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REVIEW

Physical risk factors for developing non-specific neck pain in office workers: a systematic review and meta-analysis

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Abstract
Introduction Identifying risk factors associated with the development of work-related neck pain in office workers is necessary to facilitate the development of prevention strategies that aim to minimise this prevalent and costly health problem. The aim of this systematic review is to identify individual worker (e.g., lifestyle activity, muscular strength, and posture) and workplace (e.g., ergonomics and work environment) physical factors associated with the development of non-specific neck pain in office workers.
Methods Studies from 1980 to 2016 were identified by an electronic search of Pubmed, CINAHL, EMBASE, Psychlnfo and Proquest databases. Two authors independently screened search results, extracted data, and assessed risk of bias using the epidemiological appraisal instrument (EAI). A random effect model was used to estimate the risk of physical factors for neck pain.
Results Twenty papers described the findings of ten prospective cohort studies and two randomized controlled trials. Low satisfaction with the workplace environment (pooled RR 1.28; CI 1.07–1.55), keyboard position close to the body [pooled RR 1.46; (CI 1.07–1.99)], low work task variation [RR 1.27; CI (1.08–1.50)] and self-perceived medium/high muscular tension (pooled RR 2.75/1.82; CI 1.60 /1.14–4.72/2.90) were found to be risk factors for the development of neck pain.
Conclusions This review found evidence for a few number of physical risk factors for the development of neck pain, however, there was also either limited or conflicting factors. Recommendations for future studies evaluating risk factors are reported and how these may contribute to the prevention of neck pain in office workers.

Keywords Neck pain · Office worker · Physical factors · Individual factors · Ergonomics · Work environment · Systematic review · Meta-analysis

Introduction

Non-specific neck pain is a diagnosis often attributed to neck pain of postural and mechanical origin (Côté et al. 2004; Hansson and Hansson 2005). It is a common problem in society and the workplace with two-thirds of individuals affected at some point in their life (Côté et al. 2004; Manchikanti et al. 2009; Haldeman et al. 2010). Office workers have a higher annual prevalence (ranged 17.7–63%) and incidence (ranged 34–49%) of neck pain than other occupations (Korhonen et al. 2003; Sillanpaa et al. 2003; Côté et al. 2004; Wahlstrom et al. 2004; Janwantanakul et al. 2008; Cote et al. 2009; Hush et al. 2009). This condition places a significant burden on both the individual with neck pain and industry due to the costs associated with treatment, reduced productivity and work absenteeism (Hansson and Hansson 2005; Cote et al. 2009; Van Eerd et al.

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2011). A study conducted in Sweden found that almost 10% of a sample of office workers ($n = 1283$) reported reduced productivity due to musculoskeletal symptoms with the neck (33.3%) and shoulder regions (13.8%) being the most commonly reported sites (Hagberg et al. 2002). Neck pain can also result in long periods of work absenteeism (Cote et al. 2013) with a study in the Netherlands reporting 17% of the working population taking sick leave due to neck/shoulder pain at some point over a 2-year period (Burdorf et al. 1998). In light of the rising prevalence and incidence of neck pain and escalating costs due to direct (e.g., treatment costs) and indirect (e.g., loss of productivity) health care costs (Hansson and Hansson 2005), it is not surprising that work-related neck pain is a research priority (Hoy et al. 2014).

Numerous studies have evaluated treatment strategies to resolve the symptoms of neck pain. However, more recently, there has been a shift towards the prevention of neck pain (primary prevention), or the prevention of recurrence of neck pain (secondary prevention) (Leyshon et al. 2010; Aas et al. 2011; Andersen et al. 2011; Hoe et al. 2012; Kay et al. 2012; Bertozzi et al. 2013). This distinction is relevant as the Neck Pain Task Force (Guzman et al. 2008) has defined neck pain as an episodic and recurrent disorder potentially affecting individuals through their lifespan. It is reported that greater than 60% of workers experience another episode of neck pain within 1 year of their initial episode (Carroll et al. 2009). Van Erd et al. showed that 14.2% of workers that make health claims due to neck pain will have multiple episodes of work absenteeism due to recurrence of the disorder within two years of their initial claim (Van Erd et al. 2011). This has led some investigators to identify risk factors for the development of neck pain in office workers (Korhonen et al. 2003; Wahlstrom et al. 2004; Hannan et al. 2005; Tornqvist et al. 2009; Sihawong et al. 2014).

Workplace psychosocial factors (recorded from self-reported questionnaires) have been shown to be strong predictors for the development of neck pain in office workers (Linton 2000; McLean et al. 2010; Kraatz et al. 2013). In particular high job strain (high job demand and low job support) has consistently been identified as a significant risk factor for the development of neck pain in office workers (adjusted RR 2.15, 95% CI 1.16–3.99) (Tornqvist et al. 2009). A recent systematic review demonstrated a causal relationship between high job strain and low social support, with reported neck/shoulder complaints in office workers (Kraatz et al. 2013). While psychosocial risk factors have received some attention in the literature, other potential risk factors for the development of neck pain specific to the office worker have not been comprehensively explored. In particular, Cote and colleagues have identified that quantifiable, and potentially modifiable, physical risk factors may be relevant to the development of neck pain in the general work population. As such the focus of this systematic review will be on the identification of physical risk factors (e.g., ergonomic, workplace physical environment, worker physique, time-related work behaviour) specific to the development of neck in office workers.

There has been some attention in the literature regarding the relationship between physical factors in the workplace, and the physical condition of the individual (e.g., strength, flexibility, physical activity during leisure time and posture), and the development of neck pain. Some of these studies have been specific to office workers while others have not. For example sustained sitting, mostly associated with computer use, have been linked with the rising prevalence and incidence of neck pain in office workers (Gerr et al. 2002; Andersen et al. 2008; Cote et al. 2009; Tornqvist et al. 2009). A national based study of 5400 office workers in the Netherlands found computer use for more than 6 h/day was associated with an 88% increased chance of developing neck pain, compared to individuals using computers less than 2 h/day (Blatter and Bongers 2002). Other physical risk factors identified for the development of neck pain in the workplace include the inappropriate placement of computer devices such as monitor, keyboard and mouse (Marcus et al. 2002; Kiss et al. 2012; Darivemula et al. 2016). Several studies have also reported physical inactivity during leisure time as a risk factor for neck pain (Korhonen et al. 2003; Brandt et al. 2004; Huysmans et al. 2012a).

