one study type’*; and 2) *‘evidence from at least two independent cohort studies’*. For the outcomes included in this review, these two criteria were only met for cancer and CVD. The third criterion for ‘*convincing evidence’* is that there must be ‘*no substantial unexplained* *heterogeneity within or between studies or in different populations relating to the presence or absence of an association, or direction of effect'.* As there was substantial heterogeneity in terms of the presence or absence of associations, this criterion was not met for the cancer and CVD studies.

The next level of evidence ('*probable evidence*') also requires that there is no unexplained heterogeneity. This criterion was also not met for the other outcomes in this review (BMI, DM, and mortality). Because of the heterogeneity in study results, which may reflect major differences in study designs, explanatory and outcome variables, the WCRF/AICR grade of evidence at this stage is *'limited-suggestive' (mortality)* or *'limited-no conclusion' (BMI, cancer, CVD, DM)*. This does not indicate that there is no relationship between occupational sitting and these health risks, but that further research is necessary to clarify the evidence.

The WCRF/AICH criteria for *'convincing evidence'* are useful as a guide for future good quality research. In order for the evidence to be *'convincing'*, three additional criteria, apart from the three already described in the previous paragraphs, must be met: 4) '*good quality studies to exclude with confidence the possibility that the observed association results from systematic error, and selection bias'*; 5) '*the presence of a plausible biological gradient ('dose response')'*; and 6) '*strong and experimental evidence either from human studies or relevant animal models'*, that occupational sitting can lead to the health outcome of interest.[63] To provide directions for future research, the evidence in relation to WCRF/AICH Criteria 4, 5 and 6 is considered below for BMI, cancer, CVD, DM and mortality. Regardless of the directions arising from these criteria, we suggest that all researchers use clear definitions of the term 'sedentary behavior' in future studies.

WCRF/AICH Criterion 4: ***'Are there good quality studies to exclude with confidence the possibility that the observed association results from random or systematic error, including confounding, measurement error, and selection bias?'***

In general, the quality of the studies in this review was good, but some papers omitted to report details on sampling and participant recruitment. These shortcomings could be easily addressed in future papers. Remarkably, few studies reported on the reliability and validity of the sitting time measures. There is encouraging evidence of good reproducibility and validity of self-reported measures of occupational activity including sitting, although most general occupational activity measures only provide a rough quantification of sitting duration.[64] Understanding these measurement characteristics is vital for future work in this area. Ideally, surveillance and cohort studies could include a standard valid and reliable occupational sitting measure, to facilitate comparison between studies. We acknowledge, however, that changing a measure in established longitudinal studies is not desirable as this would make comparisons over time difficult. However, the reliability and validity of the measure used should be reported in all studies.

Adjustment for physical activity in these studies should be a priority. However, fewer than half the papers we reviewed adjusted their analyses for leisure time PA or exercise (n=19, of which four cross-sectional studies). These studies were, overall, more likely to show positive associations between occupational sitting and health risks than those that did not adjust for PA; 12/22 studies that found a positive association adjusted for PA, while only 4/20 in those that found no relationship did this. Some studies that examined the relationships between occupational activity and leisure time PA found that employees in more active jobs were more likely to be active in leisure time; [65-67] this was especially the case in men.[66, 67] However, others found no association between occupational activity and leisure time PA,[15] or an inverse association.[68] We would therefore recommend that future studies include measures of both occupational and leisure time sitting and activity, so that the independent relationships between both sitting and PA with health risks can be studied. Future studies should also adjust for socioeconomic and demographic variables. We also recommend that studies include measures of energy intake, alcohol and smoking, as these may also be important confounders of the relationships between sitting time and health risks. Adjustment for these variables could limit the potential bias in the relationship between occupational sitting and health risks that could be caused by self-selection, i.e. people with certain characteristics could be more likely to choose a sedentary occupation.[69]

In future studies, consideration should also be given to differentiating between prolonged and 'interrupted' sitting at work, as there is cross-sectional evidence that increased breaks in sedentary time are beneficially associated with indicators of metabolic risk including BMI, waist circumference, triglycerides and 2-h plasma glucose.[70]

WCRF/AICH Criterion 5: 'is there a plausible biological gradient ('dose response')?'

Evidence of dose-response relationships plays an important role in gathering evidence for causal relationships. The majority of studies in this review used a categorical measure of occupational activity*, with three or four categories, for example: 1) 'sedentary'; 2) 'standing and walking'; 3) 'walking and lifting'.* These studies compared the outcomes in 'more active workers' with the risk in 'sedentary workers'. Only two case-control[35, 51] and one prospective study[6] compared the risk across different amounts of occupational sitting. The lack of occupational sitting measures with quantification of the amount of time spent sitting may have contributed to the lack of association between occupational sitting and health in those studies in this review that found no statistically significant associations. A recent study, which included a measure of leisure time sitting and a measure of occupational activity, found that people sitting more than four hours in leisure had almost double the risk of metabolic syndrome than those sitting less than one hour, whereas there was no association between occupational sitting (*'sit during the day and do not walk about very much'*) and metabolic syndrome, compared with higher occupational activity.[71] Future studies should consider the inclusion of a sitting measure with a quantification of sitting duration that allows for the analysis of dose-response relationships; objective measures may be the optimal method for doing this.[72]

WCRF/AICH Criterion 6: Is there evidence from human or animal studies that occupational sitting can lead to the health outcome of interest?

There is emerging animal and human evidence for biological plausibility of an association between sitting and health risks. The findings of Hamilton and colleagues provide emerging evidence that the chronic, unbroken periods of muscular unloading associated with prolonged sitting time may have deleterious biological consequences.[73, 74] Physiologically, it has been suggested that the loss of local contractile stimulation induced through sitting leads to both the suppression of skeletal muscle lipoprotein lipase (LPL) activity (which is necessary for triglyceride uptake and HDL-cholesterol production), and reduced glucose uptake through blunted translocation of GLUT-4 glucose transporters to the skeletal muscle cell surface.[73, 74] A more detailed account of these important mechanistic studies has been provided in several recent reviews.[1, 75] From a behavioral perspective, prolonged sitting can displace the opportunity for engagement in light-intensity, incidental activities which can lead to a reduction in whole body energy expenditure.[76] Sitting may also promote excess energy consumption (snacking),[77] which is likely to contribute to a positive daily energy balance and poor metabolic outcomes.[78]

This is the first systematic review to examine the associations between occupational sitting and BMI, DM, CVD, cancer and mortality. The strengths of this review are the extensive search strategies and the fact that papers in numerous languages were considered for inclusion. A limitation of the review is the possibility that we may have missed relevant papers, as the search was complicated by the lack of standard search terms for 'occupational sitting'. We therefore included studies in this review that used the terms 'sitting', 'sedentar*', or 'computer time' in the title or the abstract. By adopting this pragmatic approach, we may have overlooked studies that used similar measures of occupational sitting to those used in the included studies. However, we complemented our search in the primary databases with other search strategies that were not dependent on the use of these terms in the title and abstract. Another limitation is that the majority of criteria for the quality assessment in this review rated whether specific study characteristics were reported in the included papers, rather than rating the study quality on the basis of these characteristics. Because of the heterogeneity in study designs and method, a more-comprehensive rating of quality was not feasible.

Although 43 papers have examined the associations between occupational sitting and health risks, the wide heterogeneity of study findings led us to conclude that, using the WCRF/AICH criteria for judging causal relationships, there is at this time only limited evidence in support of a positive relationship between occupational sitting and health risks. Although the quality of most studies was good, it will be important to include specific measures of sitting time with demonstrated reliability and validity in future studies, as this will enable dose-response issues to be examined. The lack of such measures of sitting time and failure to account for the effects of leisure time sitting and PA make it difficult to draw firm conclusions at this stage.

