Associations of occupational standing with musculoskeletal symptoms – a systematic review with meta-analysis

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ABSTRACT

Objective: Given the high exposure to occupational standing in specific occupations, and recent initiatives to encourage intermittent standing among white-collar workers, a better understanding of the potential health consequences of occupational standing is required. We aimed to review and quantify the epidemiological evidence on associations of occupational standing with musculoskeletal symptoms.

Design: A systematic review was performed. Data from included articles were extracted and described, and meta-analyses conducted when data were sufficiently homogenous.

Data sources: Electronic databases were systematically searched (up to February 2015)

Eligibility criteria: Peer-reviewed articles on occupational standing and musculoskeletal symptoms from epidemiological studies were identified.

Results: Of the 11,750 articles screened, 50 articles reporting 49 studies were included (45 cross-sectional and 5 longitudinal; n=88,158 participants) describing the associations of occupational standing with musculoskeletal symptoms, including low-back (39 articles), lower extremity (14 articles) and upper extremity (18 articles) symptoms. In the meta-analysis, 'excessive' (>4 hours/workday) occupational standing was associated with the occurrence of low-back symptoms (pooled odds ratio [95% CI] 1.31[1.10 1.56]). Evidence on lower and upper extremity symptoms was too heterogeneous for meta-analyses. The majority of included studies reported statistically significant detrimental associations of occupational standing with lower extremity, but not with upper extremity symptoms.

Conclusions: The evidence suggests that 'excessive' occupational standing is associated with the occurrence of low-back and (inconclusively) lower extremity symptoms, but there may not be such an association with upper extremity symptoms. Only limited evidence from high quality, longitudinal studies using objectively measured standing was found.

Key words: Musculoskeletal symptoms – occupational standing – systematic review – meta analysis

WHAT IS ALREADY KNOWN:

- There are high exposures to occupational standing in specific occupations and recent initiatives encouraging intermittent standing among white-collar workers.
- In light of these (shifting) working styles, some concerns have been expressed that occupational standing may expose workers to risks of health consequences such as musculoskeletal symptoms.
- The association of occupational standing with musculoskeletal symptoms is yet unclear, with no current systematic review quantifying this association.

WHAT ARE THE NEW FINDINGS:

- We systematically reviewed literature and identified substantial evidence (50 articles from n=88,158 participants) describing associations of occupational standing with low-back, lower extremity and upper extremity symptoms.
- We found evidence (including pooled data from a meta-analysis) for associations between occupational standing and the occurrence of low-back and (inconclusively) lower extremity symptoms, however not for upper extremity symptoms.
- We found only limited evidence from high quality, longitudinal studies using objectively measured standing was found.
- Such information is needed to provide more definitive evidence to inform good work design for both blue- and white-collar workers.

INTRODUCTION

Exposure to extended periods of occupational standing is traditionally common among specific occupational groups, such as in the retail, food, healthcare, education, and manufacturing industries. For example, in a population of Australian workers, 62% reported working in a job that usually involved standing[1]; a finding consistent with that observed in a study conducted with a Canadian working population[2]. In a study with objectively measured standing (using thigh and hip worn accelerometers), it was shown that Danish blue-collar workers stood on average 2.2 (SD 1.3) hours per workday with subgroups standing for up to 3.7 (0.7) hours per workday[3].

A recent and growing body of evidence suggests that excessive sitting is associated with several adverse health outcomes including poor cardio-metabolic health and premature mortality[4-6]. Consequently, there is a growing interest in workplace initiatives to reduce the amount of sitting time for sedentary workers[7], with expert recomendations advising workers to replace some sitting periods with standing and light activity at work[8], specifically by advocating regular postural changes (i.e. shifting between sitting, standing and moving). Replacing sitting with alternatives such as standing has been shown to be feasible[8 9] and is rapidly being implemented in many workplaces, such as through the introduction of sit/stand office workstations[10]. However, some concerns have been expressed that alternatives to sitting, such as standing, may expose workers to new hazards and/or other health consequences[11].

In light of shifting working styles, a sound understanding of the health consequences of occupational standing is urgently needed to inform healthy work practice for both blue- and white-collar workers. Adverse health outcomes of standing have been reported

before[12], with standing being associated with venous disorders of the lower extremities[13 14], perinatal health complications such as pre-term delivery and pre-eclampsia[15], and musculoskeletal symptoms such as low-back and lower limb symptoms[16 17]. Despite this body of evidence, the association of occupational standing with musculoskeletal symptoms (e.g. self-reported pain, discomfort or complaints in regions of the musculoskeletal system) is yet unclear, with no current systematic review quantifying this association. The aims of this study were to systematically review the epidemiological evidence on the associations of occupational standing with non-specific musculoskeletal symptoms, and to quantify this association by means of meta-analyses.

METHODS

Search strategy

To identify relevant publications, we performed systematic searches of the literature in the following bibliographic databases: Health & Safety Science Abstracts (Proquest); CINAHL (EBSCO); EBM Reviews - Cochrane Central Register of Controlled Trials (Ovid); Embase (Ovid); Medline (Ovid); PsycInfo (Ovid). Searches were performed from database inception to 10 February 2015 with search terms including controlled key terms as well as free text terms. Search terms expressing 'standing' were used in combination with search terms for 'work-related' (Appendix 1-6). No specific terms for 'health outcomes' were used as this study is part of larger review aimed at assessing the association of occupational standing and multiple health outcomes.

Two reviewers independently screened all potentially relevant titles and abstracts for eligibility. If necessary, full-text articles were checked for eligibility. Differences in judgment were resolved through a consensus procedure. Studies were included if they met the

following criteria: the article was an original epidemiological study published in a peer-reviewed journal (i.e., excluding reviews, editorials or letters, theses and conference proceedings); it was published in English; and it reported on the association between occupational standing and any health problem. Only articles that described a general adult working population were included (e.g., studies selecting workers with chronic disorders and non-adult populations were excluded). Only studies quantifying the association of occupational standing with health outcomes were included (thereby excluding qualitative research). Studies in which occupational standing was not a main exposure variable of interest (e.g., standing was only part of a certain condition/trial such as 'lifting during standing'), or in which occupational standing was only used as a confounding variable, were excluded.

All eligible full-text articles were classified on exposure (work-related vs non-work related), outcome (musculoskeletal or other outcomes) and study design (e.g., laboratory study, cross-sectional study or longitudinal study). For the current study, only articles describing epidemiological cross-sectional (case-control or cross-sectional observational studies) or longitudinal observational studies on occupational standing and their association with musculoskeletal symptoms (i.e., self-reported pain, discomfort and/or complaints in any region of the musculoskeletal system) were included. Full-text versions of the selected articles were obtained for data extraction and quality assessment. In cases where full-text articles could not be found through online and/or offline databases, authors were contacted. Reference lists of selected articles were screened to identify additional potentially eligible articles.

Data extraction and quality assessment

Two reviewers independently assessed all selected articles for methodological quality and data extraction. In cases of disagreement, consensus was reached during a meeting. Methodological quality was evaluated using an adapted version of a published scoring system[18], based on eleven criteria for the reporting of study methods (description of recruitment, participants, allocation, measures, sample size) and results (description of variance, confounding, detail of results), with answer categories being 'yes', 'partial', 'no' and 'not applicable' (Appendix 7). Summary scores (ranging from 0 to 1) were calculated with:

Summary score = Σ[(number of 'yes' × 2) + (number of 'partial' × 1)]/ Σ[22 − (number of 'N/A') × 2]

Studies with a summary score ≥0.75 were considered to be of high methodological quality[18].

For data extraction, the following data from each included article were obtained: first author and year of publication, study name, study design, sample description (i.e., number of participants, age, gender, occupation and country), confounders, exposure (assessment and operationalisation of occupational standing), outcome (assessment and operationalisation of musculoskeletal symptoms) and exposure-outcome estimates (e.g., odds ratios [ORs], relative risks [RR]).

Data-analysis

All included studies were described according to their methodological quality and extracted data. Included articles were categorised into body areas regarding their outcomes; i.e., low-back symptoms, lower extremity symptoms, upper extremity symptoms and symptoms in any body area.

In each of the four body areas, quantitative analyses of homogenous studies (with sufficient overlap in definitions of exposure, outcome, study population and study design for which small differences in definition of exposure and outcome were accepted[19]) were performed if possible. To be able to combine information from different studies, occupational standing was treated as a dichotomous variable for which a cut-off value of 4 hours/workday was adopted (i.e., durations of standing below this threshold were considered 'not excessive' while durations of standing above this threshold were considered 'excessive' standing). In the absence of any known 'threshold' for excessive standing, we selected this cut-off value based on the data provided in the identified studies with 4 hours/workday being the most often reported (with sensitivity analysis examining other thresholds). The cut-off is also consistent with the recent recommendations for those occupations which are predominately desk-based whereby the eventual progression to a total accumulation of up to 4 hours/workday is advocated to offset the health hazards associated with excessive sitting[8]. Model parameters (i.e., unadjusted ORs; or cross-tabulations of participants exposed to not excessive and excessive standing, with and without musculoskeletal symptoms) were retrieved from the original studies. If needed, exposure categories from studies reporting multiple occupational standing categories were collated. In instances where data provided in the published articles were insufficient, corresponding authors were contacted and asked for additional information.

Review Manager (RevMan) version 5.3 was used to conduct meta-analyses and generate forest plots, using a random-effects model due to the heterogeneity of the studies. We report on ORs with 95% confidence intervals (CI) depicting each individual study as well as pooled exposure-outcome associations of excessive occupational standing and musculoskeletal symptoms, unadjusted for confounders. P-values <0.05 (two-sided) were

considered statistically significant. Heterogeneity was assessed using I^2 statistics and visual inspection of the forest plots were performed, while subgroup analyses were conducted using χ^2 statistics. Funnel plots were generated to assess publication bias (through visual inspection).

Sensitivity analyses were conducted to test the robustness of pooled-exposure associations. The sensitivity of the cut-off value for excessive occupational standing (4 hours/workday) was tested by comparing those studies for which we could estimate exposure-outcome associations with a 4 hours/workday cut-off value to those for which we could estimate exposure-outcome associations with a 2 hours/workday cut-off value (performing subgroup analysis). Due to a lack of sufficient homogeneous data, we were not able to test for the effect of other cut-off values. In a second sensitivity analysis, we compared exposure-outcome associations unadjusted for confounders to exposure-outcome associations adjusted for confounders (e.g., gender, age, other physical or mental work demands). We also tested for differences in exposure-outcome associations of studies reporting on generic samples of workers (i.e., random samples of a general working population or samples of mixed occupational groups) compared to studies on samples of specific occupational groups (e.g., only hospital staff, only construction workers). In a final sensitivity analysis we tested for differences in exposure-outcome associations of studies with low compared to high methodological quality.

RESULTS

Data-description

The flow chart of the search and selection process is presented in Figure 1. Our search strategy yielded a total of 15,857 search hits. After removing duplicates, 11,750 individual

articles remained that were screened on their titles for inclusion. After excluding 10,951 records, a total of 799 abstracts were screened after which 356 abstracts did not meet the inclusion criteria. A total of 11 full-text articles could not be retrieved (even after contacting corresponding authors), providing a total of 432 full-text articles that were screened on eligibility, of which 218 met the criteria of describing outcomes of occupational standing. A total of 44 of these articles specifically addressed the association of occupational standing and musculoskeletal symptoms using an epidemiological study design. After screening the reference lists of these articles, six more articles were added, resulting in a final total of 50 articles (reporting 49 studies) included in the current review and used for methodological quality assessment and data-extraction (see Table 1 for a summary of findings)[17 20-68].

Table 1. Summary of findings from all identified evidence describing the number of studies (N) and number of participants (n) in each of the outcome (body area), study design, exposure assessment and study findings by categories.

		Total	Study design			Exposure assessment			Study findings				
			Cross-sectional case-control	Cross-sectional observational	Longitudinal observational	Self-reports	Observations	Objective	Meta-analysis	Positive[1] (significant)	Negative[2] (significant)	Non-significant	No data reported
Low-back	N	39	4	31	4	37	1	1	16[3]	9	-	8	6
	n	82,291	9,210	6,364	9,435	81,863	401	27	54,392[3]	9,239	-	7,330	11,330
Lower extremity	N	14	3	9	2	13	1	-	-	8	1	4	4
	n	31,924	5,081	24,147	2,696	31,903	21	-	-	24,502	759	6,192	2,749
Upper extremity	N	18	5	14	1	18	1	1	-	4	1	9	10
	n	25,708	1,783	22,427	1,498	25,251	401	56	-	2,602	529	4,647	21,882
All areas	N	8	1	6	1	8	-	-	-	3	1	2	2
	n	3,114	12	1,604	1,498	3,114	-	-	-	1,960	433	231	490
Total[4]	N	49	7	37	5	45	2	2	n/a	n/a	n/a	n/a	n/a
	n	88,158	12,632	64,893	10,633	87,653	422	83	n/a	n/a	n/a	n/a	n/a

[1] Excessive being associated with higher prevalence of symptoms

[2] Excessive being associated with lower prevalence of symptoms

[3] Pooled OR (with 95% CI) of 1.31[1.10 1.56].

[4] Two articles reported on data from the same study, for which the n in the article with the highest number of participants was used.

N = number of studies

n = number of participants

The methodological quality of all included articles is shown in Appendix 8. The average methodological quality of the included articles was 0.79 (SD: 0.16) out of 1, ranging from 0.23 to 1.00, with 32 articles describing a study considered to have high (≥0.75) methodological quality. Data extracted from the selected articles are presented in Appendix 9. Seven articles reported on a cross-sectional case-control study[20 29 31 32 44 45 52], 38 a cross-sectional observational study[21-28 30 34-36 38-43 46-51 53-57 59-66 68] and five articles a longitudinal observational study[17 33 37 58 67]. Forty-six articles reported occupational standing assessed by self-reports[17 20 22-31 33-46 48-55 57-68], two articles described occupational standing assessed by observations[47 56] and two other articles described objectively measured (using accelerometers) occupational standing[21 32]. A total of 46 articles reported on samples of workers recruited from a general (not exclusively worker) population and/or a work population[17 20-23 26-43 45-51 53-68], while four others reported on data from samples of workers that were recruited through a clinical setting[24 25 44 52]. A total of 21 articles reported about random samples of the general (working) population or samples of mixed occupational groups[17 24-26 29 32 33 37 43-45 47 48 50 52 55 58-61 66] and 29 articles reported about specific occupational groups, including health care workers[21-23 27 31 34-36 39-41 46 49 53 63 64 67], factory and assembly workers[28 30 56 57], teachers[54 68], farmers[51 65] and construction workers[38].