To date, only one systematic review has specifically investigated physical risk factors for the development of neck pain, but that review was in the general population (Ariens et al. 2000). While this previous systematic review identified a positive relationship between physical factors (excessive neck extension, twisting/bending of the trunk) and neck pain, the findings of the review were based on low quality cross-sectional studies and were not specific to office workers. As a number of longitudinal studies in office workers have been conducted over the past decade (Wahlstrom et al. 2004; Hagberg et al. 2007; Lapointe et al. 2009, 2013; Tornqvist et al. 2009; Ijmker et al. 2011; Huysmans et al. 2012a, b; Lindegard et al. 2012; Paksaichol et al. 2014; Shahidi et al. 2015; Sitthipornvorakul et al. 2015), it now seems timely to undertake a systematic review addressing physical risk factors for the development of neck pain specific to office workers. Therefore, the purpose of this systematic review was to identify physical workplace and individual risk factors for the onset and development of non-specific neck pain in office workers.

Methods

Literature search

This study followed the PRISMA statement for reporting systematic reviews (Moher et al. 2009). An electronic database search was conducted in April 2014 by the first author (DJ) using PubMed, CINAHL, EMBASE, Psycinfo and Proquest databases from January 1980 to April 2014. An updated search was completed in April 2016 for the period of 2014 to 2016 using the same search strategy. The search strategy consisted of a combination of keywords including neck pain, office workers, and physical risk factors ("Appendix A"). The reference list of included studies and relevant systematic reviews were also screened for any potentially eligible studies missed by the database search.

Inclusion criteria

Prospective studies [cohort and randomised controlled trials (RCT)] were included if they met the following inclusion criteria; (1) recruited a cohort of office workers without neck pain at baseline (2) office workers primary role was computer-based (3) measured at least one physical risk factor at baseline (workplace physical factors or individual worker physical factors) (4) assessed the onset of neck pain as an outcome (5) reported the association and strength of association between the physical risk factor and the development of neck pain (e.g., odds ratio (OR) or hazard ratio (HR)), and (6) full-text articles published in English.

Definition of outcome: neck pain

The variable of interest in this review was the onset of an episode of neck pain that could include a first episode or a recurrent episode after at least a 3-month absence of symptoms. There is significant variation in how a new episode of neck pain is defined in previous studies. Some studies define 'episode' by the duration of painful symptoms (e.g., >7 days) (Jensen 2003), severity of painful symptoms (based on pain visual analogue scale) (Gerr et al. 2000), or pain that results in activity limitations (Lapointe et al. 2009). To ensure the inclusion of all relevant studies in this systematic review, we included those studies that reported episodes of neck pain/symptoms in office workers over the study period irrespective of the duration or severity of symptoms. Specific details regarding the operational definition of neck pain used in each study is provided in Table 1.

Definition of physical risk factors

A physical risk factor was defined as either workplace physical factors (an attribute of the workplace environment/ergonomic setting and work practices) or individual worker physical factors (physical condition of the worker or physical activity). Potential workplace environment/ergonomic setting risk factors are those variables such as keyboard position, monitor height, and temperature/lightning/acoustic condition of the room. Work practices are those which influence how the work or task is performed, and includes variables such as posture and duration of computer devices use (Gerr et al. 2000; Van Eerd et al. 2012). Potential risk factors associated with physical condition of the worker and physical activity may include muscle strength and flexibility, frequency of leisure activity.

Risk of bias assessment

The risk of bias of included studies was independently assessed by two reviewers (DJ, ZM) using the Epidemiological Appraisal Instrument (EAI) appropriate for cohort (prospective and retrospective), intervention (randomized and non-randomized), case-control, cross-sectional, and hybrid studies (e.g., nested case–control) (Genaidy et al. 2007). The instrument tool comprises 43 questions categorized into five domains of risk of bias: (1) reporting (17 items), (2) subject/record selection (seven items), (3) measurement quality, (4) data analysis (seven items), and (5) generalization of results (two items).

For each item on the list, a study was rated on the following levels: "yes" (verifies the information is complete); "partial" (verifies the information is partially complete); "no" (verifies the information is not described but should have been provided); "unable to determine" (when the provided information is unclear or insufficient to answer the question); and "Not applicable" (absent of the item). Except for the score for "not applicable" response, all scores for each items in the same categories made up the average of the scores for each measurement scale (yes = 2, partial = 1, no/unable to determine = 0). The average scores of the 43 items defined the level of quality of the study, ranging from 0 to 2 with three levels of quality; high quality (low bias) (≥1.4), moderate quality (moderate bias) (1.1 to <1.4), or poor quality (serious bias) (<1.1). Any disagreement with the quality assessment scores was resolved with discussion between the two authors.

Data extraction

Data extraction was performed by one reviewer (DJ) and checked for accuracy by a second reviewer (ZM). Data extracted from eligible studies included publication details (author, year, place of study), participant demographics (age, sex, sample size, participation rate, drop-out rate), study methods (follow-up duration, case definition, analysis method, covariates administration), and assessed risk

Table 1 Characteristics of included studies ($N = 20$)

