

# BMJ Open Association of occupational sitting with cardiovascular outcomes and cardiometabolic risk factors: a systematic review with a sex-sensitive/gender-sensitive perspective

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## ABSTRACT

**Objectives** Sedentary behaviour is a modifiable risk factor for cardiovascular health. Although long periods of sedentary behaviour take place at work, evidence of the relationship between such occupational sitting and cardiometabolic health risks remains limited. This systematic review aimed to update the evidence on the associations of occupational sitting with cardiovascular outcomes and cardiometabolic risk factors based on longitudinal studies.

**Design** Systematic review.

**Setting** Workplace.

**Population** Employees aged 18–65 years.

**Primary and secondary outcomes** Primary outcomes were cardiovascular diseases and cardiometabolic risk markers. The secondary outcome was all-cause mortality.

**Data sources** Ten databases, including PubMed, Web of Science and CINAHL (search January 2018, updated February 2019).

**Data extraction and synthesis** Data were screened, extracted and appraised by three independent reviewers following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

**Results** Studies were markedly heterogeneous in terms of measurement of occupational sitting, cardiometabolic risk factors and cardiovascular morbidity and mortality, so that standards were hardly identifiable and limiting the value of the evidence. The review included 27 high or acceptable quality publications. Of the eight high-quality publications from seven cohorts, three cohort studies found significant associations of occupational sitting with primary outcomes. Additionally, one study described an association with the secondary outcome. Another high-quality publication found an association between occupational sitting and ischaemic heart disease in a subgroup already at risk due to hypertension. For sex/gender analysis, 11 of the 27 high and acceptable quality publications reported sex-stratified results. Five of these found sex differences.

**Conclusions** Evidence regarding the association of occupational sitting with cardiometabolic health risks was limited because of the lack of standardised measurements for occupational sitting. Occupational sitting combined

## Strengths and limitations of this study

- This paper updated a previous review on occupational sitting and health risks based on longitudinal studies, with a special focus on cardiometabolic outcomes and sex/gender differences.
- Ten databases as well as references of the identified studies were included.
- Reliability of study selection, data extraction and risk-of-bias assessment was ensured by three independent reviewers.
- Findings were limited by the heterogeneity of measurements of occupational sitting and the wide variety of measured outcomes.
- Study heterogeneity precluded a meta-analysis.

with an overall sedentary lifestyle was associated with an elevated relative risk for several cardiometabolic outcomes. There is an urgent need for standardised measurements of occupational sitting to facilitate meta-analysis. Sex/gender aspects of this relationship require further investigation.

## INTRODUCTION

Cardiovascular events are a leading cause of death worldwide.<sup>1</sup> The contribution of sedentary behaviour to cardiovascular health risks is well-documented.<sup>2–4</sup> Sedentary behaviour is defined as ‘any waking behaviour characterised by energy expenditure  $\leq 1.5$  metabolic equivalents, while in a sitting, reclining or lying posture.’<sup>5</sup> Occupational sitting is defined as sedentary behaviour in the workplace. Prolonged occupational sitting is potentially a relevant and modifiable risk factor of cardiovascular health, as 50%–60% of individuals’ total sitting time is spent at work.<sup>6</sup> However, the role of occupational sitting in the aetiology of cardiometabolic outcomes remains unclear.

To date, only one systematic review<sup>7</sup> has summarised studies of the association of occupational sitting with body mass index (BMI), cardiovascular disease (CVD), diabetes mellitus, cancer and mortality until 2009, but found heterogeneous results. There has been no more recent update of the literature on the association between occupational sitting (as a work-related exposure) and cardiometabolic outcomes based on longitudinal studies. Yet, this is needed as a basis for recommendations by stakeholders in the field of occupational safety and health.

The onset and incidence of CVD differs between women and men<sup>8</sup> due to sex-related biological differences, as well as sociocultural differences that impact the risk for CVD. Additionally, there are sex differences in the health benefits derived from physical activity,<sup>9</sup> and there are gender differences in terms of physical inactivity and sedentary behaviour in different domains.<sup>6 10 11</sup> There is a strong horizontal and vertical segregation in the labour market between men and women with similar trends across European countries.<sup>12</sup> For sedentary work, horizontal segregation results in different sitting demands, for example, women mostly sit during computer work, while men often sit while driving. A gender-sensitive, comprehensive data analysis requires description of the gender bias of the studies included in such an analysis, and careful interpretation of sex-stratified analyses based on a general framework<sup>13–15</sup> with a focus on the workplace.<sup>16</sup> As shown above, sex-based biological factors and gendered social factors are interrelated in this context. Recognising the entanglement of the terms ‘sex’ and ‘gender’, hereinafter we use the term ‘sex/gender’ recommended by the Cochrane Sex/Gender Methods Group.<sup>15</sup>

Thus, the aim of the present systematic review was to update the evidence<sup>7</sup> regarding the association between occupational sitting and cardiometabolic outcomes, based on longitudinal studies with a sex-sensitive/gender-sensitive perspective.

## METHODS

The research protocol for this systematic review, including the search strategy, was registered in advance (PROSPERO registration: CRD42018079219),<sup>17</sup> and inclusion criteria were defined following the patient, intervention (exposure), comparison, outcome and setting (PICO) model. The review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.<sup>18</sup>

### Search strategy

The list of search terms was based on the previous review on this topic.<sup>7</sup> The search string included terms of sedentary behaviour, as an exposure, in combination with an approved search string for work-related inquiries<sup>19</sup> (figure 1). We intentionally used a broad and comprehensive search string, with no restrictions on diseases or cardiometabolic outcomes. The search strategy was developed by a senior researcher and the project leader (UL,

### General approach for search string:

Setting work (Mattioli et al. 2010) AND exposure sitting: Search in title/abstract and keywords

- Limitations: 2009–2017
- Restricted to European languages
- Restricted to peer reviewed journals, articles

### Exemplary Search String for data base searches for PubMed (including MEDLINE)

#### 1. Work context (Mattioli et al 2010)

occupational diseases [MH] OR occupational exposure [MH] OR occupational exposure\* [TW] OR "occupational health" OR "occupational medicine" OR work-related OR working environment [TW] OR at work [TW] OR work environment [TW] OR occupations [MH] OR work [MH] OR workplace\* [TW] OR workload OR occupation\* OR worke\* OR work place\* [TW] OR work site\* [TW] OR job\* [TW] OR occupational groups [MH] OR employment OR worksite\* OR industry OR employee

#### 2. AND sitting at the workplace

sedentar\*[TW] OR sitting [TW] OR seated [TW]

### Complete search string: 22.01.2018: result 2805 hits

(search in all fields)

((occupational diseases[MH] OR occupational exposure[MH] OR occupational exposure\*[TW] OR "occupational health" OR "occupational medicine" OR work-related OR working environment[TW] OR at work[TW] OR work environment[TW] OR occupations[MH] OR work[MH] OR workplace\*[TW] OR workload OR occupation\* OR worke\* OR work place\*[TW] OR work site\*[TW] OR job\*[TW] OR occupational groups[MH] OR employment OR employee OR worksite\* OR industry)) AND (sedentar\*[TW] OR sitting[TW] OR seated[TW])) AND ("2009/03/01"[Date - Publication]: "2017/12/31"[Date - Publication])

Filters activated: Publication date from 2009/03/01 to 2017/12/31

**Figure 1** Representative search strategy, showing the data search strategy used in PubMed.

E-MB), in consultation with an academic librarian, and was piloted by one researcher (KR) and calibrated by another senior medical researcher (FL).