Low-back symptoms

A total of 39 articles (n=82,229 participants in total) reported on the association of occupational standing with back symptoms, of which 33 focused on low-back symptoms[17 21 23-27 29 33-35 38-40 44-46 49 50 54-62 64-68] and six on back symptoms in general[22

28 30 31 43 63] (all referred to as low-back symptoms from here). Sixteen articles (13 cross-sectional studies[28 38 39 44-46 50 59-62 64 66] and three longitudinal studies[33 58 67], n=54,392 participants in total) provided sufficiently homogenous information to conduct a meta-analysis, pooling exposure-outcome associations on excessive occupational standing and low-back symptoms. This resulted in a pooled OR (with 95% CI) of 1.31[1.10 1.56], with I^2=90% heterogeneity (Figure 2; Table 2). Associations found in studies with longitudinal study designs (1.17[0.64 2.14]) were not statistically significant and the point estimate was slightly weaker compared to studies with cross-sectional study designs (1.32[1.09 1.59]).

Table 2. Summary of findings from meta-analyses describing the association of occupational standing and low-back symptoms. The upper rows show the findings of the main model (Figure 2) while the remaining rows show the findings of the sensitivity analyses (Appendices 10-13).

Subgroup factor	**Subgroups**	**Odds Ratio (with 95% CI)**	**Test for subgroup difference**		**Reference**
			χ^2	**p-value**	
Study design	Cross-sectional	1.32 [1.09 1.59]			
	Longitudinal	1.17 [0.64 2.14]			
	Total	1.31 [1.10 1.56]	0.14	0.71	Figure 2
Cut-off value for excessive standing	2 hours	1.34 [1.08 1.65]			
	4 hours	1.31 [1.06 1.61]			
	Total	1.32 [1.15 1.52]	0.02	0.88	Appendix 10
Adjustment for confounders	Unadjusted	1.32 [1.09 1.59]			
	Adjusted	1.23 [1.02 1.47]			
	Total	1.29 [1.13 1.48]	0.31	0.58	Appendix 11
Study population	General study population	1.40 [1.20 1.62]			
	Specific study population	1.24 [0.86 1.78]			
	Total	1.31 [1.10 1.56]	0.36	0.55	Appendix 12
Methodological quality	Low quality	1.25 [0.85 1.82]			
	High quality	1.38 [1.16 1.64]			
	Total	1.31 [1.10 1.56]	0.22	0.64	Appendix 13

CI = Confidence interval

Sensitivity analyses showed that the association of excessive occupational standing and low-back symptoms did not statistically differ when the threshold for excessive occupational standing was set at 2 hours/workday compared to 4 hours/workday (χ^2=0.02, p=0.88; Table 2, Appendix 10). Exposure-outcome associations unadjusted for confounders showed apparently stronger associations (1.32[1.09 1.59]) than those adjusted for confounders (1.23[1.02 1.47]), (Table 2, Appendix 11). Exposure-outcome associations from

studies on samples of workers in general appeared stronger (1.40[1.20 1.62]) than from those on samples of specific occupational groups (1.24[0.86 1.78]), (Table 2, Appendix 12). Exposure-outcome association from studies with high methodological quality showed apparently stronger associations (1.38[1.16 1.64]) than those from studies with low methodological quality (1.25[0.85 1.82]), (Table 2, Appendix 13). Regarding publication bias, visual inspection of the funnel plot (Appendix 14) suggested some degree of asymmetry with some larger studies reporting lower ORs than smaller studies.

The remaining 23 studies (n=27,899 participants) that reported on the association between occupational standing and low-back symptoms could not be used in our meta-analysis as insufficient homogeneous evidence was provided. Nine studies reported on significant positive (i.e., excessive standing being associated with the occurrence of low-back symptoms) associations[17 21 24 30 35 40 49 63 68], eight studies reported on comparable but non-significant associations[22 25 27 29 34 55 56 65] while in another six studies associations of occupational standing and low-back symptoms were assessed, but the outcomes of these associations were not reported (nor provided by the authors upon request)[23 26 54] [31 43 57]. These studies varied substantially in their definitions for exposure, outcome and exposure-outcome associations. Regarding variation in definitions of exposure for example, one study showed that there was a significantly higher prevalence of low-back symptoms for workers who reported that their 'work was hampered by standing' compared to workers who reported that their 'work was hampered by sitting' (OR with 95% CI; 3.07[1.88 5.01][31]. In comparison, Hill and colleagues showed that the prevalence of low-back symptoms was higher by every hour of occupational standing, though confidence intervals were wide (OR with 95% CI; 2.96[0.73 12.10])[34]. Substantial heterogeneity existed in the definitions of low-back symptoms (e.g., with studies reporting on pain,

discomfort and complaints, acute and chronic and even low-back symptoms exacerbated by occupational standing)[24 25]. Finally, some studies reported on exposure-outcome associations using metrics other than ORs, such as correlations[40], prevalence rates (PRs)[29 56] and hazard ratios (HR)[17].

Lower extremity symptoms

A total of 14 articles (n=31,924 participants) reported on the association between occupational standing and lower extremity symptoms. Three articles were on lower extremity symptoms in general[29 31 43], one on hip/knee/feet symptoms combined[17], two on hip symptoms[52 65], six on knee symptoms[37 46 48 50 57 65], two on feet symptoms[47 48], two on upper leg symptoms[28 48] and three on lower leg symptoms[28 35 48].

Eight studies reported that excessive occupational standing was significantly associated with a higher prevalence of lower extremity symptoms (with point estimate ORs ranging from 1.23 to 3.95)[17 28 31 35 43 46-48]. Four studies reported comparable but non-statistically significant exposure-outcome associations (with point estimate ORs ranging from 1.10 to 1.70)[29 37 52 65]. One study found that excessive occupational standing was associated with a significantly *lower* prevalence of lower extremity symptoms [65]. There were an additional four studies in which the association of occupational standing and lower extremity symptoms was assessed, but the outcomes of these associations were not reported[47 50 57] [17].

Upper extremity symptoms

A total of 18 articles (n=25,708 participants) reported on the association of occupational standing and upper extremity symptoms, of which three articles focused on upper extremity symptoms in general[29 31 43], five on neck/shoulder symptoms[17 27 32 56 68], 10 on neck symptoms[22 28 34 35 40 43 46 57 63 65], seven on shoulder symptoms[22 28 34 35 50 57 63], seven on forearm/hand and/or finger symptoms[17 22 28 34 50 56 65] and one on arm-only symptoms[28].

Four studies reported excessive occupational standing to be significantly associated with a higher prevalence of upper extremity symptoms[17 31 32 40], nine studies reported comparable but non statistically significant exposure-outcome associations[22 28 29 34 46 56 57 63 68] while one study found that excessive occupational standing was associated with a lower prevalence of upper extremity symptoms[28]. There were another ten studies in which the association of occupational standing and upper extremity symptoms was assessed, but the outcomes of these associations were not reported[17 27 28 31 35 43 46 50 57 65].

Symptoms in any body area

Eight articles (n=3,114 participants) reported on the association of occupational standing with musculoskeletal symptoms in any body area[17 20 36 41 42 46 51 53]. Three studies reported that excessive occupational standing was significantly associated with a higher prevalence of symptoms. For example, significant associations for excessive standing with symptoms were found for standing more compared to less than 30 minutes/hour (HR with 95%CI) 1.6[1.2 2.3])[17] and for standing more or less than 4 hours/workday (OR with 95% CI) 3.67[1.88 7.17])[51]. One study reported excessive occupational standing to be associated with a reduced prevalence of symptoms compared to rarely standing (OR;

0.56[0.34 0.94])[36]. Two studies reported on non-significant associations of occupational standing and symptoms in any body area[41 53]. Two studies in which the association of occupational standing and lower extremity symptoms was assessed reported no outcomes of these associations [46] [42].

DISCUSSION

Meta-analysis evidence from 16 articles with 54,392 participants suggested a statistically significant association between excessive occupational standing and the occurrence of low-back symptoms with a pooled OR (with 95% CI) of 1.31[1.10 1.56]. The association remained whether the cut-off value for excessive occupational standing was 2 or 4 hours/workday, however due to insufficient data we could not explore other cut-off values (e.g., 6 hours/workday). Therefore, at present we cannot draw conclusions on the dose-response association of excessive standing and low-back symptoms (i.e., how much standing should be considered *excessive*). Also evidence from studies not analysed in the meta-analysis (23 articles with n=27,899 participants) indicated an association of excessive occupational standing with the occurrence of low-back symptoms. Our findings are broadly in line with what has been reported in a (non-systematic) review previously[12]. Further evidence (from high quality, longitudinal studies using objectively measured occupational standing) and data from laboratory studies is needed to help determine the exposure-outcome relationship, understand the mechanisms (e.g., muscle fatigue[69] and postural changes[70 71]), and provide evidence for thresholds of *excessive* standing.

Although we were not able to perform a meta-analysis for the association of occupational standing and lower limb symptoms, the available evidence suggests (although inconclusively) an association between excessive occupational standing and the occurrence

of lower extremity symptoms. These findings are in line with what has been reported before[16 66]. Similar to the associations for occupational standing with low-back symptoms, future epidemiological and laboratory research may help to explain the association between excessive occupational standing and lower extremity symptoms, may provide evidence for thresholds of excessive standing and should be explored to understand the mechanisms (e.g. muscle fatigue[72] and other non-musculoskeletal vascular mechanisms such as swelling[73] due to blood pooling in the lower limbs[69]). Evidence to date does not indicate a significant association of occupational standing and upper limb symptoms (either positive or negative).

Methodological considerations

Substantial evidence on the association of occupational standing with musculoskeletal symptoms was found (with data from n=88,158 participants). However due to the large heterogeneity between studies, data were difficult to synthesise. Sources of heterogeneity included: differences in the definitions of the exposure (i.e., occupational standing) and outcome (i.e., musculoskeletal symptoms); differences in study designs and study samples; and, the methodological quality of the identified studies.

The majority of the articles described studies that were based on cross-sectional designs, and thus inferences in regards to causality – including the direction of the associations - cannot be determined. While the occurrence of musculoskeletal symptoms as a result of exposure to occupational standing is discussed in most of the identified evidence (taking a traditional ergonomics perspective), it could also be possible that participants with symptoms adopt different activity behaviours than participants without symptoms[74], with variation in posture often seen as a strategy for relief from pain[75]. In the subset of studies

that used a longitudinal design a weaker and not statistically significant association was found, reinforcing the need for caution in interpreting the cross-sectional findings.

The vast majority of the studies assessed occupational standing by self-report measures. Objective measures of occupational exposure are preferred[76], and are better able to detect true exposure-outcome associations[77]. Moreover, objective measures (e.g. using posture based monitors) allow for a more detailed assessment of activities (such as standing) that include not just the total amount of activities, but also patterns of activities. For example, a single four-hour period of static standing is likely to have different musculoskeletal consequences than four hours of standing accrued in short (e.g. <20 minute) bouts throughout the workday. There was also substantial variation in the operationalisation of occupational standing (e.g., standing in hours/day, hours/week, minutes/hour or even years of exposure). Similarly, the variation in the definitions of musculoskeletal symptoms were substantial, with variation in period (e.g., symptoms in the last 7 days, last month or last year), operationalisation of the symptoms (e.g., defining the intensity of symptoms or the yes/no presence of symptoms), and body area of symptoms. Harmonizing certain definitions would enhance synthesis of the evidence.

We found stronger associations in studies with high methodological quality compared to those with low methodological quality, supporting the value of high quality studies. It should be noted though that the methodological quality scale did not distinguish cross-sectional from longitudinal studies. One of the issues around methodological quality was the adjustment for confounders (or not). Heterogeneity in adjustments for confounding (i.e., in the variables -if any- used) was too great to allow meta-analysis on associations adjusted for confounders. However, sensitivity analysis showed weaker associations among evidence from studies that adjusted for confounders. This suggests the importance of

considering confounding or mediating variables (including gender, age, other physical or mental work demands and previous musculoskeletal symptoms) that could explain or modify the association of occupational standing with musculoskeletal symptoms. These findings suggest that the current results (that are mainly based on unadjusted associations) should be interpreted with care, and that influencing variables should be considered in future research.

Studies with samples that included various occupations (i.e., a combination of various occupations or random samples of a general working population) had stronger exposure-outcome associations than those that were reported from specific occupational groups (e.g., health care, factory or construction workers), although no significant subgroup differences were observed. These specific occupational groups are likely to have a similar occupational exposure (i.e., either standing a lot, or sitting a lot) and a lack of within-group variation in occupational standing and symptoms may explain the weaker exposure-outcome associations found[78]. The 'healthy-worker-effect', in which workers without symptoms are more likely to remain in physically demanding jobs[79], may also play a role in these findings.

With some level of asymmetry in the funnel plot from studies that were included in the meta-analysis and a number of studies not reporting on (potentially non-significant) associations, publication bias might be present. Current results should therefore be interpreted with caution.

CONCLUSION

This systematic review found evidence for associations between 'excessive' occupational standing and the occurrence of low-back symptoms (pooled OR of 1.31[1.10 1.56]) and

(inconclusively) lower extremity symptoms. The evidence did not support a significant or meaningful association of occupational standing with upper extremity symptoms. More information from high quality, longitudinal studies using objectively measured occupational standing and well-characterised symptom outcomes is needed in order to provide more definitive evidence to inform good work design.

COMPETING INTEREST

There were no conflicts of interest reported by the authors.

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CONTRIBUTORSHIP

PC, LW, SP and JWS conducted literature screening and data extraction of all included papers. LR and DMB conducted the literature search in electronic data bases. All authors (PC, LW, SP, JWS, LR, DMB, CM, GNH, DWD and LMS) analysed the data and reviewed the manuscript for important intellectual content. LMS is guarantor.

Figure 1. Flow chart, depicting the procedure of selecting articles.