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TITLES OF FIGURES

Figure 1: Information flow through the phases of the review

Figure 2: General overview of study designs, findings, quality scores, adjustment for physical activity and sample sizes

Table 1. Criteria for quality assessment and the number and proportion of studies (n, %) scoring a point for each separate item[a]

Item	Criterion	Description	n (%)
1	Objectives	Are the objectives or hypotheses of the research described in the paper stated?	43 (100)
2	Study design	Is the study design presented?	43 (100)
3a	Target population	Do the authors describe the target population they wanted to research?	41 (96)
3b	Sample	Was a random sample of the target population taken? AND was the response rate 60 percent or more?	28 (65)
3c	Sample	Is participant selection described?	42 (98)
3d	Sample	Is participant recruitment described, or referred to?	16 (37)
3e	Sample	Are the inclusion and/or exclusion criteria stated?	36 (84)
3f	Sample	Is the study sample described? (minimum description = sample size, gender, age and an indicator of socio-economic status)	26 (61)
3g	Sample	Are the numbers of participants at each stage of the study reported? (Authors should report at least numbers eligible, numbers recruited, numbers with data at baseline and numbers lost to follow up)	37 (86)
4	Variables	Are the measures of occupational sitting and the health outcome described?	42 (98)
5a	Data sources & collection	Do authors describe the source of their data? (e.g., cancer registry, health survey) AND did authors describe how the data were collected? (E.g., by mail)	42 (98)
5b	Measurement	Was reliability of the measure(s) of occupational sitting mentioned or referred to?	4 (9)
5c	Measurement	Was the validity of the measure(s) of occupational sitting mentioned or referred to?	10 (23)
6a	Statistical methods	Were appropriate statistical methods used and described, including those for addressing confounders?	41 (95)
6b	Statistical methods	Were the numbers/ percentages of participants with missing data for sitting and the health outcome indicated AND If more than 20 percent of data in the primary analyses were missing, were methods used to address missing data?	33 (77)

[a] Quality assessment for each paper is shown in Appendix A

Appendix Table A: Quality assessment for all papers included in this review per category in alphabetical order

Author/Yr	Quality item															Score
	Objective	Design	Target population and sample							Variables	Data sources / collection	Measurement		Statistics		
	1	2	3a	3b	3c	3d	3e	3f	3g	4	5a	5b	5c	6a	6b	
BMI																
Andersen, 2007[17]	y	y	y	y	y	?	n	n	y	y	y	n	y	y	y	11
Bak, 2004[31]	y	y	y	n	y	n	y	n	y	y	y	n	n	y	n	9
Chan, 2003[28]	y	y	y	n	y	y	y	y	n	n	y	n	n	n	y	9
Graff-Iversen, 2001[32]	y	y	y	?	y	?	?	n	n	y	y	n	n	y	n	7[b]
Gutierrez-Fisac, 2002[30]	y	y	y	y	y	n	y	y	y	y	y	n	n	y	y	12
Hu, 2003a[6]	y	y	y	?	y	y	y	y	n	y	y	n	n	y	n	10[a]
Ishizaki, 2004[26]	y	y	?	?	?	n	y	y	y	y	y	n	n	y	y	9[a]
Larsson, 2004[24]	y	y	y	n	y	n	y	n	y	y	y	n	y	y	y	11[a]
Mummery, 2005[27]	y	y	y	n	y	y	y	y	y	y	y	y	n	y	?	12[a]
Sargeant, 2000[19]	y	y	y	y	y	y	y	n	y	y	y	?	y	y	y	13[a]
Trojani, 2006[29]	y	y	y	y	y	n	y	n	y	y	y	n	n	n	n	9
Tudor-Locke, 2009[25]	y	y	y	y	y	y	y	y	y	y	y	n	n	y	y	13[a]
cancer																
Bak, 2005[48]	y	y	y	n	y	n	y	y	y	y	y	n	n	y	y	11[b]
Bergstrom, 2001[40]	y	y	y	y	y	y	y	n	y	y	y	n	n	y	y	12
Friberg, 2006[47]	y	y	y	y	y	y	y	y	y	y	y	n	y	y	y	14
Friedenreich, 2006[44]	y	y	y	y	y	?	y	y	y	y	y	n	n	y	y	12
Gerhardsson, 1988[38]	y	y	y	n	y	n	n	n	y	y	y	n	n	y	y	9
Lahmann, 2007[45]	y	y	y	y	y	n	y	y	y	y	y	n	y	y	y	13
Levi, 1999a[33]	y	y	y	n	y	n	n	y	y	y	y	n	n	y	y	10[a]
Levi, 1999b[34]	y	y	y	y	y	n	y	y	y	y	y	n	n	y	y	12[a]

Mahabir, 2004[46]	y	y	y	y	y	?	y	y	y	y	y	n	n	y	y	12
Pan, 2005[36]	y	y	y	y	y	y	y	y	y	y	y	n	n	y	y	13[a]
Steindorf, 2006[49]	y	y	y	y	y	?	y	y	y	y	y	y	y	y	y	14[b]
Stolzenberg-Solomon, 2002[39]	y	y	y	y	y	?	y	n	y	y	y	n	n	y	y	11
Thune, 1994[41]	y	y	y	y	y	y	y	n	y	y	y	n	y	y	n	12
Thune, 1996[42]	y	y	y	y	y	y	y	n	y	y	y	n	n	y	y	12
Thune, 1997[37]	y	y	y	y	y	y	y	?	y	y	y	n	n	y	y	12[a]
Thune, 1997[43]	y	y	y	y	y	y	y	n	y	y	y	n	n	y	y	12
Zhang, 2004[35]	y	y	y	?	y	y	y	y	y	y	y	y	?	y	y	13[a]
CVD																
Altieri, 2004[50]	y	y	y	n	y	n	y	y	n	y	y	n	n	y	y	10[a]
Hu, 2007[53]	y	y	y	y	y	n	y	y	y	y	?	n	n	y	y	11[a]
Hu, 2007b[54]	y	y	y	y	y	y	y	y	y	y	y	n	n	y	y	13[a]
Johansson, 1988[18]	y	y	y	y	y	?	n	y	y	y	y	n	y	y	y	12
Rosenman, 1977[56]	y	y	n	?	y	n	y	y	n	y	y	n	n	y	n	8[b]
Sjol, 2003[52]	y	y	y	y	y	?	n	n	y	y	y	y	n	y	n	10[a]
Hu, 2005[55]	y	y	y	y	y	n	y	y	y	y	y	n	y	y	y	13
West, 2008[51]	y	y	y	n	y	y	y	n	n	y	y	n	n	y	?	9
DM																
Andersen, 2007[17]	y	y	y	y	y	?	n	n	y	y	y	n	y	y	y	11
Hu, 2003a[6]	y	y	y	?	y	y	y	y	n	y	y	n	n	y	n	10[a]
Hu, 2003[57]	y	y	y	y	y	n	y	y	y	y	y	n	n	y	y	12[a]
Sargeant, 2000[19]	y	y	y	y	y	y	y	n	y	y	y	?	y	y	y	13[a]
Mortality																
Andersen, 2000[58]	y	y	y	y	y	n	n	y	y	y	y	n	y	y	y	12[a]
Hu, 2004[59]	y	y	y	y	y	n	y	n	y	y	y	n	n	y	y	11[a]
Hu, 2007[61]	y	y	y	y	y	n	y	y	y	y	y	n	n	y	y	12[a]
Johansson, 1988[18]	y	y	y	y	y	?	n	y	y	y	y	n	y	y	y	12[b]
Kristal-Boneh, 1995[62]	y	y	y	n	y	?	y	y	y	y	y	n	n	y	n	10
Salonen, 1988[60]	y	y	y	y	y	y	y	n	y	y	y	n	n	y	y	12[a]

BMI=body mass index; CVD=cardiovascular disease; DM=diabetes mellitus; N= no; Y= yes; ? = unclear; [a] occupational sitting associated with higher risk (adjusted analyses if reported); [b] occupational sitting associated with lower risk (adjusted analyses if reported).