Study no. countries	Authors	Sample size (F %)	Age (years)	Participation rate (%)	Follow-up duration (FR%), incidence rate	Outcome definition (pain-free duration prior to baseline for study inclusion)	Statistical model, investigated covariates
Cohort 1, Sweden	Wahlstrom et al. (2004)	671 (48.7)	M 43 Years (20–65), F 45 (22–65)	84	10 Months (NR), 36 per 100 person-years	Pain or aches in the neck and/or scapular area lasting ≥3 days during the preceding month (1 month)	Multivariate HR adjusted for muscular tension, job strain, age and gender
	Hagberg et al. (2007)	1039 (57)	NR		10 Months (91.5), 0.92 per 100 person-month	Symptoms in the neck and/ or scapular area lasting ≥3days reducing productivity or owing for sick leave (NR)	Univariate HR adjusted for gender and age
	Tornqvist et al. (2009)	1283 (61.2)	44 Years (20–65)		10 Months (74.1), 67 per 100 person-years	Pain or aches in the neck and/or scapular area lasting ≥3 days during the preceding month (NR)	Multivariate HR adjusted for job strain, social support, age and sex
	Lindegard et al. (2012)	853 (55.2)	M 42.4 Years (19.6–65.3), F 44.5 (21.4–64.7)		10 Months(NR), 50 per 100 person-years	Pain or aches in the neck and/or scapular area lasting ≥3 days during the preceding month (1 month)	Univariate HR adjusted for gender, age, and duration of daily computer work
Cohort 2, Australia	Hush et al. (2009)	53 (64)	42 Years ± 11	NR	1 Year (100), 49%	Pain lasting 24h during the last 2 weeks (3 months)	Multivariate HR adjusted for gender, psychosocial and psychological stress
Cohort 3, Denmark	Jensen (2003)	1192 (66.5)	M 42 Years ± 10, F 4 years ± 11	69	21 Months (77), 20.9%	Pain lasting 7 days in 1-year follow-up (1 year)	Multivariate OR adjusted for age, gender, psychosocial factors
Cohort 4, Canada	Lapointe et al. (2009)	1854 (59)	<35 Years: 10.19%, 35–44 years: 38.61%, 45–60 years: 51.18%	76.2	3 Years (93), 7.0% (M)/11.1% (F)	Pain, ache, or discomfort with related functional limitation in the last 6 months (6-month)	Multivariate OR adjusted for age, social support, personality, self-assessed health status, psychological distress, and symptoms to other body regions
	Lapointe et al. (2013)	1681 (58.5)	<35 Years: 10.2%, 35–44 years: 39.8%, 45–60 years: 50.1%				
Cohort 5, Denmark	Brandt et al. (2004)	6943 (63.9)	41.7 Years ± 8.9	73.2	1 Year (81.5), 1.5%	At least moderate pain lasting more than 7 days (12 months)	Multivariate HR adjusted for psychosocial, and individual factors

Table 1 (continued)

Study no. countries	Authors	Sample size (F %)	Age (years)	Participation rate (%)	Follow-up duration (FR%), incidence rate	Outcome definition (pain-free duration prior to baseline for study inclusion)	Statistical model, investigated covariates
	Andersen et al. (2008)	2146 (73.9)	M 42 Years ± 9, F 42 years ± 8	31	1 Year (83.6), 0.00306 per week/1-year (prolonged pain), 2.02% (chronic pain)	Prolonged pain: Average of pain great than 4 out of 7 VAS in the consecutive 3 weeks(4 weeks)	Prolonged pain: Multivariate (continuous variables) HR(prolonged pain) adjusted for psychosocial, ergonomic, individual factors
Cohort 6, Netherland	Ijmker et al. (2011) Huysmans et al. (2012a, b)	1951 (43,4)	41.4 Years ± 9.6	27	2 Years (51.9), 27%	Regular or prolonged pain exceeding 6 on VAS 0–10 or with medication use for the last 3 months (3 months)	Multivariate OR adjusted for individual, psychosocial and workplace physical factors, and leisure activity
Cohort 7, USA	Marcus et al. (2002)	585 (70.9)	<20 Years: 0.5%, 20–29 years: 39.9%, 30–39 years: 37.3%, 40–49 years: 18.2%, 50–59 years: 4.1%	66	1 Year (92), 34%	Pain with a severity of VAS 6 on 0–10 or a medication use during the preceding week (1 week)	Multivariate HR adjusted for individual and psychosocial factors, and leisure activities
Cohort 8, Finland	Korhonen et al. (2003)	232 (44)	25–43 Years: 32%, 44–51 years: 33%, 52–61 years: 35%	81	1 Year (78), 34.4%	Pain lasting more than 7 days during the preceding 12 months (12 months)	Multivariate OR adjusted for age, sex, smoking, VDU usage, psychosocial, and mental stress
Cohort 9, Thailand	Paksaichol et al. (2014)	559 (80.2)	39.2 Years ± 9, PR 51.6%	82	1 Year (96), 28%	Pain lasting more than 24h with greater than 3 VAS on 3–10 and with greater than 5 NDI score during the preceding month (3 months)	Multivariate OR adjusted for sex, history of pain, monitor height, physical job demands, and psychologic job demands
	Sitthipornvorakul et al. (2015)	387 (76.2)	20–29 Years: 24.3% 30–39 years: 49.1% 40–46 years: 26.6%	83.9	1 Year (94.8%), 16%		
Cohort 10, USA	Gerr et al. (2005)	356 (77.1)	18–24 Years: 18.8% 25–34 years: 46.1% 35–33 years: 23.5% 45–54 years: 9.7% >55 years: 1.9%	91.4	1 Year (Alternative/conventional/control: 94%/95%/96.5%), 33.3%/31%/30%	Neck symptoms with a greater than 5 VAS on 0–10 or a medication use during the preceding week (at a time of entry)	Multivariate HR adjusted for age, gender, hours keying during the previous week, and psychosocial factors

Table 1 (continued)

Study no. countries	Authors	Sample size (F %)	Age (years)	Participation rate (%)	Follow-up duration (FR%), incidence rate	Outcome definition (pain-free duration prior to baseline for study inclusion)	Statistical model, investigated covariates
Cohort 11, USA	Shahidi et al. (2015)	171 (79)	30.2 Years ± 8.3 (non-incidence group) 29.8 years ± 6.8 (incidence group)	NR	1 Year (97.7%), 21%	≥3 consecutive or non-consecutive months of interfering neck pain that interfered subject's daily activities, or prompted subject t to seek cost health care or to file a health claim (12 months)	Multivariate OR adjusted for age, sex, BMI, depression, anxiety, stress, catastrophization, job satisfaction, and job strain
Cohort 12, Thailand	Sihawong et al. (2014)	567 (50)	37.2 Years ± 10.1 (intervention group) 36.9 years ± 10.7 (control group)	81.7	1 Year (94.1)	Pain lasting more than 24 h with greater than 3 VAS on 3–10 and with greater than 5 NDI score during the preceding month (3 months)	Multivariate OR adjusted for sex, history of pain, monitor height, physical job demands, and psychologic job demands

CI 95% confidence interval, *F* female, *y* year, *FD* follow-up duration, *FR* follow-up rate, *h* hour, *HR* hazard ratio, *IP* individual physical factor, *M* male, *NR* not reported, *OR* odds ratio, *PR* participation rate, *RR* risk ratio, *VAS* visual analogue scale, *WP* workplace physical factor factors (see Table 1). The estimate of effect size (e.g. odds ratios) and the standard error of the effect size (e.g. 95% confidence intervals) for each physical factor were extracted for data synthesis. Contact with authors was made if further information regarding a study was required.