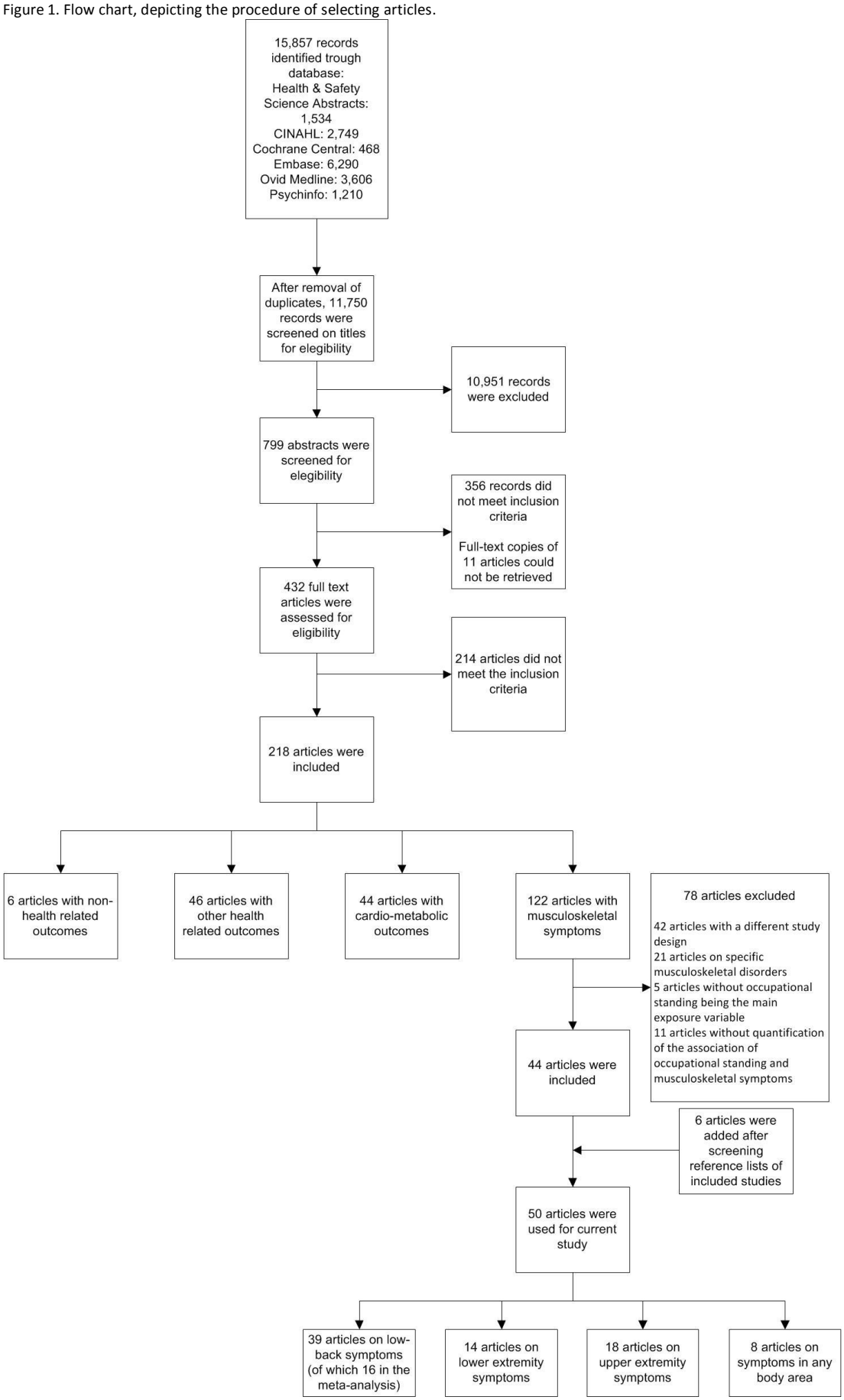
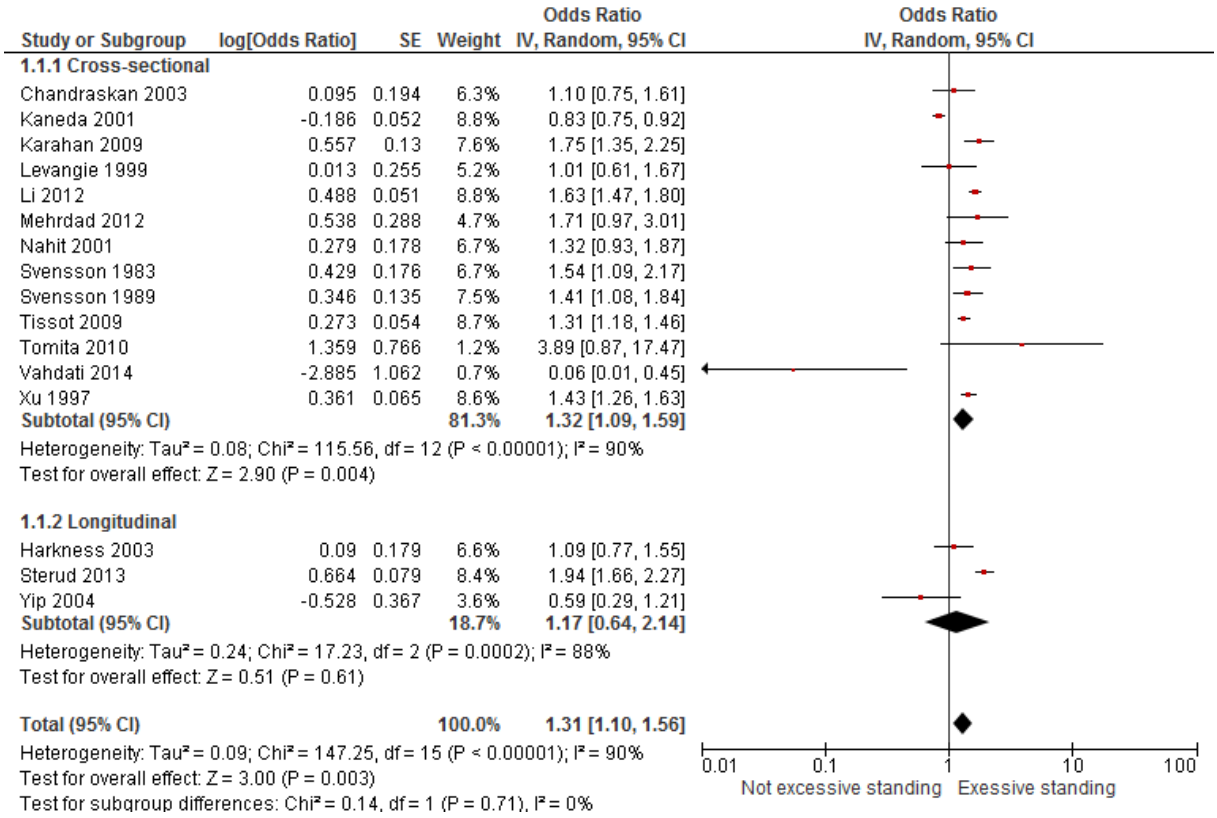


Figure 2. Forest plot of the unadjusted association of occupational standing (not-excessive standing versus excessive standing, adopting a 4 hours/workday cut-off value when possible) with low-back symptoms. Individual study, as well as pooled exposure-outcome, associations are presented. Data from cross-sectional (upper panel) as well as longitudinal (lower panel) study designs are shown. SE = standard error; CI = confidence interval; IV = inverse variance.



Appendix 1. Search strategy in Health & Safety Science Abstracts (ProQuest)

#	Search	Results
1	(((TI,AB,SU(Standing) AND TI,AB,SU(work* OR job* OR occupation* OR employee* OR staff* OR personnel OR ergonomic*)) OR (TI,AB,SU(posture* OR postural) AND TI,AB,SU(work* OR job* OR occupation* OR employee* OR staff* OR personnel OR ergonomic*)) OR (TI,AB,SU(stood OR stand) NEAR/3 TI,AB,SU(work* OR job* OR occupation* OR employee* OR staff* OR personnel OR ergonomic*)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(prolonged)) OR (TI,AB,SU(upright OR posture* OR stance) NEAR/3 TI,AB,SU(prolonged)) OR (TI,AB,SU(standing OR stand OR posture* OR stance) NEAR/2 TI,AB,SU(continuous)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(period*1)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/2 TI,AB,SU(time*1 OR duration)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(hour*1)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(day)))	
2	TI,AB,SU(trial OR trials OR study OR studies))	
3	1 and 2	
4	(((TI,AB,SU(Standing) AND TI,AB,SU(work* OR job* OR occupation* OR employee* OR staff* OR personnel OR ergonomic*)) OR (TI,AB,SU(posture* OR postural) AND TI,AB,SU(work* OR job* OR occupation* OR employee* OR staff* OR personnel OR ergonomic*)) OR (TI,AB,SU(stood OR stand) NEAR/3 TI,AB,SU(work* OR job* OR occupation* OR employee* OR staff* OR personnel OR ergonomic*)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(prolonged)) OR (TI,AB,SU(upright OR posture* OR stance) NEAR/3 TI,AB,SU(prolonged)) OR (TI,AB,SU(standing OR stand OR posture* OR stance) NEAR/2 TI,AB,SU(continuous)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(period*1)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/2 TI,AB,SU(time*1 OR duration)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(hour*1)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(day)))	
5	(TI,AB(random* OR quasirandom* OR placebo) OR TI,AB(single-blind OR double-blind OR triple-blind OR treble-blind)))	
6	4 and 5	
7	3 or 6	468

Appendix 2. Search strategy in CINAHL Plus (EBSCO)

#	Search	Results
34	S28 AND S32 LIMIT: English Language	2,746
33	S28 AND S32	2,970
32	S29 OR S30 OR S31	1,142,504
31	(TI (study or studies)) OR (AB (study or studies))	786,316
30	(MH "Prospective Studies+") OR (MH "Case Control Studies+") OR (MH "Correlational Studies") OR (MH "Cross Sectional Studies") OR (MH "Double-Blind Studies") OR (MH "Panel Studies+") OR (MH "Single-Blind Studies") OR (MH "Triple-Blind Studies") OR (MH "Quasi-Experimental Studies+") OR (MH "Multicenter Studies") OR (MH "Qualitative Studies+") OR (MH "Multimethod Studies") OR (MH "Field Studies")	519,587
29	(MH "Clinical Trials+") OR (MH "Quantitative Studies") OR PT Clinical Trial OR TI (clinical trial*) OR AB (clinical trial*) OR TI random* or AB random*	281,256
28	S8 OR S10 OR S18 OR S27	6,128
27	S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26	406
26	((stood or stand or standing) N3 (period or periods)	68
25	(standing N2 (day or time or duration))	183
24	((stood or stand or standing) N4 (hour or hours))	42
23	((longterm or long-term or sustained) N0 standing)	2
22	(prolonged N2 (upright or posture))	29
21	(prolonged N0 (orthosta* or stance))	7
20	(continuous* N1 (stand or standing or posture*))	14
19	(prolonged N4 (stand or standing))	99
18	S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17	771
17	((occupation* or profession* or job* or employee* or staff* or personnel) N3 (posture* or postural*))	83
16	((profession or professions) N2 standing)	7
15	(work* N1 stand)	36
14	(work* N3 stood)	2
13	(work* N7 posture*)	453
12	((work* or job* or occupation*) N2 upright)	3
11	((work* or job* or occupation*) N6 standing)	244
10	S7 AND S9	1,888
9	TI standing or AB standing	8,598
8	S1 AND S7	3,976
7	S2 OR S3 OR S4 OR S5 OR S6	981,422
6	(MH "Ergonomics") OR (MH "Task Performance and Analysis")	13,274
5	(MH "Absenteeism") OR (MH "Sick Leave") OR (MH "Retirement") OR (MH "Job Satisfaction") OR (MH "Job Performance")	28,005
4	(MH "Work") OR (MH "Work Environment") OR (MH "Work Capacity Evaluation") OR (MH "Work Experiences") OR (MH "Workload Measurement") OR (MH "Workload") OR (MH "Shiftwork") OR (MH "Women, Working+") OR (MH "Workforce") OR (MH "Shift Workers")	46,833
3	(MH "Occupations and Professions") OR (MH "Health Occupations+") OR (MH "Named Groups by Occupation+") OR (MH "Employment") OR (MH "Employment of Women") OR (MH "Employment of Older Workers") OR (MH "Employment Status") OR (MH "Part Time Employment")	914,979
2	(MH "Occupational Diseases") OR (MH "Occupational-Related Injuries") OR (MH "Occupational Exposure") OR (MH "Accidents, Occupational") OR (MH "Occupational Hazards") OR (MH "Occupational Health") OR (MH "Occupational Health Services") OR (MH "Occupational Medicine") OR (MH "Occupational Safety") OR (MH "Occupational Science")	53,568
1	(MH "Standing+") OR (MH "Posture") OR (MH "Balance, Postural")	18,531

Appendix 3. Search strategy in EBM Reviews - Cochrane Central Register of Controlled Trials

#	Search	Results
1	postural balance/ or posture/	3,766
2	occupational diseases/ or occupational exposure/ or occupational health/ or occupational medicine/ or Occupational Injuries/ or Occupational Health Services/ or Accidents, Occupational/	1,473
3	Health Occupations/ or Occupations/ or exp occupational groups/ or exp Employment/	6,697
4	work/ or work schedule tolerance/ or workload/ or workplace/ or Women, Working/ or Work Capacity Evaluation/ or Work Simplification/	1,062
5	Absenteeism/ or Sick Leave/ or Retirement/ or Job Satisfaction/	818
6	Human Engineering/ or ergonomic*.tw.	513
7	2 or 3 or 4 or 5 or 6	8,967
8	1 and 7	150
9	standing.ti. or standing.ab. /freq=2	1,286
10	7 and 9	36
11	((standing adj4 (posture* or position)) and (work* or job* or occupation* or employee* or staff* or ergonomic* or personnel)).mp.	50
12	((work* or job* or occupation*) adj7 standing).tw.	58
13	((work* or job* or occupation*) adj3 upright).tw.	8
14	(work* adj8 posture*).tw.	90
15	(work* adj4 stood).tw.	0
16	(work* adj2 stand).tw.	13
17	(profession*1 adj3 standing).tw.	7
18	((occupation* or profession* or job* or employee* or staff* or personnel) adj4 (posture* or postural*)).tw.	19
19	12 or 13 or 14 or 15 or 16 or 17 or 18	169
20	(prolonged adj5 (stand or standing)).tw.	28
21	(continuous* adj2 (stand or standing or posture*)).tw.	8
22	(prolonged adj (orthosta* or stance)).tw.	3
23	(prolonged adj3 (upright or posture)).tw.	7
24	((longterm or long-term or sustained) adj standing).tw.	0
25	((stood or stand or standing) adj5 hour*1).tw.	85
26	(standing adj2 (day or time or duration)).tw.	97
27	((stood or stand or standing) adj4 period*1).tw.	75
28	20 or 21 or 22 or 23 or 24 or 25 or 26 or 27	287
29	8 or 10 or 11 or 19 or 28	581
30	limit 29 to english language	468

Appendix 4, search strategy in Embase (Ovid)

#	Search	Results
1	body posture/ or standing/	63,339
2	occupational disease/ or occupational health/ or occupational exposure/ or occupational hazard/ or occupational health service/ or occupational safety/ or occupational accident/ or occupational medicine/ or industrial medicine/	190,792
3	occupation/ or medical profession/ or nursing as a profession/ or paramedical profession/ or exp named groups by occupation/ or exp employment/	1,327,430
4	work/ or work schedule/ or working time/ or workload/ or work capacity/ or work environment/ or work experience/ or workplace/	113,731
5	absenteeism/ or job satisfaction/ or medical leave/ or retirement/	48,686
6	ergonomics/	8,684
7	2 or 3 or 4 or 5 or 6	1,534,465
8	1 and 7	7,055
9	standing.ti. or standing.ab. /freq=2	16,406
10	7 and 9	1,458
11	((standing adj4 (posture* or position)) and (work* or job* or occupation* or employee* or staff* or ergonomic* or personnel)).mp.	692
12	((work* or job* or occupation*) adj7 standing).tw.	1,069
13	((work* or job* or occupation*) adj3 upright).tw.	37
14	(work* adj8 posture*).tw.	1,752
15	(work* adj4 stood).tw.	22
16	(work* adj2 stand).tw.	97
17	(profession*1 adj3 standing).tw.	28
18	((occupation* or profession* or job* or employee* or staff* or personnel) adj4 (posture* or postural*)).tw.	249
19	12 or 13 or 14 or 15 or 16 or 17 or 18	2,942
20	(prolonged adj5 (stand or standing)).tw.	438
21	(continuous* adj2 (stand or standing or posture*)).tw.	92
22	(prolonged adj (orthosta* or stance)).tw.	65
23	(prolonged adj3 (upright or posture)).tw.	129
24	((longterm or long-term or sustained) adj standing).tw.	27
25	((stood or stand or standing) adj5 hour*1).tw.	389
26	(standing adj2 (day or time or duration)).tw.	1,018
27	((stood or stand or standing) adj4 period*1).tw.	477
28	20 or 21 or 22 or 23 or 24 or 25 or 26 or 27	2,431
29	8 or 10 or 11 or 19 or 28	12,029
30	limit 29 to (clinical trial or randomized controlled trial or controlled clinical trial or multicenter study)	552
31	(random* or quasirandom* or trial or trials or placebo).tw. or clinical trial*.mp.	2,003,888
32	cohort analysis/ or case control study/ or longitudinal study/ or prospective study/ or retrospective study/	896,544
33	observational study/ or quasi experimental study/ or clinical study/ or intervention study/ or prevention study/	199,113
34	crossover procedure/ or controlled study/ or randomization/	4,565,179
35	((single or double or triple or treble) adj (blind* or mask*)).tw.	170,885
36	(study or studies).tw.	805,8649
37	31 or 32 or 33 or 34 or 35 or 36	1,103,7922
38	29 and 37	7,344
39	30 or 38	7,344
40	exp animal/ not human.sh.	4,480,661
41	39 not 40	6,923
42	limit 41 to english language	6,290

Appendix 5. Search strategy in Ovid MEDLINE.