Appendix Table B: Description of study characteristics of studies examining the association between occupational sitting and **BMI**[a]

Author, country	Design and duration	Sample	Occupational sitting	Outcome	Adjustments	Results [c]	Quality score
- author, year - country - cohort	- study design - year(s) of baseline exam - year(s) of follow up exam(s)	- number of participants (n)[b] (%women) - age at baseline - population and setting - relevant exclusion criteria	- self-report or objective - assessed sitting - units measured variable - units analyzed variable (if differs from units measured)	- health risks - analyzed variable	- variables included in adjusted model	- results	- points out of 15
BMI<25 versus BMI≥25							
- Mummery, 2005[27] - Australia	- cross-sectional - 2003	- 1,579 (45%F) - NR - general population, adults in full-time employment	- self-report - sitting during normal working day - hrs/day - 1)0-44 min; 2)45-149 min; 3)150-359 min; 4)≥ 360 min	- BMI (self-report) - BMI<25 vs. BMI ≥25	- gender, age, occupation, LTPA	- more sitting associated with higher odds of BMI≥25 in men → compared with 'sitting <44 min'; OR (95% CI) = 1.92 (1.17-3.17) in men 'sitting≥360 min'	- 12
BMI<30 versus BMI≥30							
- Bak, 2004[31] - Denmark - part of the Copenhagen City Heart Study (CCHS)	- cross-sectional and prospective - 1943-1977 - follow-up: 1982-1984 and 1991-1993	- 2,421 (0%F) - median age 19 yrs; range 18-31 yrs general population, men with juvenile onset obesity AND non-obese men (controls) were selected from 362200 Danish males examined by draft boards between 1943-1977	- self-report - OA - 1)sitting; 2)standing; 3)walking; 4)lifting or heavy work	- BMI (objective) - BMI≥30 vs. BMI<30	- age, education, , LTPA, smoking, alcohol - additional covariates prospective analyses: BMI (baseline and follow-up 1)	- cross-sectional: no clear association between OA and obesity, although some significant differences between 'sitting' and other categories in 'juvenile obese' and 'controls' in follow-up 1, but not in follow-up 2 - prospective: no significant association between OA and maintenance or development of obesity	- 9

- Gutierrez-Fisac, 2002[30] - Spain - Spanish national health survey (ENSE)	- cross-sectional - 1993	- 12,044 (49%F) - range 20-60 yrs - general population, community-dwelling adults	- self-report - main or usual activity at work - 1)sitting most of day; 2)standing most of day; 3)frequent movement; 4)heavy labor	- BMI (self-report) - BMI<30 vs. BMI≥30	- age, education, area of residence, chronic conditions, perceived health, smoking, alcohol	- crude: more OA associated with higher odds of BMI≥30 in women → compared with 'sitting'; OR (95%CI) = 1.53 (1.20-1.96) for 'standing' and 1.70 (1.19-2.42) for 'frequent movement' - adjusted: no sig. results	- 12
- Hu, 2003[6] - USA - Nurses Health Study	- prospective - 1992 - follow-up: 1992, 1994, 1996, 1998	- 50,277 (100%F) - range 46-71 yrs - female registered nurses - exclusion: BMI ≥30between 1976 and 1992 and CVD, diabetes or cancer in 1992	- self-report - average time spent sitting at work or away from home or while driving - hours/week - 1)0-1 hr; 2)2-5 hrs; 3)6-20 hrs; 4)21-40 hrs; 5)>40 hrs	- BMI (self-report) - BMI<30 vs. BMI≥30	- age, hormone use, smoking, alcohol, PA, energy intake, fat intake, fiber intake, glycaemic load	- more sitting associated with greater risk of BMI≥30 → compared with women 'sitting 0-1 hrs; RR (95%CI) = 1.25 (1.02-1.54) for women 'sitting>40 hrs' - P<.001 for trend across categories of sitting time	- 10
- Trojani, 2006[29] - Italy - study into atherosclerosis(MATISS) and centre for cardiovascular epidemiology (OEC)	- cross-sectional - 1984-1987 (MATISS) and 1998-2002 (OEC)	- 12, 885; 4,465 (54%F) and 8,420 (50%F) - range 35-69 yrs - general population - excluded: people with CVD	- self-report - PA during normal work hours - 1)sedentary; 2)standing or walking; 3)much walking and moving heavy weights; 4)much walking and lifting heavy weights - 1)sedentary; 2)standing or walking; 3)much walking and moving and lifting heavy weights	- BMI (objective) - BMI < 30 vs. BMI ≥ 30	- age, heart rate, education & other possible confoundin g variables	- no clear association OA and obesity for 'sedentary' compared with 'much walking and moving and lifting heavy weights'	- 9
BMI<27 versus BMI≥27							
- Graff-Iversen,	- cross-sectional	- 254,498 (52%F)	- self-report	- BMI (self-	- smoking,	- more OA associated	- 7

2001[32] - Norway - combined data from 3 Norwegian population screenings	- cardiovascular disease study: 1974-1988; study among people aged 40: 1985-1994; HUNT 95: 1995-97	- range 40-42 yrs - general population, community-dwelling adults	- OA in last year - 1)mostly sitting; 2)walking; 3)walking and lifting; 4)heavy activity. - 1)mostly sitting; 2)walking, walking and lifting, and heavy activity	report) - BMI<27 vs. BMI≥27	LTPA, marital status, (additional adjustments for 40+study: CVD disorders, DM; HUNT: age, self rated health)	with higher odds of BMI≥27 → compared with 'mostly sitting'; OR (95%CI) for people who are not 'mostly sitting' at work = 1.04 (1.01-1.07) in men and 1.19 (1.15-1.23) in women	
Multiple BMI categories							
- Chan, 2003[28] - Canada	- cross-sectional - NR	- 182 (87%F) - NR - volunteers of 5 workplaces with >100 employees - excluded: pregnant women	- self-report - occupational activity level - 1)highly sedentary; 2)moderately sedentary; 3)moderately active; 4)highly active.	- BMI (objective) - 1)BMI 18-24.9; 2)BMI 25-29.9; 3)BMI ≥ 30. - waist circumference (objective) women ≤88cm vs. >88cm; men ≤102cm vs. >102cm.	- no adjusted analysis	- no differences in outcomes across categories of OA	- 9
- Larsson, 2004[24] - Sweden - SOS Reference Study & SOS Registry Study	- cross-sectional - 1987-2000	- 3,176 (62%F) - range 37-60 yrs - general population, adults - excluded: people without regular work	- self-reported - OA during the last 12 months - 1)sedentary work; 2) - rather sedentary but not sitting; 3)moderately heavy work; 4)heavy work - 1)sedentary work; 2)	- BMI (NR) - 1)18.5-24.9; 2)5.0-29.9; 3)30.0-34.9; 4)35.0-39.9; 5)≥40 kg/m^2	- age, education	- higher BMI associated with lower OA in men → compared with men with BMI 18.5-24.9; OR (95%CI) for reporting lower work activity for men with BMI≥40 = 1.77 (1.16-2.71)	- 11

			- rather sedentary but not sitting; 3)moderately heavy work and heavy work			- higher BMI associated with lower odds for high OA → compared with people with 'BMI 18.5-24.9'; OR (95%CI) for reporting high OA in people with BMI 35.0-39.9 and people with BMI≥40 = 0.60 (0.39-0.91) and 0.36 (0.91-0.95) for men and 0.70 (0.50-0.97) and 0.57 (0.42-0.78) for women	
- Sargeant, 2000[19] - multiple European countries - European Prospective Investigation into Cancer (EPIC-Norfolk)	- cross-sectional - 1995-1998	- 6,473 (55%F) - mean age (SD) in men 59.6 (8.4) yrs, in women 59.0 (8.4) yrs; range 45-74 yrs - general population, adults	- self-report - physical activity involved in subject's work - 1)sedentary; 2)standing 3)physical work; 4)heavy manual work - 1)sedentary; 2)standing 3)physical work and heavy manual work	- BMI (objective) - 1)<25; 2)22.5-24.9; 3);25-27.4; 4)27.5-29.9; 5)30-4.9; 6)>35	- age, gender	- obese men more likely to be 'sedentary' (p=0.016)	- 13
BMI continuous							
- Andersen, 2007[17] - Denmark - Copenhagen City Heart Study (CCHS)	- prospective - 1976-1978 - follow-up: 1981-1983 and 1992-1994	- 14,214 (54%F) - median age 52 yrs - general population, people aged ≥ 20 yrs - NR	- self-report - OA - 1)sedentary; 2)low; 3)moderate; 4)high	- BMI (objective) - continuous	- no adjusted analysis	- no differences across categories of OA	- 11
- Gutierrez-Fisac, 2002[30] - Spain - Spanish national health survey (ENSE)	- cross-sectional - 1993	- 12,044 (49%F) - range 20-60 yrs - general population	- self-report - main or usual activity at work - 1)sitting most of day; 2)standing most of day; 3)frequent movement; 4)heavy labor	- BMI (self-report) - continuous	- age, education, area of residence, chronic conditions, perceived	- crude: more OA associated with greater BMI → compared with 'sitting'; increases in BMI (beta [SE]) of 0.27 (0.10), 0.53 (0.13), 0.59 (0.16) in men and 1.20	- 12