Relevant publications were identified in January 2018 by literature searches in 10 databases, namely, the Cochrane Central Register of Controlled Trials, CINAHL, Embase, LIVIVO, OSH UPDATE, Physiotherapy Evidence Database, PsychINFO, PubMed, SPORTDiscus and Web of Science, and included reports published from 2009 to 2017. After systematic evaluation of the data sources of the included publications, the search was updated until February 2019 in four databases (PsychINFO, Embase, PubMed and Web of Science) in which all of the relevant publications were first identified. Reference of included publications were cross-checked for potential additional records. To manage data screening, abstract and citation tracking, the reference management software package EndNote X9 was used.

In this review, we distinguished between the terms ‘publications’ and ‘studies’. We found multiple full-text publications that analysed different outcomes from the same longitudinal cohort or case-control study, for example, the Whitehall II cohort study,<sup>20–22</sup> Danish Working Environment cohort study (DWECS)<sup>23–25</sup> and the INTERHEART case-control study (a large international case-control study in different countries).<sup>26 27</sup>

### Inclusion criteria

Based on the PICO scheme for structuring quantitative searches, the inclusion criteria were as follows:

- ▶ A study population of gainfully employed adults, with a working age assumed to be 18–65 years.
- ▶ Exposure to sedentary behaviour in the workplace.
- ▶ Comparison of working populations with various amounts of sedentary time, or different physical job demands in the workplace.
- ▶ Outcomes including risk of CVDs, metabolic diseases, cardiometabolic mortality, or changes in cardiometabolic risk markers.
- ▶ A workplace setting.
- ▶ Cohort, case-control or interventional study designs.

Original, full-text, peer-reviewed articles published between April 2009 and February 2019 were included. For other reports, for example, congress presentations, abstracts or short reports, authors were requested access to original publications and study reports by email. Articles were restricted to peer-reviewed publications, with the intention of including high-quality studies, and were restricted to publications in all 24 European languages,<sup>28</sup> required by the funding bodies due to this study.

Following the PRISMA statement,<sup>18</sup> three reviewers (KR, E-MB, MP) screened the records independently and in tandem by title and abstract and identified eligible publications. Subsequently, these reviewers identified eligible publications by screening the full-text reports, using standardised forms. In the case of disagreement, consensus was sought by discussion, and if necessary, a deciding opinion was obtained from another reviewer (UL).

Data from included publications were extracted in duplicate. To ensure high accuracy and completeness, data extraction was checked and confirmed by three evaluators (KR, E-MB, MP).

Interventional studies were included but given the considerable differences in terms of study length, the measurement of exposure and subclinical outcomes (eg, lipids, glucose levels), they were evaluated separately. Studies with experimental designs were excluded. Additionally, studies investigating adolescents, subjects over 65 years of age or adults not gainfully employed exclusively were excluded.

#### Risk-of-bias assessment and methodological assessment

The methodology of publications, including potential risk-of-bias, was assessed using the methodology checklists for cohort and case-control studies of the SIGN network.<sup>29</sup> Subquestions related to specific exposures, outcomes (including selective reporting) and confounders were added. The overall rating of each study was determined by consensus between the evaluators (KR, E-MB, MP) and, if necessary, by an independent reviewer (UL). The following overall ratings were assigned: ‘high quality’ (++) , indicating a study with low risk for confounding and bias; ‘acceptable quality’ (+) and ‘unacceptable/low quality’ (0). Publications with

low quality were excluded from the narrative summary of findings.<sup>30–32</sup>

#### Sex-sensitive/gender-sensitive perspective

Findings of sex-stratified analyses and studies with only male or female populations were also analysed and summarised.

#### Measures of effect

Depending on the statistical methods employed in the included articles, principal risk estimates were proportional hazards, from Cox and Poisson regression models in cohort studies and ORs in case-control studies, reported with 95% CIs and p values. In cohort studies examining BMI, the BMI change ( $\Delta$ ) or obesity,  $\beta$  risk estimate or risk estimate for  $\Delta$  (regression analysis) were reported.

#### Data synthesis

Included articles were summarised by study designs. Publications were grouped according to the method for analysing exposure to occupational sitting. After data extraction and methodological assessment of included publications, the potential for a meta-analysis and pooling data was considered. We also performed subgroup analyses by cardiovascular risk groups (eg, participants with hypertension, overweight, metabolic syndrome (MS) or different BMI levels) in the included publications.

#### Patient and public involvement statement

We did not directly include patient and public involvement in this study as it is a systematic review with literature-based data.