#	Search	Results
1	postural balance/ or posture/	66,510
2	occupational diseases/ or occupational exposure/ or occupational health/ or occupational medicine/ or Occupational Injuries/ or Occupational Health Services/ or Accidents, Occupational/	164,970
3	Health Occupations/ or Occupations/ or exp occupational groups/ or exp Employment/	500,223
4	work/ or work schedule tolerance/ or workload/ or workplace/ or Women, Working/ or Work Capacity Evaluation/ or Work Simplification/	50,324
5	Absenteeism/ or Sick Leave/ or Retirement/ or Job Satisfaction/	37,021
6	Human Engineering/ or ergonomic*.tw.	12,042
7	2 or 3 or 4 or 5 or 6	675,628
8	1 and 7	3,706
9	standing.ti. or standing.ab. /freq=2	12,325
10	7 and 9	579
11	((standing adj4 (posture* or position)) and (work* or job* or occupation* or employee* or staff* or ergonomic* or personnel)).mp.	435
12	((work* or job* or occupation*) adj7 standing).tw.	734
13	((work* or job* or occupation*) adj3 upright).tw.	30
14	(work* adj8 posture*).tw.	1,239
15	(work* adj4 stood).tw.	16
16	(work* adj2 stand).tw.	71
17	(profession*1 adj3 standing).tw.	17
18	((occupation* or profession* or job* or employee* or staff* or personnel) adj4 (posture* or postural*)).tw.	173
19	12 or 13 or 14 or 15 or 16 or 17 or 18	2,058
20	(prolonged adj5 (stand or standing)).tw.	291
21	(continuous* adj2 (stand or standing or posture*)).tw.	67
22	(prolonged adj (orthosta* or stance)).tw.	51
23	(prolonged adj3 (upright or posture)).tw.	104
24	((longterm or long-term or sustained) adj standing).tw.	18
25	((stood or stand or standing) adj5 hour*1).tw.	280
26	(standing adj2 (day or time or duration)).tw.	739
27	((stood or stand or standing) adj4 period*1).tw.	346
28	20 or 21 or 22 or 23 or 24 or 25 or 26 or 27	1,749
29	8 or 10 or 11 or 19 or 28	7,017
30	(controlled clinical trial or randomized controlled trial).pt.	467,024
31	(random* or quasirandom* or trial or trials or placebo).tw. or clinical trial*.mp.	1,395,354
32	case-control studies/ or retrospective studies/ or cohort studies/ or longitudinal studies/ or follow-up studies/ or prospective studies/ or cross-sectional studies/ or epidemiologic studies/ or intervention studies/	1,693,552
33	control groups/ or cross-over studies/ or double-blind method/ or random allocation/ or single-blind method/	239,123
34	((case-control or cross-sectional or cohort* or (follow-up or followup or observational or longitudinal or prospective or retrospective or epidemiologic* or intervention* or incidence or prevalence)) adj (study or studies)).tw.	566,533
35	((single or double or triple or treble) adj (blind* or mask*)).tw.	124,949
36	case reports/ or comparative study/ or evaluation studies/ or multicenter study/ or twin study/ or validation studies/	3,709,309
37	(comparative study or evaluation studies or multicenter study or observational study or validation studies).pt.	2,021,391
38	(study or studies).tw.	5,922,027
39	30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38	9,419,258
40	29 and 39	4,408
41	exp animals/ not humans.sh.	3,982,927
42	40 not 41	4,103
43	limit 42 to english language	3,606

Appendix 6. Search strategy in PsycINFO. (Ovid)

#	Searches	Results
1	posture/	4,286
2	occupational exposure/ or occupational health/ or occupational safety/ or work related illnesses/ or industrial accidents/	5,846
3	exp personnel/ or occupations/ or working women/ or exp employment status/	344,148
4	working conditions/ or work scheduling/ or work load/ or workday shifts/ or working space/ or job characteristics/ or work rest cycles/	26,709
5	job satisfaction/ or job performance/ or employee productivity/ or employee characteristics/ or productivity/ or employee efficiency/ or Employee Absenteeism/	36,744
6	Human Factors Engineering/ or ergonomic*.tw.	7,220
7	2 or 3 or 4 or 5 or 6	382,120
8	1 and 7	441
9	standing.ti. or standing.ab. /freq=2	2,209
10	7 and 9	198
11	((standing adj4 (posture* or position)) and (work* or job* or occupation* or employee* or staff* or ergonomic* or personnel)).mp.	89
12	((work* or job* or occupation*) adj7 standing).tw.	412
13	((work* or job* or occupation*) adj3 upright).tw.	3
14	(work* adj8 posture*).tw.	379
15	(work* adj4 stood).tw.	9
16	(work* adj2 stand).tw.	53
17	(profession*1 adj3 standing).tw.	12
18	((occupation* or profession* or job* or employee* or staff* or personnel) adj4 (posture* or postural*)).tw.	61
19	12 or 13 or 14 or 15 or 16 or 17 or 18	885
20	(prolonged adj5 (stand or standing)).tw.	41
21	(continuous* adj2 (stand or standing or posture*)).tw.	12
22	(prolonged adj (orthosta* or stance)).tw.	5
23	(prolonged adj3 (upright or posture)).tw.	15
24	((longterm or long -term or sustained) adj standing).tw.	4
25	((stood or stand or standing) adj5 hour*1).tw.	33
26	(standing adj2 (day or time or duration)).tw.	189
27	((stood or stand or standing) adj4 period*1).tw.	56
28	20 or 21 or 22 or 23 or 24 or 25 or 26 or 27	334
29	8 or 10 or 11 or 19 or 28	1,659
30	clinical trials/ or cohort analysis/ or followup studies/ or longitudinal studies/ or retrospective studies/ or prospective studies/ or experimentation/ or interdisciplinary research/ or qualitative research/ or quantitative methods/ or causal analysis/ or exp experimental methods/ or exp experimental design/	118,841
31	random sampling/ or experiment controls/	1,406
32	(random* or quasirandom* or trial or trials or placebo).tw. or clinical trial*.mp.	240,824
33	((single or double or triple or treble) adj (blind* or mask*)).tw.	20,454
34	(study or studies).tw.	1,442,328
35	30 or 31 or 32 or 33 or 34	1,608,930
36	29 and 35	923
37	limit 29 to ("0200 clinical case study" or "0400 empirical study" or "0430 followup study" or "0450 longitudinal study" or "0451 prospective study" or "0453 retrospective study" or "0600 field study" or 1400 nonclinical case study or 1600 qualitative study or 1800 quantitative study or 2200 twin study)	1,080
38	36 or 37	1,245
39	limit 38 to english language	1,210

Appendix 7. Methodological quality scale

	Criteria	**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**
1.	Question / objective sufficiently described?				
2.	Study design evident and appropriate?				
3.	Method of subject/comparison group selection *or* source of information/input variables described and appropriate?				
4.	Subject (and comparison group, if applicable) characteristics sufficiently described?				
5.	Outcome and (if applicable) exposure measure(s) well defined and robust to measurement / misclassification bias? Means of assessment reported?				
6.	Sample size appropriate?				
7.	Analytic methods described/justified and appropriate?				
8.	Some estimate of variance is reported for the main results?				
9.	Controlled for confounding?				
10.	Results reported in sufficient detail?				
11.	Conclusions supported by the results?				
	Summary score				

Note, N/A is not a response option for items for items 1, 2, 4m 10 and 11. The summary score was calculated as: total sum[(number of 'yes' × 2) + (number of 'partial' × 1)]/total possible sum[22 − (number of 'N/A' × 2)], with a maximum possible total score of 1.

Appendix 8. Methodological quality scores of included studies.

	First author (Year)	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Sum score
1	Abd Rahman (2010)	2	2	1	0	0	0	0	0	0	0	0	0.23
2	Andersen (2007)	2	2	2	1	2	2	2	2	2	2	0	0.86
3	Babiolakis (2015)	2	2	2	2	2	1	2	2	0	1	2	0.82
4	Barghout (2011)	2	2	2	2	1	2	1	0	0	1	2	0.68
5	Bejia (2005)	2	2	2	2	1	2	2	1	0	2	2	0.82
6	Bener (2013)	2	2	1	2	1	2	2	2	1	1	1	0.77
7	Bener (2004)	2	2	1	2	1	2	2	2	1	2	1	0.82
8	Bergquist-Ullman (1977)	2	2	2	2	1	1	2	0	0	1	1	0.64
9	Bos (2007)	2	2	2	2	2	2	2	2	2	1	1	0.91
10	Chandraskan (2003)	2	2	2	2	1	2	2	2	2	2	1	0.91
11	da Silva(2006)	2	2	2	2	2	2	2	2	2	1	0	0.86
12	Duquette (1997)	2	1	2	1	1	1	1	0	0	1	1	0.50
13	Engels (1996)	2	2	2	2	2	2	2	2	2	2	1	0.95
14	Hallman (2014)	2	2	2	2	2	2	2	2	0	2	2	0.91
15	Harkness (2003)	2	2	2	2	2	2	2	2	2	2	1	0.95
16	Hill (2009)	2	2	2	2	1	0	2	2	1	2	1	0.77
17	Hou (2006)	2	2	2	2	1	2	2	2	2	2	2	0.95
18	Jellad (2013)	2	2	1	2	1	2	1	0	0	1	2	0.64
19	Jones (2007)	2	2	2	1	2	2	2	2	2	2	1	0.91
20	Kaneda (2001)	1	2	2	2	0	2	1	2	0	2	1	0.68
21	Karahan (2009)	2	2	2	2	2	2	2	2	2	1	2	0.95
22	Kulcu (2010)	2	2	2	2	2	2	1	0	0	1	2	0.73
23	Lehto (1991)	2	2	2	1	1	1	1	1	2	1	1	0.68
24	Leino (1999)	2	2	2	1	1	1	0	0	0	2	0	0.50
25	Leroux (2005)	2	2	2	2	2	2	2	2	2	1	2	0.95
26	Levangie (1999)	2	2	2	1	1	1	2	2	1	2	0	0.73
27	Li (2012)	2	2	1	2	1	2	2	2	2	2	2	0.91
28	Mehrdad (2012)	2	2	2	2	1	1	2	2	2	1	2	0.86
29	Messing (2001)	2	2	0	2	2	1	0	0	0	2	1	0.55
30	Messing (2008)	2	2	2	2	2	2	2	1	2	2	2	0.95
31	Mohseni-Banpei (2011)	2	2	2	1	1	1	1	1	1	1	2	0.68
32	Nahit (2001)	2	2	2	2	2	2	1	2	2	2	1	0.91
33	Phajan (2014)	2	2	2	2	1	2	2	2	2	2	0	0.86
34	Pope (2003)	2	2	2	2	2	2	2	2	2	2	0	0.91
35	Rodigari (2012)	2	2	1	2	1	1	2	2	2	1	2	0.82
36	Samad (2010)	2	2	2	2	1	1	1	2	0	1	1	0.68
37	Sanya (2005)	2	2	1	2	0	2	1	1	0	1	1	0.59
38	Schierhout (1995)	2	2	2	2	1	2	2	2	2	2	0	0.86
40	Smith (2002)	2	2	2	2	2	1	2	2	2	1	0	0.82
41	Sterud (2013)	2	2	2	2	2	2	2	2	2	2	2	1.00
42	Svensson (1989)	2	2	2	2	1	0	1	1	0	1	2	0.64
43	Svensson (1983)	2	2	2	2	1	1	1	1	0	1	1	0.64
44	Tissot (2009)	2	2	2	2	2	2	1	1	0	1	2	0.77
45	Tomita (2010)	2	2	2	2	1	1	2	2	1	2	1	0.82
46	Trinkoff (2003)	2	2	2	1	2	2	2	2	1	1	0	0.77
39	Vahdati (2014)	2	2	2	2	1	2	2	0	0	1	2	0.73
47	Xiao (2013)	2	2	2	2	2	2	2	2	2	2	2	1.00
48	Xu (1997)	2	2	2	1	2	2	2	1	2	1	1	0.82
49	Yip (2004)	2	2	2	2	1	1	1	1	0	1	0	0.59
50	Yue (2012)	2	2	2	2	2	2	2	2	2	2	1	0.95

Appendix 9. Data extraction table of included studies.