					health, smoking, alcohol	(0.12), 0.74(0.20), and 1.38 (0.60) in women for ‘standing’, ‘frequent movement’ and ‘heavy labor’ - adjusted: no sig. results	
- Ishizaki, 2004[26] - Japan	- cross-sectional - 1996-1997	- 6,676 (36%F) - mean (SD) 39.2 (10.2) yrs; range 20-58 yrs - employees of a metal product factory in a rural area - excluded: people who worked < 1 yr at factory; people who gave birth during study period	- self-report - sedentary hours per working day in past year - 1)<1hr; 2)1-4 hrs; 3)≥5hrs	- BMI (objective) - WHR (objective) - continuous	- age, education, marital status, alcohol, smoking, exercise	- BMI: more sitting associated with higher BMI in men → standardized beta for men = 0.169 - WHR: more sitting associated with greater WHR → standardized beta = 0.002 for men and 0.008 for women	- 9
- Tudor-Locke, 2009[25] - Australia - sub-study of the Australian longitudinal study on women’s health (ALSWH)	- cross-sectional - 2005	- 158 (100%F) - 54-59 yrs - general population, women participating in ALSWH	- self-report - time spent sitting on a usual working day - 1)all of the time; 2)most of the time; 3)some of the time; 4)a little of the time; 5)none of the time - 1)mostly and all of the time; 2)some, little and none of the time	- BMI (objective) - continuous	- no adjusted analysis	- less sitting associated with lower BMI → compared with women sitting ‘mostly and all of the time’; women in ‘some/little/no time’ had 2.4 kg/m^2 lower BMI	- 13

[a] alphabetical order within categories of classification of BMI; [b] number as reported in abstract; [c] adjusted results, unless reported otherwise; BMI = body mass index; CI = confidence interval; CVD = cardiovascular disease; DM = diabetes mellitus; min = minutes; F = female; LTPA = leisure time physical activity; NR = not reported; OR = odds ratio; OA = occupational activity; RR = relative risk; SD = standard deviation; vs. = versus.

Appendix Table C: Description of study characteristics of studies examining the association between occupational sitting and **cancer**[a]

Author, country	Design and duration	Sample	Occupational sitting	Outcome	Adjustments	Results[c]	Quality score
- author, year - country - cohort	- study design - year(s) of baseline exam - follow up period	- number of participants (n)[b] (%women) - age at baseline - population and setting - relevant exclusion criteria	- self-report or objective - assessed sitting - units measured variable - units analyzed variable (if differs from units measured)	- health risks	- variables included in adjusted model	- results	- points out of 15
Breast cancer							
- Lahmann, 2007[45] - 9 European countries - European Prospective Investigation into Cancer (EPIC)	- prospective - 1992-2000 - follow up: until 2002, mean duration (SD)=6.4 (1.8) yrs	- 218,169 (100%F) - range 20-80 years - general population, women - excluded: women with cancer at baseline; perimenopausal women; women who underwent surgical menopause	- self-report - level of physical activity at work - 1)non-worker; 2)sedentary; 3)standing; 4)manual; 5)heavy manual; 6)unknown - 1)sedentary; 2)standing; 3)manual and heavy manual	- breast cancer (cancer registries, insurance records, self-report)	- age, study centre, education, age at menarche, age at first pregnancy, oral contraceptive use, hormone replacement therapy, BMI, smoking, alcohol	- no association between OA and risk of breast cancer	- 13
- Levi, 1999[33] - Switzerland	- case-control - 1993-1998	- 620, 246 cases and 374 controls (100%F) - median age 56 yrs; range 29-74 yrs - women admitted to hospital with incident, breast cancer (cases) and women admitted for other conditions (controls)	- self-report - intensity of activity at work at age 15-19 yrs, 30-39 yrs and 50-59 yrs - 1)mainly sitting; 2)standing; 3)very tiring or tiring	- breast cancer (histologic ally confirmed breast cancer)	- age, education, age at menarche, age at first birth, number of births, menopausal status, age at menopause, family history of breast cancer, history of benign breast disease, calorie intake	- more OA associated with lower breast cancer risk → compared with 'mainly sitting' at age 15-19 yrs; OR (95%CI) 0.60 (0.40-0.91) for 'standing' at age 15-19 years. P=0.02 for trend across categories of OA. - compared with 'sitting' at age 30-39 yrs; OR (95%CI) = 0.45 (0.21-0.88) for 'standing' and 0.51 (0.26-0.98) for 'tiring' at age 30-39 yrs	- 10

- Thune, 1997[37] - Norway	- prospective - 1977-1983 - follow up: mean duration 14 yrs	- 25,624 (100%F) - mean age 45 yrs; range 20-54 yrs - general population - excluded: women diagnosed with cancer before the baseline survey; women who died or were diagnosed with cancer in the first study year	- self-report - physical activity during work hours in the preceding year - 1)mostly sedentary; 2)a lot of walking; 3)a lot of lifting and walking; 4)heavy manual labor - 1)mostly sedentary; 2)walking; 3)lifting and heavy manual labor	- breast cancer (cancer registry)	- age at entry, county of residence, number of children, BMI, height	- more OA associated with lower breast cancer risk in premenopausal women, but not in postmenopausal women → compared with 'mostly sedentary'; RR (95%CI) = 0.48 (0.24-0.95) for 'lifting and heavy manual labor' - P=0.03 for trend across categories of OA	- 12
Endometrial and ovarian cancer							
- Friberg, 2006[47] - Sweden - -Swedish Mammography Cohort	- prospective - 1997 - follow-up: until 2004-2005; mean duration 7.3 yrs	- 33,723 (100%F) - range 49-83 yrs - general population, women born between 1914-1948 - excluded: women diagnosed with cancer other than non-melanoma skin cancer before 1997; women who had a hysterectomy.	- Self-report - previous year - OA - 1)mainly sitting – 1.3 MET/hr; 2)sitting more than half the time-1.8 MET/hr); 3)mostly standing-2.2 MET/hr; 4)doing lifts-2.6 MET/hr; 5)a lot of lifts-3.0 MET/hr; 6)heavy labor-3.9 MET/hr - 1)low OA- < 1.8 MET/hr; 2)high OA- > 2.2 MET/hr	- endometrial cancer (cancer registry)	- age, education, occupation, parity, history of diabetes, fruit and vegetable intake, walking/bicycling, household work, LTPA, LT sitting, BMI	- no association between OA and risk of endometrial cancer	- 14
- Pan, 2005[36] - Canada - Canadian National Enhanced Cancer Surveillance System	- case-control - 1994-1997	- 1,198, 256 cases and 942 controls (100%F) - range 20-76 years - women included in cancer registry (cases) and women without cancer - excluded: people with	- self-report - usual activity in daily work, job or occupation in 4 life periods: early 20s, early 30s, early 50s and 2 yrs before the study - 1)sitting; 2)light;	- ovarian cancer (cancer registries)	- 10 year age group, alcohol consumption, cigarette pack-years, BMI, total calorie intake, total vegetable consumption, number of live births,	- more OA associated with lower ovarian cancer risk → compared with 'sitting'; OR (95%CI) = 0.60 (0.39-0.92) for 'moderate' in 2 yrs before study and 0.61 (0.38-0.96) for OA in	- 13