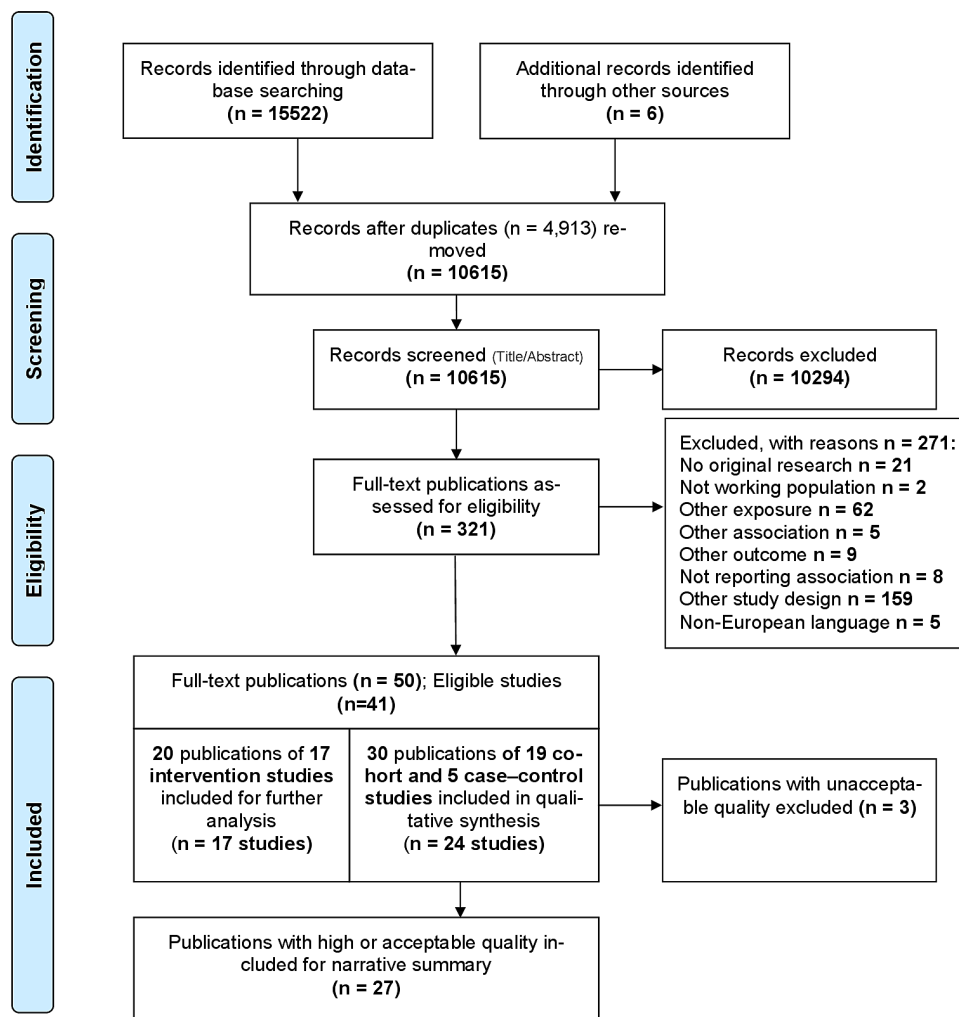
## RESULTS

### Study selection and systematic review process

Figure 2 presents the identified articles and selected publications according to the PRISMA statement.<sup>18</sup> The 30 identified publications included 24 studies (19 cohort and 5 case-control studies). Six of these 30 publications reported more than one outcome, 5 included subgroup analyses on subjects already at risk of CVD and 12 included sex-stratified analyses.

### Study setting and study characteristics

Characteristics of the 30 included publications are shown in tables 1 and 2. There were 17 studies from Europe, 5 from North America, 7 from Asia and 1 publication with data obtained from 52 countries. The number of participants ranged from 228<sup>33</sup> to 134 596.<sup>34</sup> The mean follow-up duration varied between 3.3<sup>35</sup> and 19.2 years.<sup>36</sup> Occupational groups included healthcare, white collar and mixed cohorts of white-collar and blue-collar workers, agriculturists, office workers and general working population. Results were to be analysed according to the outcomes of the included studies, as per the study protocol.<sup>17</sup>



**Figure 2** Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart of the systematic review process.

### Risk of bias

Methodological quality and risk-of-bias rating indicated acceptable to high quality of the publications (tables 1 and 2). The limitations were predominantly related to self-reported measurement of exposure. No cohort or case-control study used device-measured data (tables 1 and 2).

The relevant confounders in this context were age, sex, leisure time physical activity (LTPA), health behaviour (alcohol, smoking, diet) and socioeconomic status (SES). These main potential confounders were considered in nearly all studies, although LTPA was not considered in four<sup>26 27 32 37</sup> and SES was not considered in six publications.<sup>38–43</sup>

### Heterogeneous assessments of exposure to occupational sitting

Among the included studies, exposure to occupational sitting was assessed in three ways: on a continuous scale or in categories as self-estimated amounts of time sitting at work, or as self-reported sedentary, low occupational physical activity (OPA), or by a job exposure matrix, as illustrated in table 3.

In 11 of 30 publications, occupational sitting was analysed on a continuous scale or in categories as self-estimated amounts of time sitting at work, mostly based on a single question, “How many hours per week do you spent sitting at work?” Categories varied, for example, from self-report of occupational sitting time using a 5-point Likert scale, representing ‘never’ to ‘always’,<sup>43</sup> to using different cut-off values, for example, <24 hours per week vs ≥24 hours per week,<sup>23</sup> or short (<1 hour per day), middle 1–3 hours per day and longer ≥3 hours per day.<sup>40</sup>

In 18 publications, exposure to occupational sitting was assessed as the least demanding OPA as compared with other categories, and heavy manual work as high OPA. Some studies used the ‘Saltin-Grimby Physical Activity Level Scale’.<sup>44</sup> Self-rated OPA was categorised into four classes, with different adaptations, labelling the categories in terms of walking and lifting, with no standardised norm discernible among the included studies. Three studies assessed exposure to occupational sitting using different types of job exposure matrices.

Six studies used standardised questionnaires, such as the Baecke Physical Activity Questionnaire. All standardised questionnaires contained either self-reported



**Table 1** Characteristic Nurse of included cohort studies with risk-of-bias rating

Cohort studies		Major occupational groups	Sample	Length follow-up/ duration	Assessment of occupational sitting (as analysed)	Outcomes*	Study quality†	Sex-stratified analysis
Study	First author, country, cohort	General population or specification	n (% F); age at baseline	Duration	Categories of measurement and standardised instrument (if applicable)	(Data basis)	(++); (+); (0)	Yes/No
1.	Allesøe K <i>et al</i> <sup>38</sup> , Danish Nurse Cohort Study, Denmark	Healthcare/Nursing	n=12093 (100% F); 45–64 y; median: 51 y	(1993–2008) 15 y	Self-reported OPA in four categories (questionnaire based on OPA assessment by Saltin and Grimby <sup>44</sup> )	IHD (national register)	++	Females only
2.	Allesøe K <i>et al</i> <sup>39</sup> , Danish Nurse Cohort Study, Denmark	Healthcare/Nursing	n=12093 (100% F); 45–64 y; median: 51 y	(1993–2008) 15 y	Self-reported OPA in four categories (questionnaire based on OPA assessment by Saltin and Grimby <sup>44</sup> )	Subgroup analyses for hypertensive subjects and IHD (national register)	++	Females only
3.	Chau JY <i>et al</i> <sup>65</sup> , HUNT3, Norway	General population (including working)	n=36817 (45% F) (for occupational sitting) 18–≥60 y	(2006–2008) Mean 3.3 y	Self-reported OPA in four categories	All-cause and cardiovascular mortality (death register)	++	No
4.	Eriksen D <i>et al</i> <sup>24</sup> , DWECS, Denmark	Working population	n=3482 (51.8% F); 18–59 y	(2005–2010)	Change in self-reported sitting time (hour/week) between 2005 and 2010 in five categories	BMI change (self-reported)	+	Yes
5.	Ferrario MM <i>et al</i> <sup>47</sup> , MONICA, PAMELA, SEMM-Study	Salaried employees and general population (including working)	n=3574 (0% F); 25–64 y; mean age: 40.8 y	14 y median	BPAQ: self-reported OPA categorised in tertiles into low, moderate or high OPA	CHD (registries)	++	Males only
6.	Hall C <i>et al</i> <sup>42</sup> , Sister Study, USA	Working population	n=31270 (100% F); 35–74 y; no event mean age: 53.0 y with event mean age: 57.7 y	(2005–2015) average 5.7 y (range 2.3–10.8)	Self-reported OPA at four intensity levels	TIA and stroke (self-reported doctor's diagnoses)	+	Females only
7.	Hayashi R <i>et al</i> <sup>66</sup> , JACC study, Japan	General population (including working)	n=66161 (54.6% F); 40–79 y; mean age: 55.6 y	19.2 y median	Self-reported OPA in four categories	Cardiovascular mortality (death certificates/national register)	+	Yes
8.	Johnsen AM <i>et al</i> <sup>48</sup> , WOLF study, Sweden	Manual workers, low and intermediate non-manual workers, professionals	n=9961 (31.2% F); mean age: 42.7 y	Mean 13.1 y	Self-reported OPA levels categorised into three groups	MI (national and death register)	+	Yes