First author (Year)	**Study name**	**Study design (and potentially follow-up period)**	**Sample description (n, % Female, Age, Country, occupation, relevant inclusion/exclusion criteria)**	**Confounders**	**Exposure**	**Health Outcome (**baseline prevalence and if applicable incidence during follow-up**)**	**Exposure parameters**	**Exposure-outcome estimates**	**Quality**
Abd Rahman (2010) [20]	-	Case-control	n=12 Female: – Age: - Country: Malaysia Occupation: Car tyre service workers	-	Self-reported prolonged occupational standing (yes/no)	Self-reported musculoskeletal symptoms (pain, discomfort and injuries) in any body part (no mentioning of period) <u>Prevalence:</u> • Hand/wrist 91.7% • Shoulder 83.3% • Low-back 30% • Elbow/forearm 75% • Neck 66.7% • Lower leg 75% • Knee 58.3% • Ankle/foot 33.3% • Hip/thigh 16.7%		66.7% prolonged standing source of injury/uncomfortable	0.23
Andersen (2007) [17]	-	Prospective (24 month follow-up)	n=1498 Female: – Age: - Country: Denmark Occupation: Mixed occupations (i.e., administrative, skilled, unskilled, nurses, nurse assistant, kitchen, cleaning and technical) Exclusion: No severe pain in any region at baseline	1. Partially adjusted model: sex, age, occupational group 2. Fully adjusted model: for all other factors (physical and mental work demands)	Self-reported occupational standing (duration)	Self-reported pain in the last 12 months in: • Neck/shoulder • Elbow/forearm/hand • Low-back, • Hip/knee/foot • Any area 7 categories (not at all to very much), with the most severe categories used to operationalise outcome variable. <u>Prevalence</u>: 0% <u>Follow-up incidence:</u> • Neck/shoulder: 11.5% • Elbow/forearm/hand: 6.4% • Low-back: 10.6% • Hip/knee/foot: 9.3%	• Not standing >30 mins/hr (n=1384) • Standing >30 mins/hr (n=114)	Reference Neck/shoulder: HR: 1.8 [1.2 2.9][1] Elbow/forearm: HR: 2.0 [1.1 3.7][1] Low-back HR: 2.1 [1.3 3.3][1] HR: 1.9 [1.2 3.0][2] Hip/knee/foot HR: 1.7 [1.0 2.9][1] Any region: HR: 1.7 [1.1 2.3][1] HR: 1.6 [1.2 2.3] [2]	0.86

						• Any region: 23.6%			
Babiolakis (2015) [21]	-	Cross-sectional	n=27 Female – 100% Age: 44.1 (14.7) years (recently injured); 44.9 (14.3) years (not recently injured) Country: Canada Occupation: Nurses	-	Objectively assessed (through accelerometer-inclinometer) occupational standing (total duration and bout duration)	Self-reported recently injured low-back pain <u>Prevalence</u> • Recently injured: low-back pain in last 12 months: 29.6% (n=8) • Not recently injured low-back pain (>12 months ago or not at all): 70.4% (n=19)		<u>Standing time</u> Recently injured: 208.9 (111.0) minutes Not recently injured: 317.8 (114.0) minutes. Significant between group difference p=0.033 <u>Standing bout</u> Recently injured: 19.3 (18.6) minutes) Not recently injured: 60.2 (71.3) minutes. Significant between group difference p=0.035	0.82
Barghout (2011) [22]	-	Cross-sectional	n=200 Female: 43% Age: 40.6 years (males); 40.1 years (females) Country: Jordan Occupation: Dentists	-	Self-reported occupational standing (yes/no)	Self-reported musculoskeletal symptoms in: • Back • Neck • Shoulder • Hand/wrist <u>Prevalence</u>: • Back (56%) • Neck (47%) • Shoulder (39%) • Hand/wrist (26%).	Standing only (n=10)	• Hand/wrist pain n=6 (60%) • Neck pain n=5 (50%) • Shoulder pain n=5 (50%) • Back pain n=5 (50%)	0.68
Bejia (2005) [23]	-	Cross-sectional	n=350 Female: 49% Age: 37.0 (7.8) years Country: Tunisia Occupation: Hospital workers	-	Self-reported occupational standing (no details provided)	Self-reported common low-back pain (acute and chronic low-back pain) during the last 12 months. <u>Prevalence</u>: 50%	Standing n=174 (50%)	• Low-back pain (n=176; 49.4%) • No low-back pain (n=174; 50%)	0.82
Bener (2013)	-	Cross-sectional	n=1290	1. Univariate	Self-reported	Self-reported low-back pain		Low-back pain	0.77

[25]			Female: 41.7% Age: • <35 years (n=313) • 35-44 years (n=483) • 45-54 years (n=805) • ≥55 years (n=579) Country: Qatar Occupation: People visiting 12 health centres; mixed occupations – not working, sedentary and professional, clerk, business, army/police	2. Multivariate model: factors not described	prolonged standing (not clear whether it is just about occupational standing)	>1 day in the last 6 months. <u>Prevalence</u>: 59.2%		exacerbated by prolonged standing: Males 221/595 (41.2%)[1] Females 182/695 (29.5%)[1] Multivariable analysis[2] – no significant contribution	
Bener (2004) [24]	-	Cross-sectional	n=1103 Females: 46.9% Age: 34.9 (13.4) (males) years; 33.5 (11.8) (females) years Country: UAE Occupation: People visiting health centres. Mixed occupations (i.e., sedentary, manual work, professional, student, housewife)	1. Multivariate model: BMI, weakness in leg, heavy lifting, regular exercise, smoking	Self-reported prolonged standing (not clear whether it is just about occupational standing)	Self-reported low-back pain (>1 day in last 6 months) <u>Prevalence</u>: 64.6% [60.7 68.5]	• Not prolonged standing • Prolonged standing	Low-back pain exacerbated by prolonged standing: Males 136/333 (50.8%) Females 272/380 (71.6%) Reference RR:6.22 [4.01 9.67][1]	0.82
Bergquist-Ullman (1977) [26]	-	Cross-sectional	n=217 Females: 13% Age: 34.5 (median)	-	Self-reported occupational standing • ≥4hrs/day • 2-4 hrs/day	Self-reported low-back pain (acute or subacute pain, duration <3 months with a pain free year before the onset of the current	• Standing ≥4hrs/day • Standing 2-4 hrs/day	135 workers 39 workers	0.64

			years Country: Sweden Occupation: Manual and office workers from automotive workshop		• <2 hrs/day	episode) <u>Prevalence</u>: 100%	• Standing <2 hrs/day	43 workers	
Bos (2007) [27]	-	Cross-sectional	n=3169 Females: 82% Age: 38(10) years Country: the Netherlands Occupation: Nurses and x-ray technicians	1. Univariate 2. Multivariate model: physical and psychosocial risk factors, gender, age body mass, height, duration of employment, working hours/ week and managerial function.	Self-reported occupational standing (standing often at work)	Self-reported low-back or neck/shoulder pain in last 12 months) <u>Prevalence</u>: • Low-back pain: 75.9% • Neck/shoulder pain: 59.8%	• No standing often • Standing often	Reference Low-back pain: Non-specialised nurses (n=1977) OR:1.33 [0.95 1.86][2] Operation room nurses (n=381) OR:1.09 [0.49 2.38][2]	0.91
Chandraskan (2003) [28]	-	Cross-sectional	n=529 Females: 100% Age: 31.2 (7.4) years Country: Malaysian Occupation: Factory workers	1. Univariate 2. Multivariate model: work factors and body site	Self-reported occupational standing (duration) with options: • No standing • <2 hrs/day • 2-4 hrs/day • ≥4 hrs/day	Self-reported pain in the last 12 months (Nordic questionnaire): • Neck • Shoulder • Arm • Wrist/fingers • Upper leg • Lower leg • Back <u>Prevalence</u>: • Neck 29.7% • Shoulder 44.8% • Arm 29.1% • Wrist/fingers 22.1% • Lower leg 48.4% • Upper leg 38.8% • Back 57.8%	• Standing ≤4 hrs/day. • Standing >4 hrs/day.	Reference Neck OR: 0.8 [0.5 1.1][1] Shoulder OR: 0.9 [0.6 1.3][1] Arm OR: 1.0 [0.7 1.4][1] Wrist/fingers OR: 1.2 [0.8 1.9][1] Back OR: 1.1 [0.7 1.5][1] Lower leg OR: 4.8 [3.3 7.1][1] OR: 3.3 [2.1 5.3][2]	0.91

								Upper leg OR: 3.1 [2.1 4.5][1] OR: 1.8 [1 .1 2.9][2]	
da Silva (2006) [29]	-	Case-control	n=881 Females: 37% Age: 38 years Country: Brazil Occupation: Rag-pickers and matched controls	1. Multivariate model: all other physical work demands and demographic variables (i.e., age gender, education and marital status)	Self-reported occupational standing (duration) on 4 point scale – reduced to 2 categories: • Never/rarely • Generally/always	Self-reported pain in neck, shoulder, elbow, wrist/hands, low-back, thighs, lower leg, knees, ankles (Nordic) in the past 12 months. Pain locations were combined into: • Low-back • Lower extremity • Upper extremity. <u>Prevalence:</u> • Low-back: 49.2% (rag-pickers); 49.1% (non-rag-pickers) • Upper extremity: 35% (rag-pickers); 36.8% (non-rag-pickers)	• Never/rarely standing • Generally/always standing	Reference Low-back PR: 1.0 [0.8 1.2][1] Lower extremity PR: 1.1 [0.9 1.4][1] Upper extremity PR: 1.2 [0.9 1.6][1]	0.86
Duquette (1997) [30]	-	Cross-sectional	n=176 Females: - Age: 36.9 (10.4) years Country: Canada Occupation: Assembly workers	-	Self-reported occupational standing (for long time; work mainly requiring standing)	Self-reported back discomfort in the previous week <u>Prevalence</u>: 44.9%	• Not standing for a long time • Standing for a long time • Work not requiring mainly standing • Work requiring mainly standing	Reference OR: 2.9 (significant) Reference OR: 1.7 (not significant)	0.50
Engels (1996) [31]	-	Case–control	n=846 Females: 89.8% Age: 29.0 (8.0) years Country: the Netherlands Occupation: Nurses	1. Partially adjusted model: age, sex, employment duration, working hours, having managerial tasks 2. Fully adjusted model: as above plus all	Self-reported work hampered by standing	Self-reported complaints (Validated Dutch questionnaire, no mentioning of period) in: • Back • Arms and neck • Legs <u>Prevalence</u> • Back: 35.9% • Arm or neck: 30.4% • Leg: 15.7%	• Work not hampered by standing • Work hampered by standing	Reference Back: OR:3.07 [1.88 5.01][1] Arm and neck OR:2.75 [1.60 4.72][1] Leg OR:4.90 [2.84 8.47][1] OR:2.49 [1.17 5.24][2]	0.95

				work related factors and significant factors from univariate analysis					
Hallman (2014) [32]	-	Case-control	n=56 Females: 45% Age: cases 41 (10) years; controls 41 (9) years Country: Sweden Occupation: Office and production workers	-	Objectively measured over 7 days (using activPAL™ inclinometer) time spent standing, occupational and leisure time.	Self-reported non-traumatic chronic pain (>6 months), localized to the neck/shoulder region (i.e., primary the neck and/or trapezius muscles) <u>Prevalence</u>: 52% (29 cases, 27 controls)		Neck/shoulder pain group spent more time standing (16.4 (8.0) min/hr at work and 14.3 (5.1) min/hr in leisure time) than controls (12.2 (8.8) min/hr at work and 11.6 (5.0) min/hr) Between group difference: p=0.037	0.91
Harkness (2003) [33]	-	Prospective cohort with 12 and 24 months follow-up.	n=1048 (620 participants without pain at baseline and 428 participants without pain after 12 months; numbers overlap) Females: 36% Age: 23 (median) years Country: USA Occupation: Newly employed workers from 12 diverse occupational groups	1. Partially adjusted model: age, gender, occupational group; 2. Fully adjusted model: as above and all other postures	Self-reported duration of occupational standing, classified into: • No standing • <15 mins/day • 15 mins-<2 hrs/day • ≥2 hrs/day	Self-reported low-back pain lasting 24 hours or longer in the past month. Low-back pain was assessed at baseline and during the 12 and 24 month follow-up. <u>Prevalence</u>: 0%	• No standing (n=76 no pain, n=18 pain) • Standing <15 mins/day (n=275 no pain, n=53 pain) • Standing 15 mins- <2 hrs/day (n=254 no pain, n=69 pain) • Standing >2 hrs/day (n=234 no pain, n=58 pain)	Reference OR: 1.1 [0.6 2.1][1] OR: 1.0 [0.5 1.9][2] OR: 1.6 [0.8 2.9][1] OR: 1.4 [0.7 2.7][2] OR: 1.8 [0.9 3.4][1] OR: 1.5 [0.8 3.0][2]	0.95
Hill (2009) [34]	-	Cross-sectional	n=26 Females: 100% Age: 36.9 (8.68)	1. Univariate 2. Multivariate model: physical size, job strain,	Self-reported duration of occupational standing	Self-reported musculoskeletal symptoms during last 12 months (Nordic Musculoskeletal Questionnaire) in:	Time spent standing	Shoulder OR:1.20 [0.49 2.96][1] OR:1.01 [0.27 3.71][2] Low-back	0.77

			years Country: USA Occupation: Sonographers	time, abdominal girth, workplace variability and moving during study.		• Neck • Shoulders • Wrists/hands • Low-back <u>Prevalence</u>: • Shoulder 73% • Low-back 69% • Wrist/hand 54% • Neck 50%		OR:1.70 [0.66 4.40][1] OR:2.96 [0.73 12.1][2] Wrist/hand OR:0.95 [0.43 2.08][1] OR:0.96 [0.40 2.34][2] Neck OR:1.19 [0.54 2.65][1] OR:2.07 [0.53 8.10][2]	
Hou (2006) [35]	-	Cross-sectional	n=3950 Females: 100% Age: majority between 25 and 34 years Country: Taiwan Occupation: Nurses	1. Multivariate model: age, tenure and weekly work hours.	Self-reported occupational standing (duration)	Self-reported musculoskeletal complaints since starting current job (Chinese version Nordic Questionnaire) in • Neck • Shoulder • Low-back • Lower leg <u>Prevalence</u>: • Neck 12.2% • Shoulders 17.1% • Low-back 32.9% • Lower legs 22.3%	• Standing <4 hrs/day • Standing 4-6 hrs/day • Standing >6 hrs/day	Reference Low-back pain OR:1.31 [1.10 1.55][1] Lower leg pain OR:1.59 [1.30 1.95][1] Low-back pain OR:1.51 [1.24 1.85][1] Lower leg pain OR:1.73 [1.38 1.60][1]	0.95
Jellad (2013) [36]	-	Cross-sectional	n=433 Females: 55.9% Age: 33.6 years Country: Tunisia Occupation: Hospital workers	-	Self-reported prolonged standing (frequency of standing; not clear whether it is just about occupational standing) classified into: • Rarely: sometimes or never • Frequently: often, always	Self-reported musculoskeletal symptoms in last 12 months <u>Prevalence</u>: 65.4%	• Rarely standing • Frequently standing	74 symptoms; 25 no symptoms 209 symptoms 125 no symptoms p=0.016;	0.64
Jones (2007) [37]	The New Workers Study	Prospective (12 and 24 month follow-up).	n=1198 (671 without knee pain at baseline combined with 518 participants without knee pain at 12 months - overlapping	1. Multivariate model: age, gender, occupational group; BMI and physical activity	Self-reported duration of occupational standing, classified into: • None • Standing <15 mins in the last work day	Self-reported knee pain (lasting ≥1 day in last month), assessed at baseline and during the 12 and 24 month follow-up. <u>Baseline prevalence</u> 0%.	• No standing 12 months (n=61 no pain, n=4 pain) 24 months (n=50 no pain, n=7 pain) • Standing <15 mins/day	Reference RR: 1.3 [0.7 2.6][1]	0.91

			numbers) Females: 35.8% Age: - Country: England Occupation: Newly employed workers from 12 diverse occupational groups		• Standing >15 mins in the last work day	Incidence: 12 months 8.2%; 24 months 10.2%	12 months (n=171 no pain, n=15 pain) 24 months (n=157 no pain, n=18 pain) • Standing >15 mins/day 24 month (n=381 no pain, n=36 pain) 24 months (n=251 no pain, n=27 pain)	RR: 1.2 [0.6 2.3][1]	
Kaneda (2001) [38]	-	Cross-sectional	n=19,948 Females:- Age: 42.0 (12.3) years (low-back pain); 40.9 (13.62) years (no low-back pain) Country: Japan Occupation: Construction workers	1. Univariate model 2. Multi-variate model: All studied personal factors and physical work demands.	Self-reported occupational standing (posture often maintain at work)	Self-reported severity of low-back pain at the time of the survey, past history of low-back pain, progression, severity, relationship to work, onset. Definition of cases and controls is unclear. Prevalence: 29.3%	• Sitting often maintained • Standing often maintained	Reference OR:0.83 [0.75 0.92][1]	0.68
Karahan (2009) [39]	-	Cross-sectional	n=1600 Females: 68.6% Age: 28.02 (5.0) years Country: Turkey Occupation: Staff from 6 different hospitals	1. Univariate 2. Multivariate model: age, gender, occupation, education status, years worked, BMI, smoking behaviour, exercise patterns, perceived stress, lifting, supporting, pulling/positioning heavy objects	Self-reported total duration of occupational standing time in a typical day	Self-reported low-back pain for at least 1 day during the last 12 months Prevalence: 65.8%	• Standing 1-4 hrs/day • Standing 5-8 hrs/day • Standing >8 hrs/day	166/301 (55.1%) low-back pain; 135/301 (44.9%) no low-back pain 498/772 (64.5%) low-back pain; 274/772 (35.5%) no low-back pain 388/527 (73.6%) low-back pain; 139/527 (26.4%) no low-back pain p <0.001[1] Multivariate analysis[2]	0.95