(NECSS)		ovaries removed	3)moderate; 4)strenuous		menopause status, cancer in first-degree relative, oral contraceptive use, LTPA	early 50s - P=0.02 and P=0.04 for trend across categories of OA in 2 yrs before study and early 50s respectively	
- Zhang, 2004[35] - China	- case-control - 1999-2000	- 906, 254 cases and 652 controls (100%F) - <75 yrs hospital patients diagnosed with epithelial ovarian cancer in previous 3 years (cases) and randomly selected hospital visitors, outpatients and general population (controls)	- self-report - hours per day spent sitting at work 5 years ago, or 5 years prior to diagnosis - hours per day - 1)<2 hrs/day; 2)2-6 hrs/day; 3)>6 hrs/day	- epithelial ovarian cancer (histopatho logically confirmed)	- age, education, income, locality, marital status, menopausal status, parity, contraceptive use, tubal ligation, HRT, ovarian cancer in relative, smoking, alcohol, tea and energy intake, PA , BMI	- more sitting associated with increased ovarian cancer risk → compared with '<2 hrs'; OR (95%CI) = 1.96 (1.2-3.2) for '>6 hrs' - P=.007 for trend across categories	- 13
Colon and rectal cancer							
- Friedenreich, 2006[44] - 10 European countries - European Prospective Investigation into Cancer (EPIC)	- prospective - 1992-1998 - follow-up: until 2004; average duration 6.4 yrs	- 413,044 (69%F) - mean age (SD) 51.9 (10.0) yrs - general population aged 35-70 yrs - excluded: people with prevalent cancer at enrollment	- self-report - level of OA; housewives categorized as non-workers - 1)nonworker; 2)sedentary; 3)standing; 4)manual; 5)heavy manual - 1)sedentary; 2)standing; 3)manual and heavy manual; 4)nonworker	- colon and rectal cancer (cancer registries, pathology registries, health insurance records, self-report)	- age, study centre, education, smoking, PA, energy intake, fibre intake, fish intake, height, weight	- no association between OA and risk of colon cancer or rectal cancer	- 12
- Gerhardsson, 1988[38] - Sweden - Swedish Twin Registry	- prospective - 1967-1968 - follow-up: from 1969 until 1982; duration 14	- 16,477 (not reported) - range 42-89 yrs - general population, twins born between 1886 and 1925	- self-report - OA - 1)sedentary; 2)moderately active; 3)physically demanding - people in category	- colon and rectal cancer (cancer register)	- age and gender	- no association between OA and risk of colon cancer or rectal cancer	- 9

	yrs		'moderately active' excluded from analysis				
- Levi, 1999[34] - Switzerland	- case-control - 1992-1997	- 714, 223 cases and 491 controls (50%F) - range 35-74 years - patients admitted to hospital with colon or rectal cancer (cases) and patients with other non neoplastic conditions (controls)	- self-report - level of OA in 3 life periods: 5-19 yrs, 30-39 yrs; 50-59 yrs - 1)mainly sitting; 2)standing; 3)very tiring or tiring	- colon or rectal cancer (histologic ally confirmed)	- age, gender, education, alcohol, energy intake	- more OA associated with lower cancer risk → compared with 'sitting' for OA at age 30-39 yrs; OR (95%CI) = 0.54 (0.32-0.92) for 'standing' and 0.44 (0.26-0.73) for 'very tiring or tiring' - P<.01 for trend across categories of OA at age 30-39 yrs and p<.05 for 15-19 yrs	- 12
- Thune, 1996[42] - Norway	- prospective - 1972-1978 - follow-up: until 1992; mean duration 16.3 yrs for men and 15.5 yrs for women	- 81,516 (35%F) - range 20-49 yrs - general population - excluded: people with pre-existing malignancy or who developed a malignancy within first year of study	- self-report - PA during occupational hours in the last year: - 1)mostly sedentary; 2)with much walking; 3)with much lifting and walking; 4)heavy manual work - 1)mostly sedentary; 2)with much walking; 3)with much lifting and walking and heavy manual work	- colon and rectal cancer (cancer registry)	- age, geographic region, BMI, marital status	- no association between OA and risk of colon cancer or rectal cancer	- 12
Renal and pancreatic cancer							
- Bergstrom, 2001[40] - Sweden - Swedish Twin Registry	- prospective - 1967 and 1970 - follow-up: until 1997; mean duration 22.6 years	- 17,241 (57%F) - mean 56 yrs - general population, same sex twins born in Sweden between 1886-1925 - excluded: prevalent cancer at baseline	- self-report - OA - 1)sedentary; 2)active; 3)physically strenuous.	- renal cell cancer (cancer registry)	- age, gender, smoking, BMI and hypertension	- no association between OA and risk of renal cell cancer	- 12

- Mahabir, 2004[46] - Finland - ATBC Cancer Prevention Study	- prospective - 1985-88 - follow-up: until 1999; mean duration 12.2 yrs	- 29,133 (0%F) - mean 56 yrs; range: 50-69 yrs - general population, males smoking ≥5 cigarettes/day at study entry - excluded: people diagnosed with cancer, serious disease, or taking vitamins	- self-report - usual OA during the past year - 1)not working; 2)mainly sitting; 3)walking quite a lot; 4)walking and lifting; 5)heavy physical work	- renal cancer (cancer registry)	- age, supplement group, BMI, calories, blood pressure, years smoking regularly, total number of cigarettes smoked per day, smoking inhalation, education, fruit and vegetable intake, LTPA	- no association between OA and risk of renal cancer	- 12
- Stolzenberg-Solomon, 2002[39] - Finland - ATBC Cancer Prevention Study	- prospective - 1985-1988 - follow up: until 1999, median10.2yrs	- 29,133 (0%F) - median (interquartile range) 58 (55-62)yrs; range 50-69 yrs - general population, males smoking ≥5 cigarettes/day at study entry - excluded: people with history of malignancy, serious disease or taking vitamin supplements	- self-report - exercise and physical burden at work during the past year - 1)mainly sitting; 2)walking quite a lot; 3)walking and lifting; 4)heavy physical work - 1)mainly sitting; 2)walking quite a lot; 3)walking and lifting and heavy physical work	- pancreatic cancer (cancer registry)	- age, yrs smoked, cigarettes smoked/day, diabetes, bronchial asthma, hypertension	- no association between OA and risk of pancreatic cancer	- 11
Prostate and testicular cancer							
- Thune, 1994[41] - Norway	- prospective - 1972-1978 - follow-up: until 1992; mean duration 16.3 yrs	- 53,242 (0%F) - range:19-50 yrs - general population	- self-report - physical activity in occupational hours during the last year - 1)mostly sedentary; 2)much walking; 3)much lifting and walking; 4)heavy manual work	- testicular and prostate cancer (cancer registry)	- age, geographic region, BMI	- no association between OA and risk of testicular and prostate cancer	- 12
Lung cancer							
- Bak, 2005[48]	- prospective	- 54,422 (52%F)	- self-report	- lung	- education,	- no dose-related pattern	- 11

- Denmark	- 1993-1997 - follow-up: until 2003	- range 50-64 yrs - general population, - excluded: people with previous cancer diagnosis	- OA during past year - 1)sitting; 2)standing; 3)light activity; 4)heavy activity	cancer (cancer registry)	occupational exposure to lung carcinogen, smoking, LTPA, fruit and vegetable intake	→ compared with 'sitting'; IRR (95%CI) for 'standing' = 1.66 (1.06-2.61) in men and 1.71 (1.07-2.73) in women	
- Steindorf, 2006[49] - 10 European countries - European Prospective Investigation into Cancer (EPIC)	- prospective - 1992-2000 - follow up: until 2003; average duration 6.3 yrs	- 416,227 (69%F) - median 51 yrs; range 35-70 yrs - general population - excluded: prevalent cancer other than non melanoma skin cancer	- self-report: EPIC physical activity questionnaire - current OA - 1)unemployed; 2)sedentary; 3)standing; 4)manual; 5)heavy manual - 1)unemployed; 2)sedentary; 3)standing; 4)manual and heavy manual	- lung cancer (cancer registries, pathology registries, health insurance records, self-report)	- age, centre, education, occupational exposure to lung carcinogens, smoking, alcohol, LTPA, energy intake, intake of fruit /vegetables/ meat, weight, height	- no clear association between OA and lung cancer risk → compared with 'sedentary'; only in men RR (95%CI) = 1.35 (1.02-1.79) for 'standing' and 1.57 (1.20-2.05) for 'unemployed'	- 14
- Thune, 1997[43] - Norway	- prospective - 1972-1978 - follow-up: until 1992	- 81,516 (35%F) - mean 42 yrs; range 20-49 yrs - general population - excluded: pre-existing malignancy or malignancy within first year of study	- self-report - OA in the last year - -1)mostly sedentary; 2)with much walking; 3)with much lifting and walking; 4)heavy manual work	- lung cancer (cancer registry)	- age, geographic residence, smoking, BMI,	- no association between OA and lung cancer risk	- 12

[a] alphabetical order within location of cancer; [b] number as reported in abstract; [c] adjusted results, unless reported otherwise; ATBC = Alpha-Tocopherol, Beta-Carotene; BMI = body mass index; CI = confidence interval; F = female; IRR = incidence rate ratio; LT = leisure time; LTPA = leisure time physical activity; OA = occupational activity; OR = odds ratio; PA = physical activity; RR = relative risk; SD = standard deviation; yrs = years.