Continued

Table 1 Continued

Cohort studies		Study	Sample	Major occupational groups	Length follow-up/ duration	Assessment of occupational sitting (as analysed)	Outcomes*	Study quality†	Sex-stratified analysis
Nr.	First author, country, cohort	n (% F); age at baseline	General population or specification	General population or specification	General population or specification	Categories of measurement and standardised instrument (if applicable)	(Data basis)	(++); (+); (0)	Yes/No
9.	Johnsen AM <i>et al.</i> <sup>48</sup> , Japan	n=36516 (44.4% F); mean age: 58.7 y; 50–74 y	Agriculture, forestry, fishing, salaried workers, home business, professionals	General population (including working)	(2000–2011) Average 10.1 y	Self-reported occupational sitting time in three categories: short <1 hour/day; middle 1 to ≤3 hours/day; longer ≥3 hours/day	All-cause mortality (death certificates/national register)	+	Yes
10.	Kim Y <i>et al.</i> <sup>34</sup> , Multiethnic Cohort Study, USA	n=134596 (54.4% F); 45–75 y	General population (including working)	General population (including working)	13.7 y median	Self-reported work sitting time hour/day analysed in three categories: <1 hour/day; 1–4 hours/day; >5 hours/day	All-cause and cardiovascular mortality (death certificates/national register)	+	Yes
11.	Lin T-chi <i>et al.</i> <sup>60</sup> , NLSY79, USA	n=5285 (46.7% F); 38–45 y	20 different occupations (including working)	General population (including working)	(2002–2010)	Job exposure matrix: self-reported job information used to extract time spent sitting at work from O*NET database by occupation	BMI (self-reported)	+	Yes
12.	Martin KR <i>et al.</i> <sup>32</sup> , British Birth Cohort, Great Britain	n=3035 (51.5% F); 53 y	Different occupations (including working)	Different occupations (including working)	Not reported	Job exposure matrix: self-reported occupation, assigned to five categories of OPA, with one of them sitting >2 hours/day, summed up into three categories: sitting unlikely, somewhat likely, highly likely	BMI (standardised protocol)	0	Yes
13.	Moe B <i>et al.</i> <sup>45</sup> , HUNT2, Norway	n=7300 (49.2% F); mean 44.1 y	General population (including working)	General population (including working)	(1995–2008) 12.4 y median	Self-reported OPA, analysed in three categories	All-cause and cardiovascular mortality (death register)	+	No
14.	Møller SV <i>et al.</i> <sup>24</sup> , DWCECS, Denmark	1990: n=5420 (47.9% F); 18–59 y	Working population	Working population	(1991–2010) mean 12.16 y (2001–2010) mean 7.5 y	Self-reported work sitting time categorised as sedentary work >25 hours/week and non-sedentary work <25 hours/week	IHD (national register)	++	No

Continued

Table 1 Continued

Cohort studies		Study	Sample	Major occupational groups	Length follow-up/ duration	Assessment of occupational sitting (as analysed)	Outcomes*	Study quality†	Sex-stratified analysis
Nr.	First author, country, cohort	n (% F); age at baseline	General population or specification	General population or specification	Length follow-up/ duration	Categories of measurement and standardised instrument (if applicable)	(Data basis)	(++); (+); (0)	Yes/No
15.	Picavet HSJ <i>et al</i> <sup>51</sup> , Doetinchem Cohort Study, The Netherlands	n=1509 (% F not reported); 20–60 y	Paid employment and self-employed, general population (including working)	General population and self-employed, general population (including working)	(1987–2010) 15 y	Self-reported OPA in four categories at five time points, categorised into stable sitters (sedentary at least at three out of five measurements) and non-stable sitters at work	BMI and obesity (objective/measured) and cardiometabolic health risk markers‡	+	No
16.	Pinto Pereira SM, <sup>52</sup> 1958 British Birth Cohort, Great Britain	n=6562 (49.4% F); 45–50 y	General population (including working)	General population (including working)	5 y	EPIC-Norfolk physical activity questionnaire: self-reported work sitting time hour/week categorised into six levels from 0 hour/day to >4 hours/day	BMI and BMI change (objective/measured and self-reported)	+	No
17.	Pulsford RM <i>et al</i> <sup>20</sup> , Whitehall II cohort study, Great Britain	n=1971 (25% F); mean age 40.5 y	Clerical and office support, executive, senior administratives grades	Clerical and office support, executive, senior administratives grades	(1997–2004)	Self-reported work sitting time hour/week, summed up into four categories: >0 to <8 hours/week; >8 to <25 hours/week; >25 to <40 hours/week; >40 hours/week	Incident obesity BMI >30 (objective/measured)	+	No
18.	Pulsford RM <i>et al</i> <sup>21</sup> , Whitehall II cohort study, Great Britain	n=5132 (27.5% F); mean age low sitting: 46.6 y; mean age high sitting: 41.5 y	Clerical and office support, executive, senior administratives grades	Clerical and office support, executive, senior administratives grades	Mean 17.7 y (±2.2 y)	Self-reported work sitting time/week summed up into four categories: ≥0 to <8 hours/week; >8 to <25 hours/week; >25 to <40 hours/week; >40 hours/week	All-cause mortality (national register)	++	No
19.	Sajid M <i>et al</i> <sup>41</sup> , Health 2006 cohort, Denmark	n=1403 (54% F); 18–69 y; mean age: 44 y	General population (including working)	General population (including working)	(2006–2011) 5 y	Physical Activity Scale 2, assessing self-reported time spent in daily sedentary work (hour/day)	BMI and metabolic health markers§ (objective/measured)	+	No
20.	Sakaue A <i>et al</i> <sup>43</sup> , Seven Countries Study, Japan	n=1680 (58.8% F); 40–95 y; mean age: 61.1 y	General population (including working)	General population (including working)	Mean 15.9 y (±3.8 y)	BPAQ: self-reported work sitting time on a 5-point Likert scale: never, seldom, sometimes, often, always	All-cause mortality (obituaries, medical records, registries and other)	++	Yes