								– standing not significantly associated with low-back pain (ORs not reported)	
Kulcu (2010) [40]	-	Cross-sectional	n=206 Females: 57% Age: 23.5 (5.0) years Country: Turkey Occupation: Dentists, students and nurses without back/neck symptoms.	-	Self-reported duration of occupational standing (mins/day)	Self-reported experience of low-back and neck pain in specific positions. Neck Disability Index (NPDI), Roland-Morris low-back pain and Disability Questionnaire (RMQ) <u>Prevalence</u>: • Low-back pain 61% • Neck pain 34%	Average duration of work while standing 73.4(14.3) mins/day	Correlation between working while standing and RMQ: r=0.252, p<0.001 NPDI: r=0.334, p<0.001 Neck pain (VAS) r=0.279, p<0.001 Low-back pain (VAS) r=0.200, p=0.005 Frequency of low-back pain while standing: r=0.310, p<0.001	0.73
Lehto (1991) [41]	-	Cross-sectional	n=131 Females: 68% Age: 46 [33-65] years Country: Finland Occupation: Dentists	1. Multivariate model: age, gender.	Self-reported occupational standing	Self-reported pain and disability in the last 12 months combining information from different pain sites: neck, shoulder, elbow, wrist, upper back and lower back. <u>Prevalence</u>: • Neck 17% (male), 35% (female) • Shoulder (R) 28%; (L) 29% (male), (R) 38; (L) 36 (female) • Elbow (R) 7%, (L) 2% (male), (R) 16%; (L) 8%. • Wrist (R) 12%; (L) 10% (male), (R) 16%; (L) 11% (female) • Upper back 10% (male), 18% (female) • Lower back 26% (male), 43% (female)	• Working in sitting posture • Working in standing posture	58% pain and disability 41% pain and disability No statistically significant differences	0.68
Leino (1999)	-	Cross-sectional	n=85	-	Self-reported	Self-reported discomfort	Standing	33.7%	0.50

[42]			Females: 95.3% Age: 36 years (small salons); 29 years (large salons) Country: Finland Occupation: Hairdressers		occupational standing	from work factors <u>Prevalence</u>: -		No effect 55.4% Some discomfort 9.6% A lot of discomfort 1.2% Cause a disease	
Leroux (2005) [43]	Quebec Health Study	Cross-sectional	n=9496 Females: 42% Age: 18-65 years Country: Canada Occupation: All people living in private households with a paid occupation	Stratified by gender. 1. Multivariate model: age, psychological distress, smoking, traumatic events and work factors; and variables significantly associated with musculoskeletal pain	Self-reported occupational standing (standing/sitting most of the time at work)	Self-reported musculoskeletal pain ("having disturbed activities, often or always" during the past 12 months) grouped into: • Neck • Back • Upper extremities • Lower extremities <u>Prevalence</u>: • Neck: 10.9% (men); 18.4% (women) • Back: 28.9% (men); 30.4% (women) • Upper extremities: 19.7% (men); 22.3% (women) • Lower extremities: 18.5% (men); 20.4% (women)	• Sitting most of the time at work • Standing most of the time at work	Reference Lower extremities Men OR: 2.4 [1.8 3.1][1] Women OR: 2.9 [2.1 3.9][1]	0.95
Levangie (1999) [44]	-	Case-control	n=283 Female: 60% (cases), 61% (controls) Age: 35.2 years (cases), 35.5 years (controls) Country: USA	-	Self-reported standing (not clear whether it is just about occupational standing; duration)	Self-reported low-back pain with cases (seeking treatment of low-back pain, ≤1 year in duration) and controls (patients treated by a physical therapist for an upper extremity problem that was not obviously neck or back-related) <u>Prevalence</u>: 52.1% (150 cases, 138 controls)	• Standing ≤3 hrs/day (46 cases, 43 controls) • Standing 4-5 hrs/day (34 cases, 31 controls) • Standing 6-8 hrs/day (35 cases, 37 controls)	Reference OR:1.03 [0.54 1.94] OR:0.88 [0.47 1.65]	0.73

			Occupation: Patients seeking physical therapy services				• Standing ≥9 hrs/day (34 cases, 27 controls)	OR:1.18 [0.61 2.25]	
Li (2012) [45]	-	Case-control	n=7200 Females: 16% Age: Several age groups Country: China Occupation: Researchers and occupational health service providers	Same distribution of gender and age groups for cases and controls. 1. Multivariate model: Anthropometrics, SES and working factors.	Self-reported occupational standing (for long periods; yes/no)	Self-reported low-back symptoms in the last year <u>Prevalence</u>: 50% (3600 cases; 3600 controls)	• Not standing for long periods (992 cases, 1377 controls) • Standing for long periods (2608 cases, 223 controls)	Reference OR:0.822 [0.720 0.938][1]	0.91
Mehrdad (2012) [46]	-	Cross-sectional	n=405 Females: 47% Age:44.6(7.9) years Country: Iran Occupation: Physicians	1. Multivariate model: individual and work-related factors (e.g., age, gender, BMI, shift work, employment type, and secondary job).	Self-reported prolonged occupational standing (>20 minutes)	Self-reported symptoms (in the past 12 months; modified version of the Nordic questionnaire) in: • Neck • Low-back • Knees • Three areas combined Prevalence: • Neck 9.9% • Low-back 15.1% • Knee 17.3%	• No prolonged standing • (n=191) • Prolonged standing >20 minutes (n=214)	Reference Low-back OR:1.159 [1.003 1.339][1] Knee OR:1.229 [1.066 1.416][1]	0.86
Messing (2001) [47]	-	Cross-sectional	n=21 Females: 81% Age: standing workers 38.2(10.3) years, non-standing workers 37.2(7.3) years Country: Sweden Occupation: Workers presumed to be standing (i.e.,	-	Observations of occupational standing, classified into: • Standing group (stood on average 62.2(6.5)% of the workday) • Non-standing (stood on average 2.7(2.3)% of the workday)	Self-reported pain in the feet during last 3 months <u>Prevalence</u>: 38.1%	• Standing personnel • Non-standing personnel	7/10 with pain 1/11 with pain	0.55

			works from department store and a restaurant) and non-standing workers (i.e., research personnel)						
Messing (2008) [48]	Quebec Health and Social Study	Cross-sectional	n=7757 Females:41% Age: 18-65 years. Country: Canada Occupation: General population	Stratified by gender. 1. Multivariate model: age, BMI, job strain and other physical work demands.	Self-reported occupational standing. Participants who reported on standing most of the timey were questioned on the nature of their standing postures.	Self-reported (adapted Nordic questionnaire) significant pain in a lower extremities during the past 12 months, interfering with usual activities in the following areas: • Lower legs/calves • Ankles / feet • Knees • Hips or thighs <u>Prevalence</u> • Lower legs/calves 6.3% • Ankles / feet 9.4% • Knees 8.6% • Hips or thighs 5.0%	• Sitting with the possibility of getting up at will • Standing with the possibility of sitting down at will • Standing in a fixed or relatively fixed position	Reference Lower-leg or calf Men OR:3.21[1] OR:2.11 [0.97 4.61][2] Women OR:1.63[1] OR:1.45[0.67 3.14][2] Total 1.80[1.04 3.11][2] Ankle or foot Men OR:2.07[1] OR:1.90 [0.99 3.65][2] Women OR:1.28[1] OR:1.07 [0.54 2.12][2] Total 1.38 [0.87 2.21][2] Lower-leg or calf Men OR:4.37[1] OR:3.46 [1.52 7.89][2] Women OR:4.86[1] OR:3.64[1.84 7.20][2] Total OR:3.60 [2.12 6.09][2] Ankle or foot Men OR:6.38[1] OR:6.29 [3.46 11.5][2] Women: OR:3.98[1]	0.95

							• Usual posture sitting • Usual posture standing	OR:2.78 [1.49 5.21][2] Total OR:3.95 [2.56 6.10][2] Reference Lower-leg or calf pain Men OR:2.85[1] Women 3.72[1] Ankle or foot pain Men OR:2.81[1] Women OR:3.61[1]	
Mohseni-Banpei (2011) [49]	-	Cross-sectional	n=223 Females: 51.6% Age: 42.66 (7.51) years. Country: Iran Occupation: Surgeons	-	Self-reported occupational prolonged standing	Self-reported low-back pain (visual analog scale with 0 mm indicating no pain and 100 mm indicating unbearable pain). Definition of cases and controls is not specified. <u>Prevalence</u>: • Currently 39.9% • Last month 50.2% • Six month 62.3% • Annual 71.7% • Lifetime 84.8%		Prolonged standing, was the most significant aggravating factors: (85.2%)	0.68
Nahit (2001) [50]	-	Cross-sectional	n=1081 Females: 32% Age: 23 (median) years Country: UK Occupation: Range of occupations and industries with	1. Multivariate model: age and gender.	Self-reported occupational standing (duration), classified into • <15 minutes/day • 15 minutes to <2 hrs/day • 2 hrs to <4 hrs/day • ≥4 hrs/day.	Self-reported pain experienced in the past month lasting longer than 24 hours, in the following areas: • Low-back • Shoulder • Wrist/forearm • Knee <u>Prevalence</u>:	• Not standing ≥4 hrs/day (n=880, n=205 with pain) • Standing ≥4 hrs/day (n=192, n=55 with pain)	Reference Low-back OR:1.4 [0.97 2.0][1]	0.91

			presumed high prevalence of musculoskeletal symptoms.			• Low-back 24.1% • Shoulder 20.4% • Wrist/forearm 8.6% • Knee 20.5%			
Phajan (2014) [51]	-	Cross-sectional	n=540 Females: 57.59% Age: 44.75(7.67) years Country: Thailand Occupation: Sugarcane farmers	-	Self-reported duration of standing (not clear whether it is just about occupational standing)	Self-reported musculoskeletal pain (Nordic questionnaire) in the last 12 months in any of the following regions neck, shoulder, elbow, wrist, upper back, low-back, hip, knee, ankle, and foot. <u>Prevalence</u>: 88.70%	• Not standing for >4 hrs/day (15 no pain, 39 pain) • Standing for >4 hrs/day (46 no pain, 440 pain)	Reference OR: 3.67 [1.88 7.17]	0.86
Pope (2003) [52]	-	Case-control	n=3354 Females: 63,6% (cases), 49,4% (controls) Age: >18 years Country: UK Occupation: General population of participants recruited through general practices	1. Partially adjusted model: age and gender. 2. Fully adjusted model: all significant physical demands.	Self-reported history of occupational standing (in years).	Self-reported hip pain in the past month lasting at least 24 hours <u>Prevalence</u>: 10.5%	• Not exposed to standing (53 cases, 692 controls) • Exposed to 1–15 years of standing (52 cases, 606 controls) • Exposed to >16 years of standing (71 cases, 576 controls)	Reference OR: 1.19 [0.80 1.78][1] OR:1.46 [1.00 2.14][1]	0.91
Rodigari (2012) [53]	-	Cross-sectional	n=100 Females: 26% Age: 40.1(10.85) years Country: Italy Occupation: Surgery unit workers.	1. Multivariate model: body measurements, working activity, fatigue and pain, sporting activities and awareness of guidelines.	Self-reported occupational standing (mainly working in sitting, standing or alternating posture)	Self-reported onset of pain (visual-analog scale) in any of the following areas: shoulder, elbow, hands, cervical spine, vertebral column, lumbar spine, hips, knees and feet. Definition of cases and controls is unclear. <u>Prevalence</u>: 70%	• Standing • Sitting • Alternate	Pain: 53 (71.6%) No pain: 21 (28.4%) Pain: 12 (70.6%) No pain: 5 (29.3%) Pain: 5 (62.5%) No pain: 3 (37.5%) P=0.865	0.82
Samad (2010) [54]	-	Cross-sectional	n=272 Females: 67%	-	Self-reported prolonged standing contributing to pain (not clear whether it is	Self-reported low-back pain. (Nordic questionnaire) in the previous 12 months.		Prolonged standing contributed in 26 (23.4%) participants to low-back pain.	0.68

			Age: 34.74 (7.7) years Country: Malaysia Occupation: Teachers		just about occupational standing)	<u>Prevalence</u>: 40.4%			
Sanya (2005) [55]	-	Cross-sectional	n=604 Females: 14.7% Age: 20-60 years Country: Nigeria Occupation: Nine different industries (e.g., manufacturing, food and drink processing industries)	-	Self-reported occupational prolonged standing	Self-reported low-back pain. Definition of cases and controls is unclear. <u>Prevalence</u>: • Point 59.7% • 12-month 59.5%		62.4% of low-back pain was caused by prolonged standing (p=0.61)	0.59
Schierhout (1995) [56]	-	Cross-sectional	n=401 Females: 62% Age: - Country: South-Africa Occupation: Factory workers	1. Univariate: stratified for gender. 2. Multivariate model: gender, age, height, all work demands	Observations of occupational standing	Self-reported musculoskeletal pain in any site (symptoms that have been developed since working in the current job). Authors distinguish between acute and chronic pain (the definition and outcome used for analysis is unclear). Analyses were performed on: • Neck/shoulder • Low-back and • Forearm/wrist/hand. <u>Prevalence</u>: -	• Seated work • Standing work (n=225)	Neck/shoulder pain Men Prev:0.13 [0.000 0.294] Women Prev:0.31 [0.188 0.432] Back pain Men Prev:0.13 [0.000 0.294] Women Prev:0.23 [0.118 0.341] Forearm/wrist/hand Men Prev:0.06 [0.015 0.105] Women Prev:0.02 [0.009 0.031]	0.86