Statistical methods

The reliability of the risk of bias assessment scores between the two assessors was examined by κ Statistics using SPSS V.22 software (Chicago, IL. 2013) in which greater than 0.81 kappa value was considered as almost perfect (Landis and Koch 1977). Data management and data analysis for meta-analysis were executed with Review Manager 5.3 (The Nordic Cochrane Centre. 2014). A random effect model was chosen because of the variability between study definitions for physical factors and neck pain. The statistically significant heterogeneity among studies was assessed by Chi square value test indicating heterogeneity when p values were lower than 0.05. In addition higher I^2 values supplemented a solely expected chance of variability among studies (range 0–100%).

Studies reporting adjusted risk estimates (adjusted for relevant covariates as determined by authors and reviewers) were included in the analysis. This strategy of study selection is recommended in the Cochrane Handbook (Chap. 13. 6. 2.2. Combining studies) to minimize confounding between dependent and independent variables. Hazard ratios were reported as the common measure of risk estimate in the studies; however, odds ratios were also derived from the few studies. As odds ratio's tend to be an overestimate (odds ratio is always higher than risk ratio when the value is greater than 1, and it is always smaller than risk ratio when the value is smaller than 1) (Zhang and Yu 1998; Di Lorenzo et al. 2014), odds ratios were converted to risk ratio (RR) format for meta-analysis (Wang 2013). Hazard ratios tend to be similar to risk ratio values when calculated over a similar time period (Zhang and Yu 1998; Spruance et al. 2004; van Dooren et al. 2013; van de Vorst et al. 2016) and therefore were included in the meta-analysis. When exposure group were divided in multiple levels of exposure categories, the alternative combining method proposed by Hamling et al. (2008) was used to generate a combined risk estimate. For double reported risk estimate in different studies but from the same cohort group, the less significant risk estimate was chosen for meta-analysis. Summary statistics for the meta-analysis were, therefore, presented in the form of adjusted risk ratio with a 95% confidence intervals. Pooled risk estimates (e.g., RR) of >1 indicate negative effects of physical factors, while RR < 1 indicate positive effects of physical factors. The effect size was defined as small (<1.25 but >1 or >0.8 but <1), medium (1.25–2 or 0.5–0.08), large (>2 or <0.5) (Cohen 1988).

Pooled summary estimates were not appropriate for some physical factors due to heterogeneity between studies due to different exposure measurement use, different study period, or single study existence. For studies not included in the meta-analysis, a narrative synthesis was performed.

Strength of evidence

To determine the level of evidence for each physical factor (Van Tulder et al. 2003; McLean et al. 2010; Dowling et al. 2014) they were defined as; (1) strong evidence: pooled results obtained from three or more studies with minimum of two high quality studies (statistically homogenous) or consistent findings from narrative synthesis in multiple high-quality studies, (2) moderate evidence: statistically significant pooled results obtained from multiple studies with at least one high quality study (statistically homogenous) or consistent findings from narrative synthesis in multiple studies including at least one high quality study, (3) limited evidence: findings from one high quality study or consistent findings from multiple moderate quality study or low quality studies, (4) very limited evidence: findings from one moderate quality study or one low quality study (5) conflicting evidence: inconsistent findings with regardless of study quality, (6) no evidence: insignificant pooled results derived from multiple studies in which statistical heterogeneous found with regardless of quality.

Results

Study selection

The electronic database search yielded a total of 5952 citations (Fig. 1). Initial screening excluded 3950 citations through the identification of irrelevant key words such as animal, rheumatism, and cancer. The title and abstract of the remaining 2002 citations were screened independently by two reviewers (Kappa = 0.90; 95% CI 0.864–0.926) with 45 articles remaining for full text review. A further 25 papers were excluded when the full text articles were reviewed (kappa = 0.648; 95% CI 0.426–0.870). The remaining 20 papers described the findings of the ten prospective cohort studies (Marcus et al. 2002; Jensen 2003; Korhonen et al. 2003; Brandt et al. 2004; Wahlstrom et al. 2004; Hagberg et al. 2007; Andersen et al. 2008; Hush et al. 2009; Lapointe et al. 2009, 2013; Tornqvist et al. 2009; Ijmker et al. 2011; Huysmans et al. 2012a, b; Lindegard et al. 2012; Paksaichol et al. 2014; Shahidi et al. 2015; Sitthipornvorakul et al. 2015) and two prospective randomised controlled trial (Sihawong et al. 2014; Gerr et al.