Continued

Table 1 Continued

Cohort studies		Major occupational groups	Assessment of occupational sitting (as analysed)	Outcomes*	Study quality†	Sex-stratified analysis
Study	Sample	General population or specification	Length follow-up/duration	(Data basis)	(++); (+); (0)	Yes/No
<b>Nr.</b>	<b>First author, country, cohort</b>	<b>n (% F); age at baseline</b>	<b>Length follow-up/duration</b>	<b>Categories of measurement and standardised instrument (if applicable)</b>		
21.	Smith P, <sup>37</sup> Canadian Community Health Survey (CCHS), Canada	Different occupations general population (including working)	(1003–2015) 12 y	Job exposure matrix: primary type of posture for occupations in four categories after respondents occupation	+	Yes
22.	Stamatakis E <i>et al</i> , <sup>46</sup> Health Survey for England Scottish Health Survey, Great Britain	General population (including working)	Mean 12.9 y (±3.3 y)	Self-reported predominant OPA categorised into predominant sitting activity at work versus predominant standing/walking activity at work	+	Yes
23.	Stamatakis E <i>et al</i> , <sup>22</sup> Whitehall II cohort study, Great Britain	Clerical and office support, executive, senior administrative grades	(1997–2011) mean 13 y	Self-reported work sitting time/week summed up into three categories: 0 to <15 hours/week; 15 to <35 hours/week; >35 hours/week	+	No
24.	Thompson WG, <sup>33</sup> USA	Healthcare/Clinic: ac or ca	Average 6.9 y	Women's Health Initiative Physical Activity Questionnaire; self-reported job as ac with 90% workday sitting or ca with median 25% workday sitting	+	Females only
25.	van der Ploeg HP <i>et al</i> , <sup>23</sup> DWECS, Denmark	Working population	(1990–2010) average 12.61 y	Self-reported occupational sitting time, analysed in two categories: <24 hours/week and ≥24 hours/week work sitting	++	No

n (% F); number of participants (per cent female).

\*IHD, CHD, MI, AMI, acute coronary syndrome, BMI, TIA.

†Methodological assessment including risk of bias: assessment after the SIGN checklists resulting in overall ratings of 'high quality' (++), 'acceptable quality' (+) and 'unacceptable/low quality' (0), synonymous with 'high quality' (++)/low risk of bias, 'acceptable quality' (+)/acceptable risk of bias and 'unacceptable/low quality' (0)/unacceptable risk of bias.

‡Hypertension, hypercholesterolaemia, blood pressure, total cholesterol.

§WC, HDL-cholesterol, triglycerides, insulin level, blood pressure.

ac, appointment coordinators; AMI, acute myocardial infarction; BMI, body mass index; BPAQ, Baecke Physical Activity Questionnaire; ca, clinical assistants; CHD, coronary heart disease; HDL, high-density lipoprotein; IHD, ischaemic heart disease; MI, myocardial infarction; OPA, occupational physical activity; TIA, transient ischaemic attack; WC, waist circumference; y, year.



**Table 2** Characteristics of included case-control studies with risk-of-bias rating

Case-control studies		Major occupational groups	Sample	Length of recruitment	Assessment of occupational sitting	Outcomes	Study quality**	Sex-stratified analysis
Study	First author, country	General population or specification	n (% F); age at baseline	General population	Categories of measurement and standardised instrument (if applicable)	(Data basis)	(++) , (+) , (0)	Yes/No
1.	Cheng <i>et al</i> <sup>27</sup> China INTER-HEART study	General population (including working)	Case: n=2909 (30.3% F); mean age: 55.2 y; Control: n=2947 (30.5% F); mean age: 54.5 y; 35–74 y hospital-based	February 1999–March 2003	Self-reported OPA in four categories	AMI (medical records)	+	Yes
2.	Held <i>et al</i> <sup>26</sup> INTER-HEART study 52 countries worldwide	General population (including working)	n=9805 case; n=14200 control; F not reported hospital-based	Elsewhere reported	Self-reported OPA in four categories	MI (medical records)	+	Yes
3.	Kumar <i>et al</i> <sup>30</sup> North Indian	General population (including working)	Case: n=224 (17.9% F); mean age: 53.47 y; control: n=224 (17.9% F); mean age: 52.92 y 18–85 y population-based	February 2009–February 2012	Self-reported occupation, categorised into: sedentary occupations, moderate physical work, heavy physical work	Stroke (medical records)	0	No
4.	Ma <i>et al</i> <sup>49</sup> China	General population (including working)	Case: n=354 (22.6% F); mean age: 55.28 y; control: n=241 (45.2% F); mean age: 51.94 y; 24–65 y population-based	December 2015–November 2016	Occupational physical activity questionnaire: self-rated OPA in four categories	CHD (medical records)	+	No
5.	Selim <i>et al</i> <sup>31</sup> Bangladesh	General population (including working)	Case: n=200 (12.5 F); mean age: 55.13 y; control: n=200 (14% F); mean age: 48.91 y; 30–80 y hospital-based	Not reported	Self-reported sedentary occupation yes/no	ACS (national register)	0	No

n (% F); number of participants (per cent female).

\*Methodological assessment including risk of bias: assessment after the SIGN checklists resulting in overall ratings of 'high quality' (++), 'acceptable quality' (+) and 'unacceptable/low quality' (0), synonymous with 'high quality' (++)/low risk of bias, 'acceptable quality' (+)/acceptable risk of bias and 'unacceptable/low quality' (0)/unacceptable risk of bias.

ACS, acute coronary syndrome; AMI, acute myocardial infarction; BMI, body mass index; CHD, coronary heart disease; HDL, high-density lipoprotein; MI, myocardial infarction; OPA, occupational physical activity; TIA, transient ischaemic attack; WC, waist circumference ; y, year.