Appendix Table D: Description of study characteristics of examining the association between occupational sitting and **CVD**[a]

Author, country	**Design and duration**	**Sample**	**Occupational sitting**	**Outcome**	**Adjustments**	**Results**[c]	**Quality score**
- author, year - country	- study design - year(s) of	- number of participants (n)[b]	- self-report or objective	- health risks - analyzed	- variables included in	- results	- point s out

- cohort	baseline exam - follow up period	(%women) - age at baseline - population and setting - relevant exclusion criteria	- assessed sitting - units measured variable - units analyzed variable	variable	adjusted model		of 15
- Altieri, 2004[50] - Italy	- case control - 1995-1999	- 985, 507 cases and 478 controls (31%F) - median 60 yrs; range 25-79 - patients with a first episode of AMI at a hospital (cases) and people admitted for other acute conditions not related to neoplasm, smoking or alcohol (controls) - excluded: people with previous history of AMI	- self-report - OA at age 12, 15-19, 30-39, 50-59 - 1)very heavy; 2)heavy; 3)average; 4)standing; 5)mainly sitting - 1)mainly sitting; 2)standing; 3)average; 4)very heavy and heavy	- non fatal AMI	- age, sex, education, cholesterol, diabetes, hypertension, hyper-lipidemia, family history of AMI, BMI, smoking, coffee, alcohol, energy intake	- more OA associated with lower risk of myocardial infarctions → compared with ‘sitting’; - OA at age 15-19 yrs: OR (95%CI) = 0.61 (0.38-0.97) for ‘heavy and very heavy’ - OA at age 30-39 yrs: OR (95%CI) = 0.56 (0.35-0.90) for ‘average’ and 0.57 (0.34-0.95) for ‘heavy and very heavy’. P=0.045 for trend across categories of OA. - OA at age 50-59 yrs: OR (95%CI) = 0.54 (0.33-0.89) for ‘standing’, 0.59 (0.35-0.99) for ‘average’ and 0.51 (0.29-0.90) for ‘heavy and very heavy’	- 10
- Hu, 2007[53] - Finland	- prospective - 1972,1977,1982, 1987 - follow-up: 10 yrs from each baseline survey	- 44,906 (47%F) - mean 43.5 yrs; range 25-64 yrs - general population - excluded: people with history of CHD or stroke	- self-report - OA - 1)physically very easy, sitting office work; 2)moderate - including standing and walking; 3)high - including walking and lifting or heavy manual labour	- myocardial infarction (hospital discharge register) or death	- study year, education, family history of CHD, Framingham risk score, LTPA, active commuting BMI, alcohol	- more OA associated with lower risk of infarction → compared with ‘sitting’; HR (95%) for ‘moderate’ = 0.66 (0.55-0.79) and for ‘high’ 0.74 (0.65-0.85) in men and 0.53 (0.40-0.70) and 0.58 (0.44-0.76) in women - P<.001 for trend across categories of OA in men and women	- 11

- Hu, 2007[54] - Finland	- prospective - 1972, 1977, 1982, 1987, 1992, 1997 - follow-up: until 2004; mean 18.9 yrs	- 47,840 (53%F) - mean 44.3 yrs; range 25-64 yrs - general population - excluded: people with a history of CHD or stroke, people who died within first 2 follow-up yrs	- self-report - OA - 1)physically very easy, sitting office work; 2)moderate - including standing and walking; 3)high - including walking and lifting or heavy manual labour	- coronary heart disease (hospital discharge register) or CHD death	- age, study year, education, blood pressure, cholesterol, history of diabetes, alcohol, smoking, BMI, active commuting, LTPA	- more OA associated with lower CHD risk → compared with ‘sitting’; HR (95%CI) = 0.87 (0.78-0.97) for ‘moderate’ and 0.90 (0.82-0.98) for ‘high’ in men and 0.75 (0.66-0.86) and 0.80 (0.70-0.91) in women - P=0.019 for trend across categories of OA in men and P<.001 in	- 13
- Johansson, 1988[18] - Sweden - primary prevention study (PPS)	- prospective - 1968-1984 - follow-up: mean duration 11.8 yrs	- 7,495 (PPS); 1,273 (after infarction) (both 0%F) - mean 51 yrs; range 47-55 yrs - general population (PPS) and men registered with post-myocardial infarction clinic - excluded: for the ‘after infarction analyses’ men on long-term sick leave or with disability pension	- self-report - OA during the last 12 months - 1)sedentary work; 2)easy mobile; 3)rather heavy; 4)very heavy work	- myocardial infarction - (myocardial infarction registry) - total CHD	- no adjusted analysis	- no association between OA and infarction and total CHD in the general population and in men after their first infarct	- 12
- Rosenman, 1977[56] - USA	- prospective - 1970 - follow-up: 4 yrs	- 2,065 (0%F) - range 35-59 yrs - federal employees - excluded: CHD at baseline	- self-report - OA - 1)sedentary (mostly sitting); 2)moderate; 3)heavy	- CHD (clinical CHD or CHD death)	- stratified by age: 53-39 yrs; 40-49 yrs; 50-59 yrs	- more OA associated with higher CHD risk → 40-49 yrs (ANOVA, p=0.001) and 50-59 yrs (ANOVA, p=0.041)	- 8

- Sjol, 2003[52] - Denmark - monitoring trends and determinants in cardiovascular diseases (MONICA)	- prospective - pooled data from several cohorts studied from 1964 - follow-up: until 1994	- 13,925 (50%F) - age groups of 30-60 yrs - general population in Copenhagen county	- self-report - OA - 1)sedentary; 2)moderate active; 3)highly active; 4)heavy manual	- AMI or AMI death (registries)	- age, sex, smoking, education, BMI, cholesterol, blood pressure	- more OA associated with lower AMI risk → compared with 'sedentary'; RR (95%CI) = 0.61 (0.44-0.84) for 'moderate and high' in 1964 and 1976	- 10
Thromboembolism and stroke							
- Hu, 2005[55] - Finland	- prospective - 1972-1997 - follow-up: until 2004; mean duration 19 yrs	- 47,721 (52%F) - range 25-64 yrs - general population - excluded: people with a history of coronary - heart disease, stroke, or cancer	- self-report - OA - 1)physically very easy, sitting office work; 2)moderate - including standing and walking; 3)high - including walking and lifting or heavy manual labour	- stroke (hospital discharge register) and stroke deaths (death register)	- age, study year, gender, education, area, diabetes, blood pressure, cholesterol, smoking, alcohol, BMI, active commuting, LTPA	no clear association between OA and risk of stroke → no association in men and women separately, but compared with 'sitting'; OR (95%CI) = 0.89 (0.81-0.98) for 'high' in all subjects	- 13
- West, 2008[51] - New Zealand	- case-control - 2005-2006	- 203, 97 cases and 106 controls (43%F) - mean age (SD) cases 44.9 (13.1) yrs, controls 52.4 (9.7) yrs - thrombosis patients attending clinic after hospital discharge (cases) and patients admitted to coronary care	- self-report - prolonged seated immobility in a 24-hr period 4 weeks before VTE - 1)8 hrs/day and 3 hrs without getting up; 2)10 hrs/day and 2 hrs without getting up; 3)12 hours/day and 1 hr without getting up	- VTE (clinical diagnosis)	- age, family history of VTE, medical VTE history, medical risk factors, surgery or trauma, prolonged travel	- no clear association between occupational sitting and VTE	- 9

	unit (controls) - excluded: people with superficial thrombophlebitis, arterial thrombosis or embolism	

[a] alphabetical order within categories of heart disease and stroke and thrombosis; [b] number as reported in abstract; [c] adjusted results, unless reported otherwise; AMI = acute myocardial infarction; ANOVA = analysis of variance; BMI = body mass index; CHD = coronary heart disease; CI = confidence interval; CVD = cardiovascular disease; F = female; HR = hazard ratio; LTPA = leisure time physical activity; OA = occupational activity; OR = odds ratio; SD = standard deviation; VTE = venous thrombo-embolism; yrs = years.