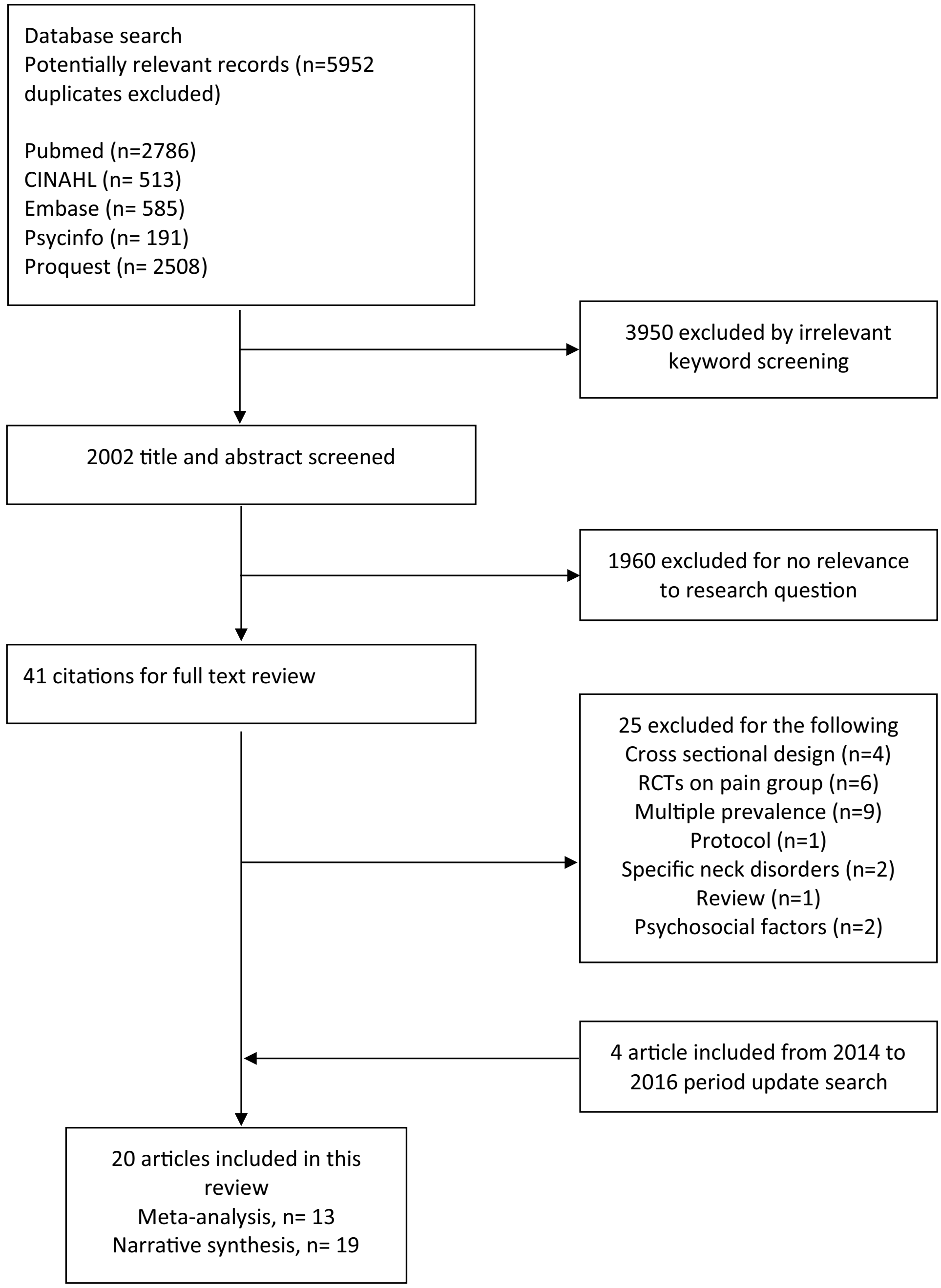

Fig. 1 Study selection procedure. Flow diagram depicting the process for selection of studies included in the systematic review

2005). Papers reporting the same cohort of participants were grouped and referenced as a single cohort as follows; cohort 1 (Wahlstrom et al. 2004; Tornqvist et al. 2009; Lindegard et al. 2012; Hagberg et al. 2007), cohort 2 (Hush et al. 2009), cohort 3 (Jensen 2003), cohort 4 (Lapointe et al. 2009, 2013), cohort 5 (Andersen et al. 2008; Brandt et al. 2004), cohort 6 (Ijmker et al. 2011; Huysmans et al. 2012a, b), cohort 7 (Marcus et al. 2002), cohort 8 (Korhonen et al. 2003), cohort 9 (Paksaichol et al. 2014; Sitthipornvorakul et al. 2015), cohort 10 (Gerr et al. 2005), cohort 11 (Shahidi et al. 2015), cohort 12 (Sihawong et al. 2014) (Table 1: Characteristics of included studies).

Description of the studies

Studies varied in terms of location, years, and population size. The publication years of included studies ranged from 2002 to 2016. Three cohort studies were conducted in USA, two in Denmark, and one each in Sweden, Australia, Canada, Netherland, Finland, and Thailand. Table 1 presents the characteristics of study population, participant rates, length / frequency of follow-up, and drop-out rates. The number of office workers in the studies ranged from 53 (Hush et al. 2009) to 6943 (Brandt et al. 2004) participants. Four cohort studies enrolled more than 1000 subjects, and five cohort studies achieved more than 200 subjects. The lowest participation rate was 27% (cohort 6); however, the majority of studies (63.6%) achieved more than 50% participation rates. The shortest follow-up period was 10 months (cohort1) and the longest follow-up period was 3 years (cohort 4). Multiple follow-up methods (e.g., monthly or weekly) were chosen by cohort 1, cohort 2, cohort 5, cohort 6, cohort 7, cohort 9, cohort 10, cohort 11, and cohort 12 for the outcome measure. The follow-up response rate in the studies ranged from 51% (cohort 6) to 100% (cohort 2).

Risk of bias

Risk of bias assessment using the EAI showed the majority of the studies rated as high quality. Thirteen studies of the included 20 studies were rated as high quality (Marcus et al. 2002; Jensen 2003; Korhonen et al. 2003; Gerr et al. 2005; Lapointe et al. 2009, 2013; Ijmker et al. 2011; Huysmans et al. 2012a, b; Paksaichol et al. 2014; Sihawong et al. 2014; Shahidi et al. 2015; Sitthipornvorakul et al. 2015), and seven studies were classified as moderate quality (Hush et al. 2009; Brandt et al. 2004; Wahlstrom et al. 2004; Hagberg et al. 2007; Andersen et al. 2008; Tornqvist et al. 2009; Lindegard et al. 2012). The quality scores ranged from 1.11 to 1.76 (out of a possible score of 2.0) (see "Appendix B"). The inter-rater reliability of the two assessors overall (all 860 decisions) demonstrated substantial agreement ($\kappa = 0.69$, 95% CI 0.65–0.74) (Landis and Koch 1977). Over each of the 43 items, 20 items had perfect agreement (>80%), 18 items had substantial agreement (61–80%), and 5 items had moderate agreement (41–60%; item 19, 21, 25, 26 and 42, 43) ("Appendix B": Results of quality assessment).