**Table 3** Qualitative summary of findings by measurement of exposure and outcomes

Exposure	Occupational sitting time (continuously)	Occupational physical activity*	Job exposure matrix
<b>Cohort studies</b>			
<b>Qualitative summary of findings† by study for overall sample/for subgroups</b>			
All-cause mortality	↔Pulsford <i>et al</i> <sup>21</sup> ↑Sakaue <i>et al</i> <sup>43</sup> ↔van der Ploeg <i>et al</i> <sup>23</sup> ↔/↑Kikuchi <i>et al</i> <sup>40</sup> ↔Kim <i>et al</i> <sup>34</sup>	↑Chau <i>et al</i> <sup>35</sup> ‡ ↔/↑Moe <i>et al</i> <sup>45</sup> ♀↑; ♂↔Stamatakis (2013) <sup>46</sup> ‡	
Cardiovascular mortality	↔Kim <i>et al</i> <sup>34</sup>	↔Chau <i>et al</i> <sup>35</sup> ‡ ↔/↑Hayashi <i>et al</i> <sup>36</sup> ‡ ↔/↑Moe <i>et al</i> <sup>45</sup> ↔Stamatakis <i>et al</i> <sup>46</sup> ‡	
Cardiovascular heart diseases¶	↔Møller <i>et al</i> <sup>25</sup> (IHD)	↑Ferrario <i>et al</i> <sup>47</sup> (CHD) ↔/↑Allesøe <i>et al</i> <sup>39</sup> (IHD) ↑Allesøe <i>et al</i> <sup>39</sup> (IHD) ↔Johnsen <i>et al</i> <sup>48</sup> (MI)	↔Smith <i>et al</i> <sup>37</sup>
Cardiovascular morbidity (CHD and stroke)		↑Ferrario <i>et al</i> <sup>47</sup>	
Transient ischaemic attack and stroke		↔Hall <i>et al</i> <sup>42</sup>	
BMI, BMI change and obesity	↑Eriksen <i>et al</i> <sup>24</sup> ↔Pinto Pereira <i>et al</i> <sup>52</sup> ↔Pulsford <i>et al</i> <sup>20</sup>	↔Picavet <i>et al</i> <sup>51</sup> ↔Saidj <i>et al</i> <sup>41</sup> ↔Thompson <i>et al</i> <sup>33</sup>	↑/♀↔; ♂↑Lin <i>et al</i> <sup>50</sup>
Other cardiometabolic risk markers**	↔Picavet <i>et al</i> <sup>51</sup> (HT, HCL) ↔Stamatakis <i>et al</i> <sup>22</sup> (DM)	↔/(WC)↑Saidj <i>et al</i> <sup>41</sup>	
<b>Case-control studies</b>			
Cardiovascular heart diseases¶		↔/♂↑Cheng <i>et al</i> <sup>27</sup> ‡ (AMI) ↑Held <i>et al</i> <sup>26</sup> ‡ (MI) ↑Ma <i>et al</i> <sup>49</sup> (CHD)	

♀Female; ♂male.

\*Risk-of-bias rating is indicated by lettering: bold for low risk-of-bias (high quality) rated studies, *cursive/italic* for acceptable risk-of-bias rating.

†Explanation for qualitative summary of findings: ↑statistical significant positive associations of exposure and outcome reported. ↔No statistical significant association reported.

‡Indicated if highest category of occupational sitting or sedentary/low occupational physical activity is reference group for statistical analysis.

¶IHD, CHD, MI, AMI

\*\*WC, HDL-cholesterol, triglycerides, insulin level, blood pressure, HT, HCL, DM.

ACS, acute coronary syndrome; AMI, acute myocardial infarction; BMI, body mass index; CHD, coronary heart disease; DM, diabetes mellitus; HCL, hypercholesterolaemia; HDL, high-density lipoprotein; HF, heart failure; HT, hypertension; IHD, ischaemic heart disease; MI, myocardial infarction; WC, waist circumference.

occupational sitting time, OPA or job information. Other studies used adapted or self-constructed questionnaires to measure occupational sitting.

(Online supplemental table 1 demonstrates the heterogeneous nature of exposure assessment, exemplified for studies examining the association between occupational sitting and all-cause mortality. Online supplemental tables 2–7 describe details of the types of self-reported questionnaires or ‘job exposure matrices’ that were used.)

### Study heterogeneity

Studies showed marked heterogeneity. Sources of heterogeneity included different populations (eg, only male subjects or only female subjects, or major occupational groups), exposure measurements, reference categories and outcomes. The varied reference categories are illustrated in online supplemental table 1 for studies examining the association between occupational sitting and all-cause mortality. Reference categories of those

studies quantifying occupational sitting time ranged from <8 hours per week of occupational sitting<sup>21</sup> to <24 hours per week of occupational sitting.<sup>23</sup> Due to study heterogeneity, meta-analysis was impossible. Consequently, we have included a narrative summary of findings, from which publications with unacceptable quality were excluded.<sup>30–32</sup>

### Association between occupational sitting and all-cause mortality

Eight cohort studies examined the association between occupational sitting and all-cause mortality, including four high-quality<sup>21 23 35 43</sup> and four acceptable-quality publications<sup>34 40 45 46</sup> (online supplemental table 2). Among the former, Chau *et al*<sup>35</sup> reported that participants who self-rated their jobs as requiring ‘much walking and lifting’ had a 35% lower risk of all-cause mortality than those who reported sitting most of the time. Sakaue *et al*<sup>43</sup> reported that occupational sitting time was significantly associated

with all-cause mortality in male subjects only, Pulsford *et al*<sup>21</sup> and van der Ploeg *et al*<sup>23</sup> reported no difference in all-cause mortality between participants sitting for different durations.

Among the four acceptable-quality studies, Kim *et al*<sup>34</sup> found no association between occupational sitting and all-cause mortality, for either sex. Kikuchi *et al*<sup>40</sup> reported a borderline association of longer occupational sitting time with all-cause mortality in a subsample of male primary industry workers. Moe *et al*<sup>45</sup> found a significant association in a subgroup with MS, but not in the overall sample. Stamatakis *et al*<sup>46</sup> found that a standing/walking occupation among women posed a lower risk of all-cause mortality than a sitting occupation.

### Association between occupational sitting and cardiovascular mortality

Five cohort studies examined the association between occupational sitting and cardiovascular mortality, including one high-quality<sup>35</sup> and four acceptable-quality studies<sup>34 36 45 46</sup> (online supplemental table 3). The high-quality study found no difference in risk for participants with mostly sitting jobs compared to jobs with higher OPA.<sup>35</sup> The remaining prospective cohort studies reported no associations for overall samples.<sup>34 36 45 46</sup> For a subsample of overweight individuals, Hayashi *et al*<sup>36</sup> reported a significantly higher risk for participants with MS, as well as Moe *et al*.<sup>45</sup>

### Association between occupational sitting and cardiovascular heart diseases

Eight publications examined the association between occupational sitting and CVDs. Of these, three cohort studies<sup>25 38 39 47</sup> had high and two had acceptable quality,<sup>37 48</sup> while three case-control studies had acceptable quality<sup>26 27 49</sup> (online supplemental table 4).