								Neck/shoulder Men: Prev:0.08 [0.025 0.135] Women: Prev: 0.16 [0.097 0.223] Total OR:3.91 [1.11 13.7][2] Back pain Men Prev:0.13 [0.068 0.198] Women Prev:0.22 [0.149 0.291] Forearm/wirst/hand Men Prev:0.02 [0.000 0.048] Women Prev:0.04 [0.006 0.074]	
Smith (2002) [57]	-	Cross-sectional	n=149 Females: 18.8% Age: 35.1(8.8) years Country: Japan Occupation: Factory workers	1. Multivariate model: age, gender, duration of employment	Self-reported occupational standing (does the job usually involve sitting or standing)	Self-reported musculoskeletal pain (in the previous 12 months) in: • Low-back • Shoulder • Neck • Knee <u>Prevalence</u>: • Low-back (20.1%) • Shoulder (15.4%) • Neck (10.1%) • Knee (4.0%)	• Not standing • Standing	Reference Neck OR:8.2 [1.2 81.7][1]	0.82
Sterud (2013) [58]	-	Prospective (3 year follow-up)	n=6745 Females: 47% Age: 6.8% 18-24 years; 19.9% 25-34 years; 29.7% 35–44	1. Partially adjusted model: low-back pain at baseline, gender and age.	Self-reported occupational standing (duration and change in duration; comparing baseline outcomes with follow-up), with outcome categories:	Self-reported low-back pain and low-back pain intensity over the past month <u>Prevalence</u>: 12.8% (861) at follow-up with 4.7% (319) cases at both time points.	• Not exposed • Standing a quarter of the working day	Reference OR:1.21 [0.91 1.63][1] OR:0.8 [0.81 1.48][2]	1.00

			years; 27.0% 45–54 years; 16.6% 55–66 years. Country: Norway Occupation: General population	2. Fully adjusted model: factors above and education, occupation, psychological distress and other work-related mechanical and/or psychosocial exposures.	• Almost the whole time • Three-quarters of the working day • Half of the working day • A quarter of the working day • Very little of the working day.		• Standing 1/ of the work day • Standing three quarters of the working day • Pooled estimate • Not exposed to standing • Decreased (baseline vs follow-up) • Increased (baseline vs follow-up) • Exposed at baseline and follow-up	OR:1.39[1.10 1.74][1] OR:1.24[0.96 1.59][2] OR: 1.74[1.46 2.07][1] OR: 1.48[1.20 1.83][2] OR: 1.56[1.33 1.83][1] OR: 1.32[1.09 1.60][2] Reference OR:1.55[1.23 1.95][1] OR:1.38[1.08 1.77][2] OR:1.33[0.94 1.87][1] OR:1.17[0.82 1.66][2] OR:1.65[1.39 1.95][1] OR:1.41[1.14 1.73][2]	
Svensson (1989) [60]	-	Cross-sectional	n=1400 Females: 100% Age: Two age groups: 38-49 years and 50-64 years Country: Sweden Occupation: General population	-	Self-reported occupational standing (duration), classified into • 0-2 hrs/day • 2-4 hrs/day • >4 hrs/day	Self-reported low-back pain. Participants reporting on low-back pain were divided into two main groups: those who had had pain at some time in life (lifetime incidence group) and those with ongoing pain (prevalence group). <u>Prevalence</u>: Incidence group: 66% for both age groups. Prevalence group 33% in the younger age group and 37% in the older age group.	• Standing <2 hrs/day • Standing 2-4 hrs/day	Younger age group No low-back pain: n=85 Incidence group: n=156 Prevalence group: n=71 Older age group No low-back pain: n=60 Incidence group: n=80 Prevalence group: n=37 Younger age group No low-back pain: n=45	0.64

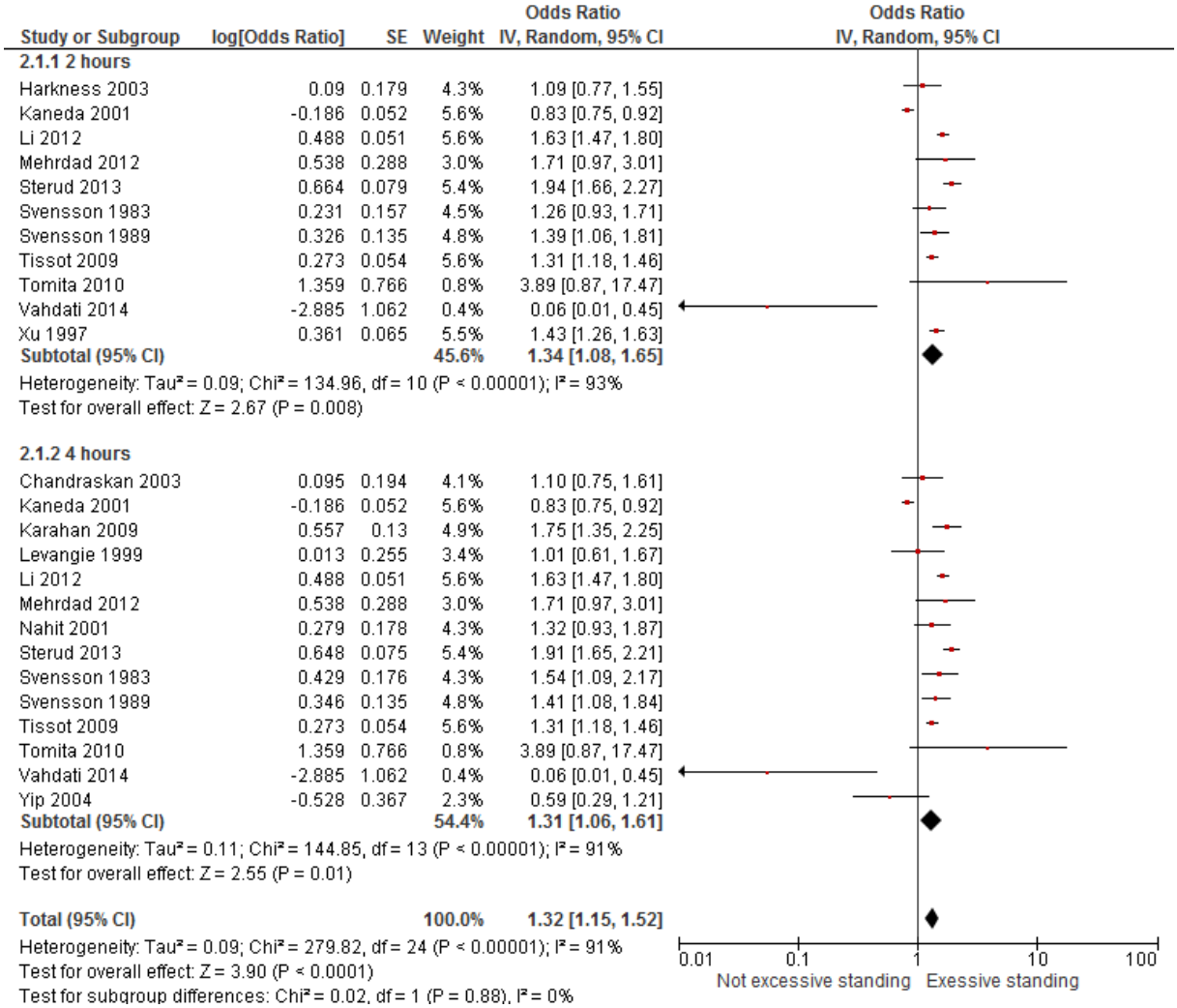
							• Standing >4 hrs/day	Incidence group: n=91 Prevalence group: n=46 Older age group No low-back pain: n=33 Incidence group: n=60 Prevalence group: n=30 Younger age group No low-back pain: n=79 Incidence group: n=187 Prevalence group: n=96 Older age group No low-back pain: n=47 Incidence group: n=122 Prevalence group: n=67	
Svensson (1983) [59]	-	Cross-sectional	n=714 Females: 0% Age: Between 40 and 47 years. Country: Sweden Occupation: General population	-	Self-reported occupational standing (duration), classified into: • 0-2 hrs/day • 3-4 hrs/day • 5-6 hrs/day • 7-8 hrs/day	Self-reported low-back pain Participants reporting on low-back pain were divided into two main groups: those who had had pain at some time in life (lifetime incidence group) and those with ongoing pain (prevalence group). <u>Prevalence</u>: Incidence group: 61.6% Prevalence group: 31.4%	• 0-2 hrs/day of occupational standing • 2-4 hrs/day of occupational standing • 4-6 hrs/day of occupational standing • 6-8 hrs/day of occupational standing	No low-back pain incidence: n=143 Low-back pain incidence: n=204 No low-back pain incidence: n=58 Low-back pain incidence: n=80 No low-back pain incidence: n=32 Low-back pain incidence: n=58 No low-back pain incidence: n=33 Low-back pain incidence: n=83	0.64

								P<0.05	
Tissot (2009) [61]	Quebec Social and Health Survey	Cross-sectional	n=7730 Females: 41.6% Age: 18-65 year Country: Canada Occupation: General population	-	Self-reported occupational standing. Those who reported that they usually stood at work were questioned on the nature of their standing postures	Self-reported significant low-back pain during the previous 12 months interfering with usual activities 'fairly often' or 'all the time'. <u>Prevalence</u>: 24.5%	• Sitting (n=3237) • Standing (n=4493) • Standing with the possibility of sitting down at will (18.2% of people standing) • Moving around (70.0% of people standing) • Standing in a fixed or relatively fixed position (11.8% of people standing)	Low-back pain: 21.7% Low-back pain: 26.7% Low-back pain: 17.4% Low-back pain: 28.6% Low-back pain: 30.4%	0.77
Tomita (2010) [62]	-	Cross-sectional	n=165 Females: 68.5% Age: 30.3(10.4) years Country: Thailand Occupation: Seafood processing industry workers	1. Multivariate model: age and gender	Self-reported occupational standing (duration) categorised into: • Seldom/never • Sometimes/most of the time	Self-reported current low-back pain <u>Prevalence</u>: point 28.5%	• Standing seldom or never (n=20, prevalence 10%) • Standing sometimes, often or most of the time (n=149, prevalence 30%)	Reference OR:3.07 [0.65 14.41][1]	0.82
Trinkoff (2003) [63]	-	Cross-sectional	n=1163 Females: 94% Age: 45 years Country: USA Occupation: Nurses	1 Multivariate model: age	Self-reported occupational prolonged standing in one place/static position (>30 minutes)	Self-reported musculoskeletal symptoms in the past year that lasted >1 week, or occurred at least monthly in: • Neck • Shoulder • Back With at least moderate pain on average (based on a 5-point pain scale). Non–work-related injuries were excluded.	• Not stand in one place/static position • Stand in one place/static position (>30 minutes)	Reference Neck OR:1.57[1.09 2.24][1] Shoulder OR:1.87[1.28 2.74][1] Back OR:1.69[1.21 2.37][1]	0.77

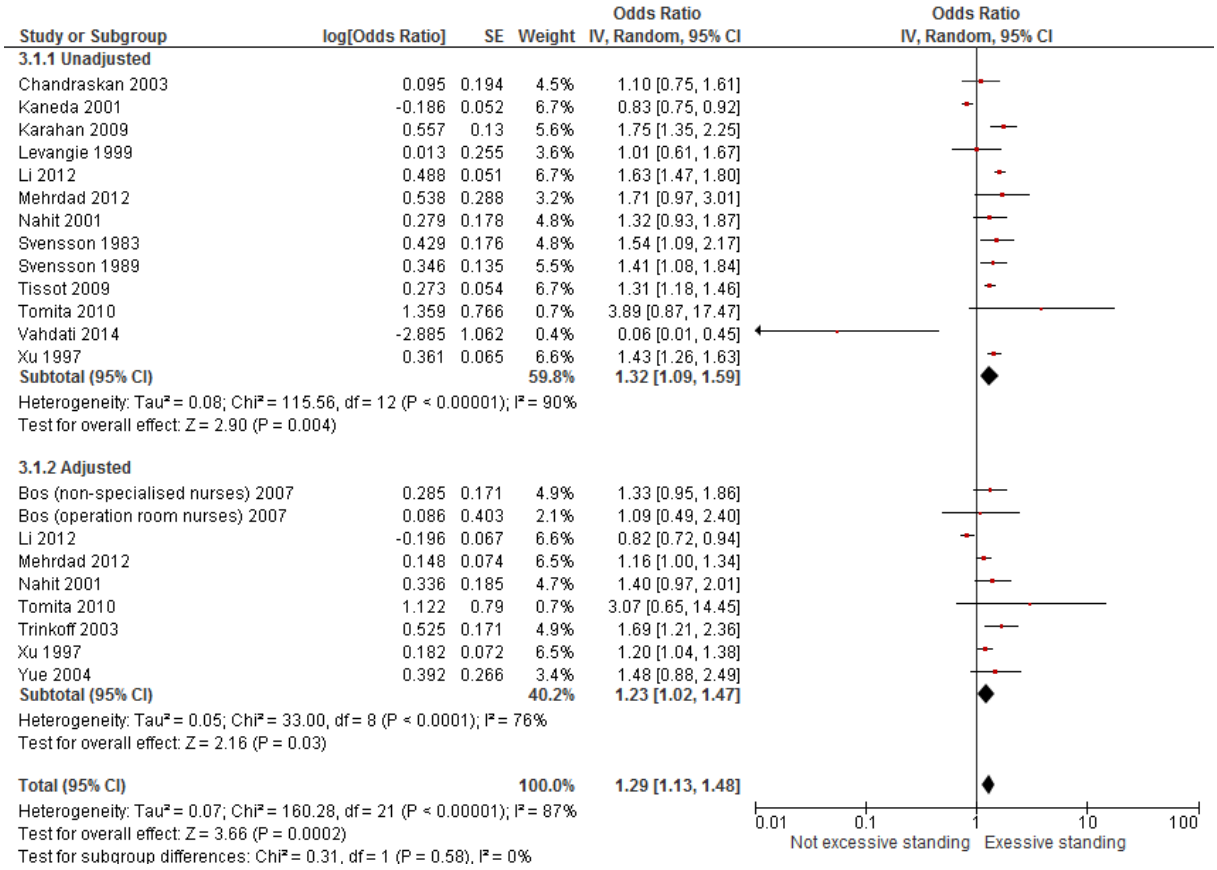
						Prevalence:-			
Vahdati (2014) [64]	-	Cross-sectional	n=125 Females: 41.6% Age: 33.6(4.81) years Country: Iran Occupation: Medical residents	-	Self-reported occupational standing	Self-reported low-back pain during the past 12 months. Prevalence: 56.8%	• Not standing for a long time (n=12, 11 with low-back pain) • Standing for a long time (n=113, 43 with low-back pain)	Standing for long periods was significantly associated with low-back pain	0.73
Xiao (2013) [65]	MICASA study	Cross-sectional	n=759 Females: 44.7% Age: 37.9 (median) years Country: USA Occupation: Farm workers	Stratified by gender. 1 Multivariate model: age, smoking status and years working in agriculture.	Self-reported duration of occupational standing	Self-reported musculoskeletal pain over the last 12 months at six sites: • Low-back, • Hip • Knee • Neck • Hand • Finger Those who answered yes were if the pain lasted for ≥6 weeks and chronic pain at each site was defined as pain lasting six weeks or longer Prevalence: • Low-back pain: 24.5% • Knee pain: 13.7% • Hip pain: 12.1% • Neck pain 8.9% • Hand pain 7.4% • Finger pain: 7.1%	• Standing 0 hrs/wk (n=27 women, n=193 men) • Standing 1<60 hrs/wk (n=115 women, n=113 men) • Standing ≥60 hrs/wk (n=179 women, n=98 men)	Reference Hip Women OR:0.89 [0.32 2.47][1] Men OR:0.78 [0.32 1.86][1] Low-Back: Women OR:1.10 [0.45 2.69][1] Men OR:0.65 [0.35 1.20][1] Hip: Women OR:1.33 [0.47 3.78][1] Men OR:0.27 [0.06 1.18][1] Low-back: Women OR:1.86 [0.75 4.66][1] Men OR:0.33 [0.14 0.82][1]	1.00
Xu (1997) [66]	-	Cross-sectional	n=5185 Females: - Age: -	1 Partially adjusted model: sex, age, educational, and	Self-reported occupational standing (duration), classified into: • All of the time • ¾ of the time	Self-reported low-back pain in the past 12 months. Symptoms were defined as all conditions of pain, ache, or discomfort localised in the lower back, regardless	• Never or seldom standing (n=1363, 499 with pain) • Standing at least ¼ of the working time	Reference OR: 1.18[2], p=0.058 OR: 1.20 [1.04 1.38][1]	0.82