Appendix Table E: Description of study characteristics of studies examining the association between occupational sitting and **DM**[a]

Author, country	**Design and duration**	**Sample**	**Occupational sitting**	**Outcome**	**Adjustments**	**Results**[c]	**Quality score**
- author, year - country - cohort	- study design - year(s) of baseline exam - follow up period	- number of participants (n)[b] (%women) - mean age at baseline - population and setting - relevant exclusion criteria	- self-report or objective - assessed sitting - units measured variable - units analyzed variable	- health outcome	- variables included in adjusted model	- results	- points out of 15
- Andersen, 2007[17] - Denmark - Copenhagen City Heart Study	- prospective - 1976-1978 - follow-up: up to 1992-1994	- 14,214 (54%F) - median age 52 yrs - general population, people aged ≥ 20 yrs	- self-report - OA - 1)sedentary; 2)low; 3)moderate; 4)high	- self-reported DM	- no adjusted analysis	- no differences across categories of OA	- 11
- Hu, 2003[6] - USA - Nurses Health Study	- prospective - 1992 - 1992, 1994, 1996, 1998	- 68,497 (100%F) - 46-71 yrs - female registered nurses - exclusion: CVD, diabetes or cancer in 1992	- self-report - average time spent sitting at work or away from home or while driving - hours/wk - categories: 1)0-1 hr; 2)2-5 hrs; 3)6-20 hrs; 4)21-40 hrs; 5)>40 hrs	- self-reported diagnosed DM	- age, hormone use, PA, smoking, alcohol, fat intake, fiber intake, glycaemic load, family history diabetes	- more sitting associated with higher RR → compared with women 'sitting 0-1 hrs'; RR (95%CI) = 1.48 (1.10 – 2.01) for those 'sitting>40 hrs' - P<.005 for trend across categories of sitting time	- 10
- Hu, 2003[57] - Finland	- prospective - 1982, 1987 and 1992 - 1998	- 14,290 (52%F) - 35-64 yrs - general population - exclusion: people with history of	- self-report - categories of OA - 1)light - physically very easy, sitting office work; 2)moderate - work	- incident cases of diabetes (as reported in national registers)	- age, study year, gender, education, systolic blood pressure, smoking,	- more OA associated with lower HR for DM → compared with 'sitting'; RR (95%CI) = 0.70 (0.52-0.96) for 'moderate' and 0.74 (0.57-0.95) for	- 12

		CHD, stoke or diabetes	involves standing and walking; 3)active - work includes walking, lifting or heavy manual labour		LTPA, commuting PA, BMI	‘active’ - P=.020 for trend across categories of OA	
- Sargeant, 2000[19] - multiple European countries - European prospective investigation into cancer (EPIC-Norfolk)	- -cross-sectional - 1995-1998	- 6,473 (55%F) - mean age (SD) in men 59.6 (8.4) yrs, in women 59.0 (8.4) yrs; range 45-74 yrs - general population	- self-report - physical activity involved in subject’s work - 1)sedentary; 2)standing 3)physical work; 4)heavy manual work - 1)sedentary; 2)standing 3)physical work and heavy manual work	- diabetes (doctor diagnosed and/or blood-sample diagnosed)	- age, gender, BMI, WHR, family history of diabetes, smoking, alcohol	- more OA associated with lower DM risk → Beta (SE) for risk of diabetes per category increase in OA = -0.262 (0.117)	- 13

[a] alphabetical order; [b] number as reported in abstract; [c] adjusted results, unless reported otherwise; BMI = body mass index; CI = confidence interval; CVD = cardio vascular disease; DM = diabetes mellitus; F = female; HR = hazard ratio; OA = occupational activity; PA = physical activity; RR = relative risk; SD = standard deviation; SE = standard error; WHR = waist-to-hip ratio; yrs = years.

Appendix Table F: Description of study characteristics of studies examining the association between occupational sitting and **mortality**[a]

Author, country	Design and duration	Sample	Occupational sitting	Outcome	Adjustments	Results[c]	Quality score
- author, year - country - cohort	- study design - year(s) of baseline exam - follow up period	- number of participants (n)[b] (%women) - age at baseline - population and setting - relevant exclusion criteria	- self-report or objective - assessed sitting - units measured variable - units analyzed variable	- health risks	- variables included in adjusted model	- results	- points out of 15
- Andersen, 2000[58] - Denmark - Copenhagen city heart study (CCHS), Glostrop population studies (GPS) and Copenhagen male study (CMS)	- prospective - 1964 (GPS), 1970-1971 (CMS),1976-1978 (CCHS) - follow-up: until 1995; mean duration 14.5 yrs, range 0–28 yrs	- 30,640 (44%F) - mean (SD) 50.4 (12.7) yrs in women and 49.7 (11.2) yrs in men; range 20-93 yrs - general population (CCHS and GPS) and 14 major work sites (CMS)	- self-report - OA during last year - 1)primarily sitting; 2)sitting or standing and now and then walking; 3)walking and now and then lifts; 4)heavy manual work	- all cause mortality (population registry)	- age, education (estimates similar in multivariate analyses [+, cholesterol, triglycerides, BMI, blood pressure, smoking], but RR (95% CI) not reported for these analyses)	- no clear association between OA and mortality → compared with 'sitting'; only in women RR (95%CI) = 0.86 (0.77-0.96) for 'sitting or standing' and 0.86 (0.74-0.99) for 'heavy manual work'	- 12
- Hu, 2004[59] - Finland	- prospective - 1972 - follow-up: until 2002; average duration 18.4 yrs	- 3,316 (50%F) - mean 50.6 yrs; range 25-74 yrs - people with confirmed diagnosed type 2 diabetes, those with severe disease at baseline and	- self-report - OA - 1)physically very easy, sitting office work; 2)work involves standing and walking; 3)work includes walking, lifting or heavy manual	- all cause and CVD mortality (registered with statistics Finland)	- age, gender, study year, smoking, BMI, blood pressure, cholesterol, active commuting, LTPA	- more OA associated with lower mortality risk → compared with 'sitting'; HR (95%CI) = 0.67 (0.57-0.78) for all-cause mortality and 0.69 (0.57-0.85) for CVD mortality for 'walking, lifting or heavy manual labour' - P =0.001 for trend across	- 11

		those who died within first 2 study years	labour			categories of OA for both outcomes	
- Hu, 2007[61] - Finland	- prospective - 1972 - follow-up: until 2004; mean 19.9 yrs; range 6.6-31.7 yrs	- 26,643 (46%F) - mean 46.8 yrs; range 25-64 yrs - general population, people with diagnosed hypertension - excluded: people with coronary heart disease, stroke, or type 1 diabetes	- self-report - OA - 1)physically very easy, sitting office work; 2)work involves standing and walking; 3)work includes walking, lifting or heavy manual labour	- CVD mortality (death register)	- age, study year, education, alcohol, smoking, BMI, blood pressure, cholesterol, use of antihypertensive drugs, diabetes, active commuting, LTPA	- more OA associated with lower mortality risk in men and women → compared with 'sitting'; HR (95%CI) for 'work involving standing and walking' = 0.84 (0.74-0.96) for men and 0.85 (0.74-0.98) for women; for 'work includes walking, lifting or heavy manual labour' = 0.86 (0.78-0.96) for men and 0.84 (0.73-0.96) for women - P=.006 for trend across categories of OA in men and p=.014 for trend in women	- 12
- Johansson, 1988[18] - Sweden - primary prevention study (PPS)	- prospective - 1968-1984 - follow-up: mean duration 11.8 yrs	- 7,495 (PPS); 1273 (after infarction) (both 0%F) - mean 51 yrs; range 47-55 yrs - general population (PPS) & men after first heart infarct - excluded: for the 'after infarction	- self-report - OA during the last 12 months - 1)sedentary work; 2)easy mobile; 3)rather heavy; 4)very heavy work	- coronary mortality (myocardial infarction registry) - all-cause mortality (registry)	- PPS: not adjusted - after first heart infarct: age, marital status, prognostic index, cholesterol, blood pressure, angina pectoris, smoking	- PPS - coronary mortality: no association - all-cause mortality: more OA associated with more all-cause mortality (p=0.045) - after first heart infarct - crude: more OA associated with less coronary mortality (p=0.033) - adjusted: no sig	- 12