Ischaemic heart disease (IHD), myocardial infarction (MI), coronary heart disease (CHD) as well as acute coronary syndrome were considered as outcomes. Among the three high-quality publications, Møller *et al*<sup>25</sup> showed no difference in IHD risk between sedentary and non-sedentary employees. Allesøe *et al*<sup>38</sup> showed no significant association of sedentary work with increased IHD risk in female nurses, but found an association in those who were hypertensive.<sup>39</sup> Ferrario *et al*<sup>47</sup> compared low and moderate OPA in males, and found a significant CHD risk starting 3–5 years after baseline. Both acceptable-quality cohort studies found no association.<sup>37 48</sup> Among the case-control studies, Ma *et al*<sup>49</sup> showed significant association between sedentary occupations and CHD risk, particularly for participants working prolonged hours. They observed a significant linear relationship between OPA and CHD: the lesser the OPA during working, the higher the incidence of CHD. Held *et al*<sup>26</sup> showed a significantly reduced MI risk for occupations predominantly involving walking at one level and walking uphill and lifting objects, compared with sedentary work. Cheng *et al*<sup>27</sup> showed that associations between OPA levels and acute MI (AMI) risk

were not linear, and that walking, compared with mostly sitting, at work reduced AMI risk in women.

### Association between occupational sitting and cardiovascular morbidity and stroke

Two studies (one high-quality<sup>47</sup> and one acceptable-quality<sup>42</sup>) reported an association between occupational sitting and cardiovascular morbidity and stroke (online supplemental table 5). Ferrario *et al*<sup>47</sup> reported that low OPA posed a higher risk for CHD and stroke than intermediate OPA in working men. Hall *et al*<sup>42</sup> reported no associations between sitting/standing OPA and transient ischaemic attack (TIA), compared with mostly sitting.

### Association of occupational sitting with BMI and obesity

Seven acceptable-quality cohort studies examined the association between occupational sitting and BMI, BMI change or obesity<sup>20 24 33 41 50–52</sup> (online supplemental table 6). One study found a significant trend for female but not for male subjects.<sup>24</sup> Lin *et al*<sup>50</sup> showed that more sitting was significantly associated with higher BMI in men but not in women. Thompson *et al*<sup>33</sup> found a borderline association of sitting with BMI increase in women. Four studies found no association of occupational sitting with BMI and obesity,<sup>51</sup> BMI or BMI change,<sup>52</sup> incident obesity<sup>20</sup> or 5-year BMI change.<sup>41</sup>

### Association of occupational sitting with other cardiometabolic risks and risk markers

Three acceptable-quality publications of cohort studies examined the association between occupational sitting and different cardiometabolic risk markers<sup>22 41 51</sup> (online supplemental table 7). Stamatakis *et al*<sup>22</sup> found no significant association of occupational sitting with incident diabetes. Picavet *et al*<sup>51</sup> reported that stable sitting at work was not associated with hypertension or hypercholesterolaemia. Saidj *et al*<sup>41</sup> showed association of increased sitting time with waist circumference, but not other cardiometabolic health markers.

### Findings regarding sex/gender

All 27 high-quality and acceptable-quality publications reported results adjusted for sex, and 12 provided a sex-stratified analysis.

### Findings of publications with sex-stratified analysis

Twelve of 27 publications reported sex-stratified findings concerning all-cause and cardiovascular mortality,<sup>34 36 40 43 46</sup> CHDs,<sup>26 27 37 48</sup> BMI change<sup>24</sup> and BMI<sup>32 50</sup> (online supplemental tables 2–7). One low-quality publication<sup>32</sup> was excluded from the narrative summary.

Of the 11 included sex-stratified publications, associations of occupational sitting with mortality<sup>43 46</sup> and AMI<sup>27</sup> in females were found in three studies, and with BMI alone in males,<sup>50</sup> with BMI change in females<sup>24</sup> and with MI in both sexes,<sup>26</sup> in one study each.

Six publications found no differences in risks between women and men,<sup>26 34 36 37 39 48</sup> five found no associations and one found an association in both sexes.

### Female-only publications

In four female-only publications, one study reported no association with IHD,<sup>38</sup> except for hypertensives.<sup>39</sup> One study<sup>42</sup> reported no difference in risk for TIA and stroke among females with low-level OPA (mostly sitting, compared with those who were sitting and standing or mostly standing). One study<sup>33</sup> found a borderline significant association of predominantly sitting, as compared with standing/walking at work, with BMI increase in women.

### Male-only publications

Ferrario *et al*<sup>47</sup> showed associations of low OPA with CHD and cardiovascular morbidity (CHD and stroke) in men.

### Additional stratified analyses

In 6 of the 27 publications, additional analyses examined the combined effect of different levels of OPA (low/moderate/high) and LTPA or other physical activity levels with cardiometabolic outcomes.<sup>22 36 38 41 47 48</sup> Four of these found an association, and two did not. The combined effects of different levels of OPA and LTPA showed complex associations, rather than a dose-response relationship with cardiometabolic health risk for occupational sitting.

### Summary of risk estimates

With regard to the multiple cardiovascular outcomes investigated across studies, most publications examined all-cause or cardiovascular mortality (n=10), CHDs (n=5) or BMI (n=8) as an outcome. Of the 27 publications included in the narrative synthesis, 9 publications (n=4 with high-quality, n=5 with acceptable-quality) showed that occupational sitting increased cardiometabolic risk (table 3). No study found a lower risk of the defined outcomes with sitting. One high-quality study reported a risk estimate of 1.28 for occupational sitting for cardiometabolic outcomes.<sup>43</sup> Another high-quality cohort study<sup>35</sup> reported a 35% lower risk for employees who were walking and lifting weights compared with those who were sitting. High-quality studies comparing groups with higher OPA to lower levels (sitting) reported risk estimates of 1.22<sup>38</sup> to 1.61.<sup>47</sup>

Additionally, five subgroup analyses showed a noticeable effect on at-risk persons with hypertension,<sup>39</sup> MS,<sup>45</sup> overweight<sup>36</sup> or working prolonged hours.<sup>49</sup>

## DISCUSSION

In this systematic review of studies considering the effect of occupational sitting on cardiometabolic outcomes, we identified eight high-quality publications that presented results from seven cohort studies. Three cohort studies<sup>38 39 43 47</sup> found significant associations of occupational sitting with the primary outcomes. The study by Chau *et al*<sup>35</sup> reported no association with the primary outcome CVD mortality but with the secondary outcome all-cause mortality. In a subanalysis of the study by Allesøe

*et al*,<sup>39</sup> occupational sitting was associated with IHD in the subgroup already at risk due to hypertension.<sup>39</sup> The strength of the association in the included high-quality studies was weak to moderate.