Measurement of physical risk factors (workplace and individual worker)

The physical risk factors identified from included studies are reported in Table 2. Nine cohort studies and one RCT reported a relationship between at least one workplace physical factor and the onset of neck pain, and seven cohort studies and another RCT showed a relationship between the individual worker physical factors and neck pain. Self-report questionnaires were the most widely used measurement of physical risk factors (cohorts 1–6, 8–9). Six cohort studies (cohorts 2, 5, 6, 7, 9, 11) objectively measured individual worker and workplace physical factors (isometric muscle endurance, cervical range of motion, and neurophysiological deficient, working posture, and duration of computer device use). It should be noted that while most studies account for psychosocial factors as covariates in analysis, two cohorts (cohort 4 and 9) use combined risk categories (e.g., high postural risk/high job strain) in their final regression models.

Identification of a new episode of neck pain

There was large variation between studies in the definition of a new episode of neck pain (Table 1: Characteristics of included studies). Identification of a new episode of neck pain was defined by self-reported neck pain intensity level (e.g., pain greater than 3 on a 0–10 pain scale or medication use for relief) in three cohorts (cohorts 6, 7, 10) with two of these cohorts additionally confirming pain localized to the cervical spine via a physical examination (cohorts 7, 10). A new episode of neck pain was defined by self-reported duration of neck pain (e.g., pain lasting more than 7 days during preceding year) in four cohorts (cohort 1, 2, 3, 8), and by a combination of duration and intensity of neck pain in other cohorts (cohort 9 and 12—pain lasting more than 24 h with greater than 3 on a 0–10 pain scale). Functional limitations associated with neck pain were also used to define an episode of neck pain in two cohorts (cohort 4, 11).

Statistics describing risk associated with physical variables and the onset of neck pain

Five cohorts reported adjusted Hazard Ratios (cohorts 1, 2, 5, 7, 10) for the time-dependent risk of physical factors and the onset of neck pain. Seven cohorts reported adjusted Odds Ratio (cohorts 3, 4, 6, 8, 9, 11, 12) or for the cumulative absolute risk of physical factors for the onset of neck pain.

Meta-analysis

Eight cohorts (cohorts 1–3, 5–7–9) were included in the meta-analysis and pooled summary estimates of risk factors for the development of neck pain in office workers were calculated for variables; satisfaction/comfort of work environment, screen height, close keyboard position, insufficient work breaks, duration of mouse use, duration of keyboard use, duration of computer use, low work task variation and self-perceived muscular tension.

Workplace physical factors

The summary of pooled risk ratio for eight workplace physical factors are reported in Table 2. Three significant relationships were found for workplace physical factors. Specifically, an increased risk of developing neck pain in those with lower satisfaction/comfort with their workplace environment (Pooled RR 1.28 (CI 1.07–1.55), I^2 0%) (Fig. 2.1) (Korhonen et al. 2003; Tornqvist et al. 2009; Huysmans et al. 2012a), and close keyboard position to the body (RR 1.46 (CI 1.07–1.99), I2 0%) (Fig. 2.2) (Korhonen et al. 2003; Marcus et al. 2002) were found. Another meta-analysis showed that low work task variation to have a medium adverse effect on the development of neck pain (RR 1.27 (CI 1.08–1.50),

Table 2 Risk Association between physical factors and the development of neck pain in office workers in included studies

Physical factors	Studies (level of study quality)	Level of exposures		Risk ratio	Confidence intervals		Result in meta-analysis		Effect (size)	Strength of evidence
Workplace physical factors										
		Unexposed (Ref.)	Exposed	Risk estimation	Lower	Upper	Pooled RR	95% CI		
Satisfaction/comfort of workplace environment	Tornqvist et al. (2009) (M)	Medium or High comfort work environment (> 3 score in range −44 to + 44)	Low comfort of the computer work environment (≤2 scale)	RR 1.39*	1.06	1.82	RR 1.28	1.07–1.55	Adverse effect (medium)	Strong
	Huysmans et al. (2012a) (H)	Comfortable work at desk	Uncomfortable work at desk	RR 1.10	0.82	1.48				
	Korhonen et al. (2003) (H)	Satisfaction with work environment (>3 score in range 0 to 5)	Score ≤3	RR 1.59	0.93	2.72				
Close keyboard position	Marcus et al. (2002) (H)	Distance from table edge to "J" key (>17 cm)	Distance from table edge to "J" key (≤17 cm)	HR 1.36	0.85	2.18	RR 1.46	1.07–1.99	Adverse effect (medium)	Moderate
	Korhonen et al. (2003) (H)	Distance for the keyboard from the table edge (≥15 cm)	Distance for the keyboard from the table edge (<15 cm)	RR 1.64*	1.0	2.68				
Screen height	Jensen (2003) (H)	Lower than eye level	Screen height above eye level (women)	RR 1.28	0.96	1.72	RR 1.12	0.88–1. 42	No effect	Moderate
	Huysmans et al. (2012a) (H)	At or lower than eye level	Screen height above eye level	RR 1.00	0.79	1.28				
Chair adjustment	Paksaichol et al. (2014) (H)	Adjustable chair	Non-adjustable chair	OR 1.80*	1.16	2.81	–		Adverse effect	Limited
Chair arm rest	Korhonen et al. (2003) (H)	Absence of chair armrest	Presence of chair armrest	HR 0.80	0.53	1.20	–		No effect	Limited
Arm support during keyboard work	Huysmans et al. (2012a) (H)	None	Supporting arms during keyboard use	OR 1.7*	1.2	2.4	–		Adverse effect	Limited
Placement of mouse	Tornqvist et al. (2009) (M)	Optimal	Non-optimal	HR 0.94	0.74	1.20	–		No effect	Very limited