		analyses’ men on long-term sick leave or with disability pension				association	
- Kristal-Boneh, 2000[62] - Israel - CORDIS study	- prospective - 1985-1987 - follow-up: until 1994; mean 8 yrs	- 3,488 (0%F) - median 43 yrs - employees of 21 industrial plants - excluded: men with CVD or on chronic medication	- self-report - prevalent working posture - 1)sitting; 2)standing; 3)walking	- cardiovascular, cancer and all-cause mortality (death registry)	- age, smoking, systolic blood pressure	- no association prevalent working posture and mortality → percentage men with ‘sitting’ not different for men who died compared with men still alive	- 10
- Salonen, 1988[60] - Finland - North Karelia Project	- prospective - 1972 and 1977 - follow up: 1977 and 1982	- 15,088 (52%F) - range 30-59 yrs - general population - excluded: people with history of CVD, or condition that hindered PA	- self-report - OA - 1)sedentary; 2)active	- cardiovascular mortality (death register)	- age, gender, cohort, province, education, social network, CVD symptoms, medication, disability, CVD and hypertension family history, smoking, cholesterol, blood pressure, LTPA, BMI	- more OA associated with lower ischemic heart disease mortality → compared with ‘active’; RR (95%CI) = 1.4 (1.1-1.7) for ‘sedentary’	- 12

[a] alphabetical order; [b] number as reported in abstract; [c] adjusted results, unless reported otherwise; BMI = body mass index; CVD = cardiovascular disease; CI = confidence interval; F = female; HR = hazard ratio; LTPA = leisure time physical activity; OA = occupational activity; RR = relative risk; yrs = years.

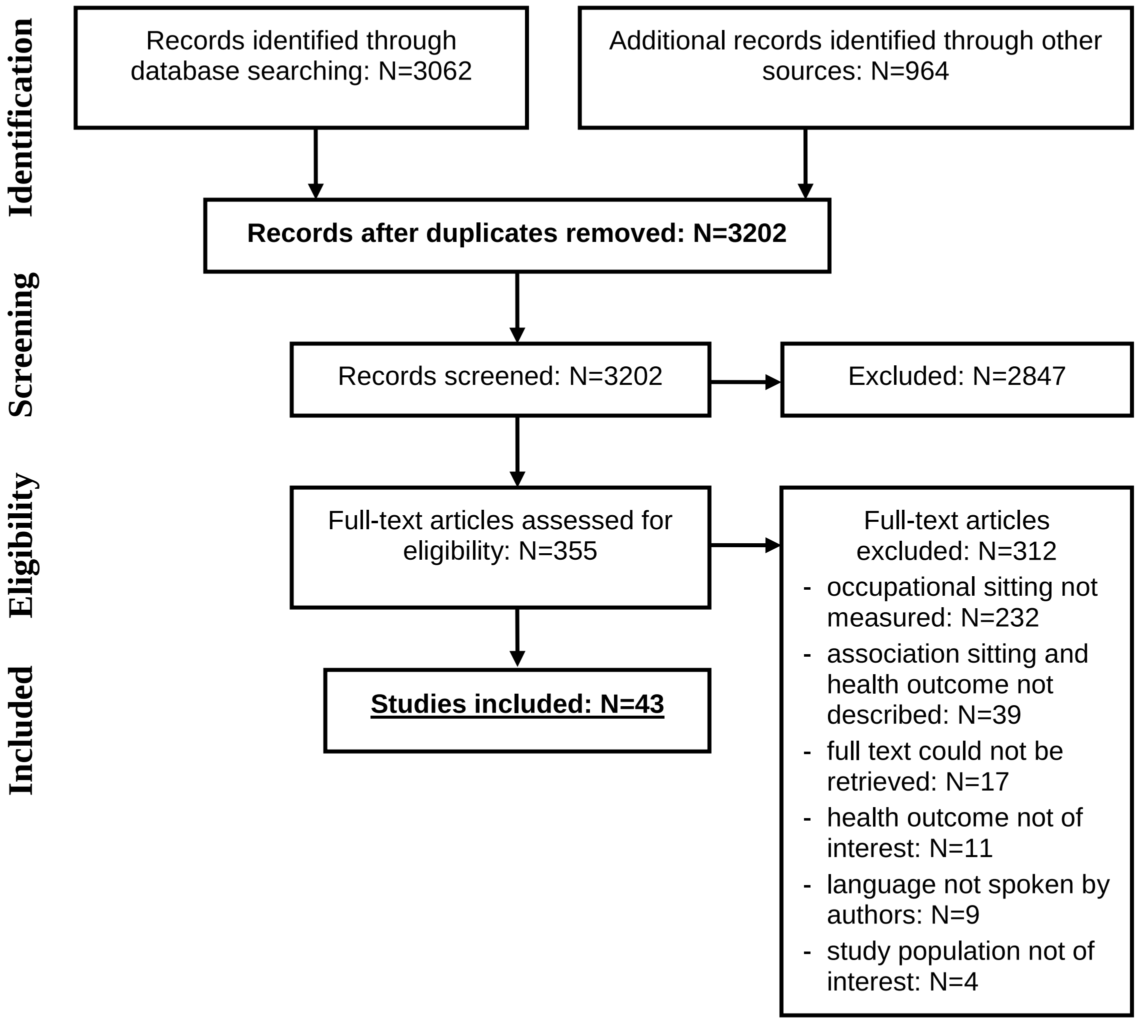

Figure 1: Information flow through the phases of the review[23]

			Number of studies												
			1	2	3	4	5	6	7	8	9	10	11	12	13
BMI (N=12)[b]	X	Quality [ref]	11 [24]	13 [25]	13 [19]	**9 [26]**	**12 [27]**	9 [28]	9 [29]	12 [30]	**9 [31]**	**7[32]**			
		N sample	*3,176*	*158*	*6,473*	*6,676*	*1,579*	*182*	*12,885*	*12,044*	*2,421*	*254,498*			
	P	Quality [ref]	**10 [6]**	11 [17]	**9 [31]**										
		N sample	*50,277*	*14,214*	*2,421*										
Cancer (N=17)	C	Quality [ref]	10 [33]	12 [34]	**13 [35]**	**13 [36]**									
		N sample	*620*	*714*	*906*	*1,198*									
	P	Quality [ref]	12 [37]	9 [38]	11 [39]	12 [40]	12 [41]	12 [42]	12 [43]	12 [44]	13 [45]	**12 [46]**	**14 [47]**	**11 [48]**	**14 [49]**
		N sample	*25,624*	*16,477*	*29,133*	*17,241*	*53,242*	*81,516*	*81,516*	*413,044*	*218,169*	*29,133*	*33,723*	*54,422*	*416,227*
CVD (N=8)	C	Quality [ref]	10 [50]	9 [51]											
		N sample	*985*	*203*											
	P	Quality [ref]	10 [52]	**11 [53]**	**13 [54]**	12 [18]	**13 [55]**	8 [56]							
		N sample	*13,925*	*44,906*	*47,840*	*7,495*	*47,721*	*2,065*							
DM (N=4)	X	Quality [ref]	13 [19]												
		N sample	*6,473*												
	P	Quality [ref]	**10 [6]**	**12 [57]**	11 [17]										
		N sample	*68,497*	*14,290*	*14,214*										
Mortality (N=6)	P	Quality [ref]	12 [58]	**11 [59]**	**12 [60]**	**12 [61]**	10 [62]	12 [18]							
		N sample	*30,640*	*3,316*	*15,088*	*26,643*	*3,488*	*7,495*							

Figure 2: General overview of study designs, findings, quality scores, adjustment for physical activity and sample sizes [a]

[a] ordered by increasing quality score, within categories of adjustment for physical activity, findings based on adjusted analysis if presented in included papers; [b] number adds up to 13, because one study[31] reports both cross-sectional and prospective findings. BMI = body mass index; C = case-control study; CVD = cardiovascular disease; DM = diabetes mellitus; n =number; P = prospective study; Quality = quality score (range 0-15 points, higher score indicates better quality); ref = reference; X = cross-sectional study. Dark = sitting associated with higher risk; Light = no association; Medium = sitting associated with lower risk. **Bold font** = analysis adjusted for physical activity.