The results based on the high-quality studies are similar to the results when additional 19 publications with at least acceptable quality are considered. Out of all 27 publications included, 9 showed associations of occupational sitting with cardiometabolic outcomes for the overall sample. Furthermore, the 27 publications allow to answer questions regarding subgroups. Risk estimates seem to be higher in at-risk subgroups (eg, Allesøe *et al*<sup>39</sup>). Four of six publications that considered occupational sitting together with a lack of sufficient LTPA reported a higher risk of cardiometabolic outcomes for the combination of both exposures.

The informative value of this review seems to be mainly restricted by the extreme heterogeneity of both measurements and reference categories of occupational sitting as well as the variety of measured outcomes considered in the studies included. Furthermore, the spectrum of study participants' work was broad ranging from population samples to single occupations, for example, one high-quality study included nurses only.<sup>38 39</sup>

Despite including longitudinal studies from the past 10 years, and the rapid literature update in PubMed,<sup>53–56</sup> the results remained inconclusive, similar to the earlier systematic review.<sup>7</sup> A recent comprehensive systematic review<sup>6</sup> identified differences in physical activity, sedentary behaviour and cardiometabolic health and fitness across occupational groups (including professional drivers and office workers). Cardiometabolic outcomes investigated in studies (included in the above-mentioned review) with different designs, including cross-sectional and experimental studies, included BMI, waist-to-hip ratio, body fat percentage, blood lipids and blood glucose.<sup>6</sup> Clinical cardiovascular outcomes (such as MI) and mortality were not considered. Prince *et al*<sup>6</sup> stated that the relationship between occupational sitting time and cardiometabolic health, with considerations of the effect of sex and LTPA, require investigation. The present review contributes to addressing these research needs.

The inconclusive results of occupational sitting are in contrast to the conclusive results of the relationship between cardiovascular outcomes and overall sedentary behaviour (work and leisure time) in the general population.<sup>57 58</sup> This may be due to the difference between occupational sitting and sitting in other domains (eg, TV viewing).<sup>59</sup> Moreover, the heterogeneity of exposure measurements using different concepts and questionnaires, and comparisons with different reference categories in these studies, differs from the more homogeneous exposure assessment for overall sedentary behaviour.

Underestimation of risk due to misclassification of exposure remains an issue. The reference category in four of the seven high-quality studies (eight publications) comparing different intensities of OPA was heavy or moderate manual work. Four of the seven high-quality



studies considering different duration of sitting time also used different categories. Description of exposure was comparable in the total number of studies. While LTPA is well-documented to promote health,<sup>60</sup> it is increasingly recognised that highly strenuous OPAs are associated with CVDs and premature mortality.<sup>61 62</sup> Additionally, six of the eight high-quality publications (and most of all publications included) examined the general working population, without details on occupational groups or contexts.

Thus, occupational sitting presumably also included sitting in forced postures, for example, professional driving. Occupations with highly strenuous OPAs and sitting in forced postures are related to lower SES, which is associated with cardiovascular risk factors.<sup>63 64</sup> Thus, further risk attenuation may be attributed to confounding by SES.

Nonetheless, at least half of the high-quality studies suggested an association with the primary or secondary outcome. Thus, there is a need for addressing occupational sitting to prevent cardiometabolic disease. Since none of the included studies examined device-measured occupational sitting time, quantitative recommendations for stakeholders in the field of occupational safety and health could not be deduced. To date, examples<sup>65–67</sup> for interventions addressing occupational sitting have shown promising possibilities, based on objective measurements, and require further evaluation. Findings on sex/gender differences were inconclusive and do not support a more pronounced association in men or in women.

### Strengths and limitations

This study used a comprehensive search strategy in 10 databases, with a sophisticated search string for occupational determinants of disease<sup>19</sup> and adhered to the PRISMA guidelines.<sup>18</sup> This review involved independent reviewers working in tandem at different stages of the review process. Moreover, it was limited to longitudinal studies and focused on sex/gender aspects of the association, contributing to an important but often neglected aspect of occupational health.

It could be disputed whether studies measuring occupational sitting as the lowest level of OPA should be included. This measurement assesses occupational and physical activity, but is not validated as a measure of sedentary behaviour in the workplace. Based on van Uffelen *et al.*,<sup>7</sup> we included studies with self-estimated duration of sitting, studies applying a job-exposure matrix and objective measurement (although none of the included studies used the latter). Considering only those studies that quantified occupational sitting time, the overall findings of associations between occupational sitting and cardiometabolic risk factors remained. Nevertheless, no definition of subgroups (eg, persons already at risk, persons with low LTPA) was a priori included in the study protocol. Moreover, because of the heterogeneity of the included studies, a meta-analysis was not reasonable.

### CONCLUSION

Given the heterogeneity of exposure measurements in studies included in this review, future research should focus on using a standardised, valid and reliable measurement of occupational sitting. Combining self-reported measures with device-measured data have been recommended for improving the comprehensiveness and accuracy of sedentary behaviour measurements,<sup>68 69</sup> and result reliability. Studies should also include a sex/gender perspective.

Subgroup analyses of at-risk individuals (eg, groups with existing health issues) might deserve further attention. Individuals with extended occupational sitting time combined with low LTPA may have particularly high risk. At least 6 hours per week of physical activity is needed to compensate for the risk imposed by sitting >8 hours per day.<sup>70</sup> WHO recommends about 3 hours per week LTPA for adults.<sup>71</sup> Doubling this amount is difficult for employees with full-time sedentary employment, particularly those with family responsibilities. Given the low adherence to the physical activity recommendations,<sup>72</sup> preventive measures in all settings are needed.

To date, only the effect of sedentary behaviour in general, and not specifically of occupational sitting, on cardiovascular outcomes is known. Thus, interventions reducing prolonged sitting periods during both leisure and work time are recommended. From a public health perspective, the workplace is an ideal setting for health promotion and interventions, particularly for hard-to-reach populations, given the amount of sitting time spent at work.<sup>6</sup> Since this review does not exclude association of occupational sitting with cardiometabolic risk, further high-quality studies are needed, particularly as sedentary work is expected to increase in digital workplaces in future.

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