Table 2 (continued)

Physical factors	Studies (level of study quality)	Level of exposures		Risk ratio	Confidence intervals		Result in meta-analysis	Effect (size)	Strength of evidence
Space for mouse use	Huysmans et al. (2012a) (H)	Enough space for mouse use	Restricted space for mouse use	OR 1.1	0.9	1.3	–	No effect	Limited
Comprehensive postural risk	Lapointe et al. (2009) (H)	Low postural risk (>2.5 score in range of 0 to 6) × Low and high job strain (men)	High postural (≤2.5 score) × Low and high job strain	OR 2.01*	1.0	4.04	–	Adverse effect	Limited
		Low postural risk (>2.5 score in range of 0 to 6) × Low and high job strain (women)	High postural (≤2.5 score) × Low and high job strain	OR 1.00	0.65	1.53	–	No effect	Limited
Combined postural risk + job strain	Lapointe et al. (2009) (H)	Low postural risk (>2.5 score in rage of 0 to 6) × Low job strain (men)	High postural (≤2.5 score in rage of 0 to 6) × High job strain	OR 2.94	0.97	8.94	–	No effect	Limited
		Low postural risk (>2.5 score in rage of 0 to 6) × Low job strain (women)	High postural (≤2.5 score in rage of 0 to 6) × High job strain	OR 3.38*	1.58	7.22	–	Adverse effect	Limited
Combined ER imbalance + postural risk	Lapointe et al. (2013) (H)	Low postural risk (>2.5 score in rage of 0 to 6) × Balance effort-reward (men)	High postural (≤2.5 score in rage of 0 to 6) × Imbalance effort-reward	OR 1.85	0.65	5.23	–	No effect	Limited
		Low postural risk (>2.5 score in rage of 0 to 6) × Balance effort-reward (Women)	High postural (≤2.5 score in rage of 0 to 6) × Imbalance effort-reward	OR 2.27*	1.14	4.51	–	Adverse effect	Limited

Table 2 (continued)

Physical factors	Studies (level of study quality)	Level of exposures		Risk ratio	Confidence intervals		Result in meta-analysis	Effect (size)	Strength of evidence
Keyboard elbow angle per hours of typing (°/hours)	Marcus et al. (2002) (H)	≤121° inner elbow angle when typing	>121° inner elbow angle with regardless of hours of typing	HR 0.16*	0.04	0.62	–	Prevention effect	Limited
			>121° inner elbow angle when 10 h typing per week	HR 0.27	Not reported				
			>121° inner elbow angle when 20 h typing per week	HR 0.44	Not reported				
			>121° inner elbow angle when 30 h typing per week	HR 0.72	Not reported				
Mouse elbow angle (°)	Marcus et al. (2002) (H)	≤137° inner elbow angle when mouse use	137° to 148°	HR 1.67*	1.09	2.55	–	Adverse effect	Limited
			>148°	HR 0.94	0.56	1.59			
Keyboard height (distance)	Marcus et al. (2002) (H)	Elbow height is lower than keyboard level (≤0 cm)	Elbow is higher than keyboard level (>0 cm)	HR 1.42	0.96	2.10	–	No effect	Limited
Keyboard shoulder abduction angle (°)	Marcus et al. (2002) (H)	≤10° shoulder abduction angle when typing	11° to 14°	HR 1.12	0.69	1.82	–	No effect	Limited
			15° to 17°	HR 0.88	0.46	1.59			
			>17°	HR 0.94	0.54	1.63			
Keyboard shoulder flexion angle (°)	Marcus et al. (2002) (H)	≤22° shoulder flexion angle when typing	23° to 28°	HR 1.41	0.85	2.34	–	No effect	Limited
			29° to 35°	HR 1.16	0.69	1.96			
			>35°	HR 0.73	0.40	1.31			
Mouse shoulder abduction angle (°)	Marcus et al. (2002) (H)	≤21° shoulder abduction angle when mouse use	22° to 27°	HR 0.80	0.48	1.34	–	No effect	Limited
			28° to 33°	HR 0.89	0.52	1.53			
			>33°	HR 1.12	0.67	1.86			
Mouse shoulder flexion angle (°)	Marcus et al. (2002) (H)	≤25° shoulder flexion angle when mouse use	26° to 234°	HR 1.29	0.75	2.22	–	Adverse effect	Limited
			35° to 44°	HR 1.73*	1.00	2.98			
			>44°	HR 1.28	0.72	2.26			
Monitor head angle (°)	Marcus et al. (2002) (H)	>3° head tilt angle	≤3° head tilt angle	HR 1.58	0.94	2.65	–	No effect	Limited

Table 2 (continued)

Physical factors	Studies (level of study quality)	Level of exposures		Risk ratio	Confidence intervals		Result in meta-analysis	Effect (size)	Strength of evidence
Monitor head rotation angle (°)	Marcus et al. (2002) (H)	≤10° head rotation on monitor or document	>10° head rotation	HR 1.17	0.75	1.84	–	No effect	Limited
Telephone shoulder rest use	Marcus et al. (2002) (H)	Absence of telephone shoulder rest	Presence of telephone shoulder rest	HR 2.05*	1.14	3.71	–	Adverse effect	Limited
Phone use while working	Huysmans et al. (2012a) (H)	No computer and Phone use at the same time	Sometime/often/always	OR 1.2	0.9	1.6	–	No effect	Limited
Physical work load other than computer work (hands squeezing/carrying load/raising hands)	Huysmans et al. (2012a) (H)	Never/sometimes firmly squeezing with hands	Often/always	RR 1.2	0.7	2.2	–	No effect	Limited
		Never carrying loads >5 kg	Sometimes/often/always	RR 1.0	0.8	1.3			
		Never working with hands above height	Sometimes/often/always	OR 0.9	0.7	1.1			
Postural ergonomic intervention	Gerr et al. (2005) (H)	Control (no intervention)	Alternative intervention (Postural + ergonomic treat)	HR 1.07	0.64	1.80	–	No effect	Limited
			Conventional intervention (Basic recommendation)	HR 1.00	0.60	1.68			
Computer skill	Jensen (2003) (H)	Very good computer skills	Good	OR 1.3	0.7	2.5	–	No effect	Limited
			Less than good	OR 0.4	0.2	1.1			
Ergonomic use technique	Lindegard et al. (2012) (M)	≥14 overall scores in range 1 to 22 (good working technique)	12 to 13 score (acceptable)	HR 1.06	0.77	1.43	–	No effect	Very limited
			<12 score (poor)	1.03	0.67	1.51			