			Country: Denmark Occupation: Random sample of the working population	employment duration 2 Fully adjusted model: all the above and relevant physical demands.	• ½ of the time • ¼ of the time • Seldom or never	of intensity and severity. Prevalence: -	per day (n=3814, 1728 with pain) • Never or seldom standing (n=1363, pain prevalence 36.6%) • ¼ of the time (n=1035, pain prevalence 42.9%) • ½ of the time (n=1022, pain prevalence 44.3%) • ¾ of the time (n=532, pain prevalence 47.7%) • All of the time (n=1225, pain prevalence 47.1%)	Reference OR:1.31[2] OR:1.40[2] OR:1.61[2] OR:1.55[2]	
Yip (2004) [67]	-	Prospective (12 month follow-up) with participants free from low-back pain in the 12 months prior to the baseline 52measurement	n=144 Females: 85.5% Age: 31.10 [29.91 32.29] years Country: Hong Kong Occupation: Hospital nurses	-	Self-reported occupational standing (duration)	Self-reported low-back pain for at least one day during the past 12 months Prevalence: 38.8% (n=56)	• <2 hrs (n=21 pain (47.7%), n=23 no pain) • At least 4 hrs (n=35 pain (35.0%), n=65 no pain)	Reference p=0.19	0.59
Yue (2012) [68]	-	Cross-sectional	n=893 Females: 67.0% Age: 32.21 (10.61) years Country: China Occupation: School teachers	1 Multivariate model: age and gender and all significant work demand factors.	Self-reported prolonged occupational standing (≥2 hrs/day)	Self-reported pain in the neck or/and shoulder and low-back lasting for >1 day during the previous 12 months. Prevalence: • Neck/shoulder 48.7% • Low-back 45.6%	• Not prolonged standing • Prolonged standing	Reference Neck/shoulder pain OR:2.23 [1.48 3.78][1] OR;1.74 [1.03 2.95][2] Low-back pain: OR:1.88 [1.25 2.84][1] OR:1.48 [0.88 2.50][2]	0.95

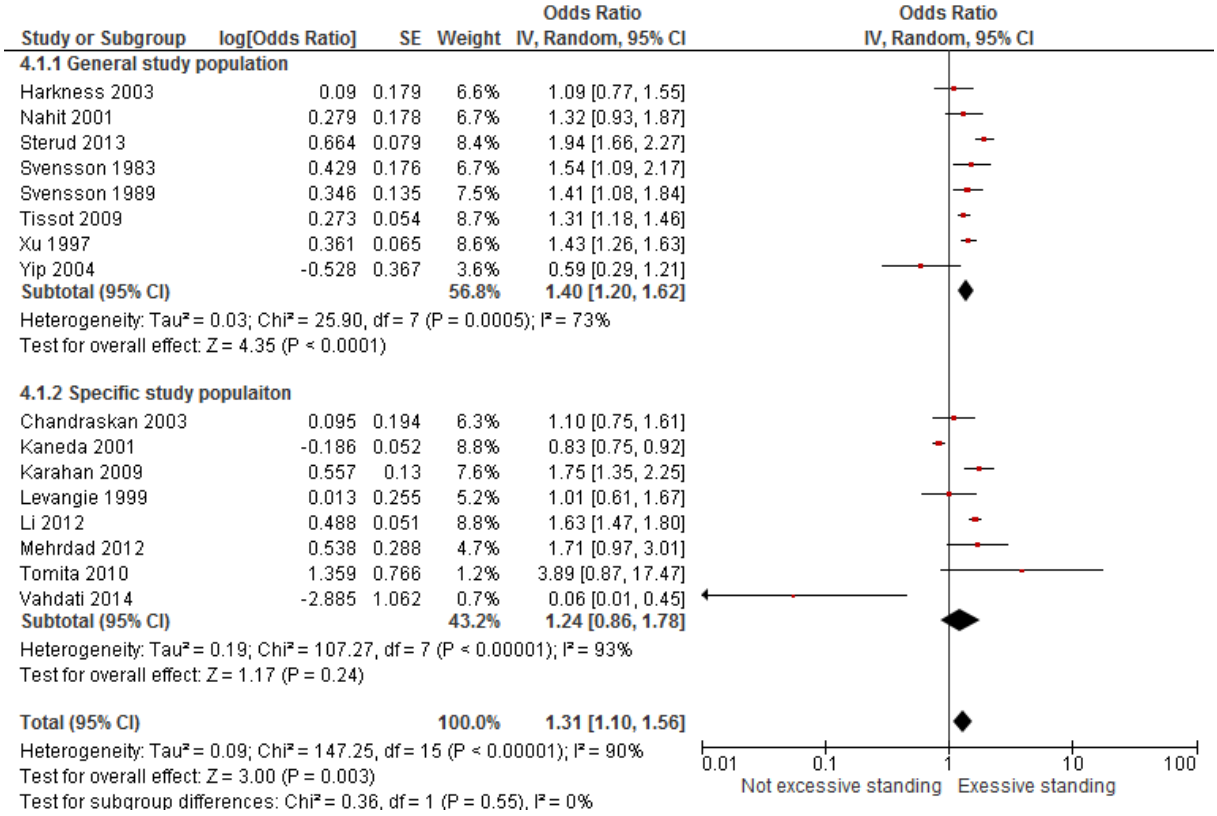
Appendix 10. Forest plot of the comparison not-excessive standing versus excessive standing on the unadjusted association with low-back symptoms. Individual study as well as pooled exposure-outcome associations are presented. Data shown for studies for which a cut-off value to distinguish not excessive standing from excessive standing of 4 hours/workday (upper panel) and 2 hours/workday (lower panel) could be adopted. SE = standard error; CI = confidence interval; IV = inverse variance.



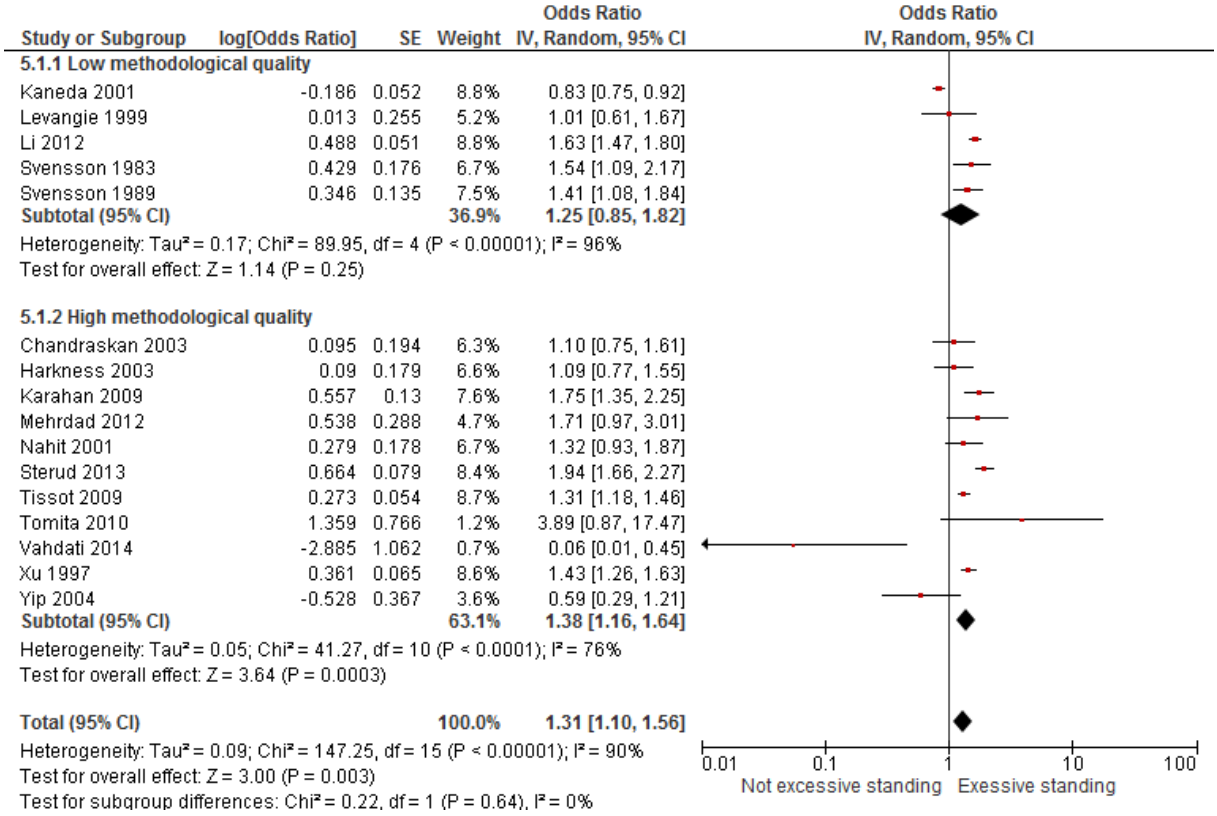
Appendix 11. Forest plot of the comparison not-excessive standing versus excessive standing (adopting a 4 hours/workday cut-off value when possible) on the association with low-back symptoms. Individual study as well as pooled exposure-outcome associations are presented. Data for studies for which unadjusted (upper panel) as well as adjusted (lower panel) associations were reported. SE = standard error; CI = confidence interval; IV = inverse variance.



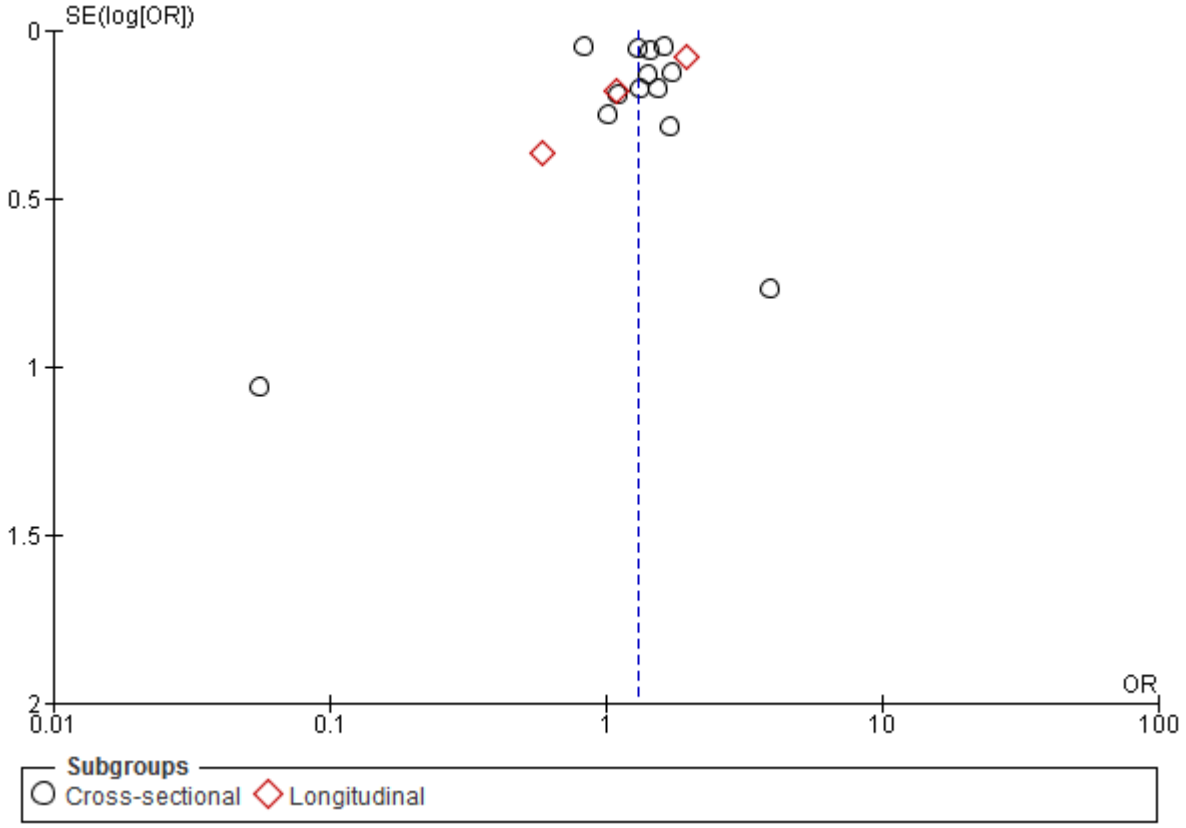
Appendix 12. Forest plot of the comparison not-excessive standing versus excessive standing (adopting a 4 hours/workday cut-off value when possible) on the unadjusted association with low-back symptoms. Individual study as well as pooled exposure-outcome associations are presented. Data for studies that reported on general occupational study samples (upper panel) as well as those which reported on specific occupational study samples (lower panel). SE = standard error; CI = confidence interval; IV = inverse variance.



Appendix 13. Forest plot of the comparison not-excessive standing versus excessive standing (adopting a 4 hours/workday cut-off value when possible) on the unadjusted association with low-back symptoms. Individual study as well as pooled exposure-outcome associations are presented. Data shown for studies that were considered of low methodological quality (upper panel) as well as high methodological quality (lower panel). SE = standard error; CI = confidence interval; IV = inverse variance.



Appendix 14. Funnel plot for the association of excessive standing and low-back symptoms. Dots represent (with circles being cross-sectional study designs and diamonds being longitudinal study designs) the individual study estimates while the vertical line depicts the summary effect of the exposure-outcome associations.



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