Table 2 (continued)

Physical factors	Studies (level of study quality)	Level of exposures		Risk ratio	Confidence intervals		Result in meta-analysis		Effect (size)	Strength of evidence
Duration of mouse use (self-reported)	Tornqvist et al. (2009) (M)	≥3 h of mouse use per day	<3 h	RR 0.80*	0.67	0.95	RR 1.05	0.70–1.75	No effect	Strong
	Huysmans et al. (2012a) (H)	≥4 h of mouse use per day	<4 h	RR 1.36*	1.1	1.68				
	Andersen et al. (2008) (M)	≥20 h mouse use per week	<3 h	RR 2.4	0.8	6.8				
	Jensen (2003) (H)	<50% time of work for mouse use	>50%	OR 1.7	0.5	5.7	–		No effect	
Duration of mouse (software programme)	Andersen et al. (2008) (M)	Recorded inter-quartile range	Per unit	HR 1.01	0.97	1.06	–		No effect	Moderate
	Ijmker et al. (2011) (H)	<5 h of recorded mouse use per week	5 to <7	RR 0.8	0.6	1.1				
			7 to 22	RR 0.8	0.6	1.1				
Mouse speed (software programme)	Andersen et al. (2008) (M)	Mouse 25 clicks per min	Per unit	HR 0.84	0.63	1.12	–		No effect	Very limited
Mouse activity (software programme)	Andersen et al. (2008) (M)	Mouse average activity periods per 10 min	Per unit	HR 1.02	0.92	1.13	–		No effect	Very limited
Mouse break (software programme)	Andersen et al. (2008) (M)	Micro-pauses per minute	Per unit	HR 0.96	0.75	1.24	–		No effect	Very limited evidence
Duration of keyboard use (self-reported)	Tornqvist et al. (2009) (M)	<3 h of data/text entry per day	≥3 h	RR 1.0	0.68	1.46	RR 1.20	0.71–2.03	No effect	Limited
	Brandt et al. (2004) (M)	<15 h of keyboard use per week	≥15 h	RR 1.78	0.82	3.87				
Duration of keyboard use (software programme)	Ijmker et al. (2011) (H)	<2 h of recorded keyboard use per week	2 to 3	RR 1.1	0.8	1.6	–		No effect	Moderate
			3 to 13	RR 1.0	0.7	1.4				
	Brandt et al. (2004) (M)	Recorded inter-quartile range	Per unit	RR 1.08	0.80	1.47				
Keyboard speed (software programme)	Brandt et al. (2004) (M)	100 keystrokes per min	Per unit	HR 0.85	0.80	1.47	–		No effect	Very limited

Table 2 (continued)

Physical factors	Studies (level of study quality)	Level of exposures		Risk ratio	Confidence intervals		Result in meta-analysis		Effect (size)	Strength of evidence
Keyboard activity (software programme)	Brandt et al. (2004) (M)	Mouse average activity periods per 2 min	Per unit	HR 1.06	0.96	1.16	–		No effect	Very limited
Keyboard break (software programme)	Brandt et al. (2004) (M)	Micro-pauses per minute	Per unit	HR 0.95	0.84	1.07	–		No effect	Very limited
Duration of computer use (self-reported)	Tornqvist et al. (2009) (H)	<4 h of computer use per day	≥4 h	RR 1.03	0.77	1.38	RR 1.07	0.91–1.24	No effect	Strong
	Ijmker et al. (2011) (H)	<4 h of computer use per day	≥4 h	RR 1.08	0.90	1.30				
	Jensen (2003) (M)	0–25% of work time in computer use	50%	OR 1.5	0.7	3.1	–			
			75%	OR 1.3	0.6	2.7				
			100%	OR 1.6	0.8	3.3				
Duration of computer (software programme)	Ijmker et al. (2011) (H)	1 to <10 h of computer use per week	10 to <14 h	RR 1.2	0.8	1.6	–		No effect	Limited
			14 to 36 h	RR 0.8	0.6	1.1				
Duration of total computer use during leisure time	Huysmans et al. (2012a) (H)	Never use computer during leisure time	>0 h of computer use	OR 0.9	0.7	1.0	–		No effect	Limited
Less break time	Tornqvist et al. (2009) (M)	<2 h of continuous work before break	2–3 h of hours daily or <3 h few times per week, and >3 h at least a few times per week	RR 1.18	0.94	1.50	RR 1.13	0.92–1.39	No effect	Moderate
	Hush et al. (2009) (M)	<1 h of sitting before break	≥1 h of sitting before break	RR 0.49	0.20	1.20				
	Huysmans et al. (2012a) (H)	Formal break	Continuation work during formal break	RR 1.18*	1.03	1.35				
Break reminder	Huysmans et al. (2012a) (H)	Use of break and reminder software	None	OR 0.9	0.7	1.0	–		No effect	Limited

Table 2 (continued)

Physical factors	Studies (level of study quality)	Level of exposures		Risk ratio	Confidence intervals		Result in meta-analysis		Effect (size)	Strength of evidence
Low work task variation	Tornqvist et al. (2009) (M)	High work task variation (≥5 work tasks lasting longer than half an hour)	<5 work tasks	RR 1.14	0.77	1.70	RR 1.27	1.08–1.50	Medium Adverse effect	Moderate
	Huysmans et al. (2012a) (H)	High work task variation (0 to 3 score in range 0 to 12 score)	4 to 12 score	RR 1.3*	1.09	1.56				
Repetitive/precision work	Wahlstrom et al. (2004) (M)	Low exposure to precision and repetitive work	Medium exposure	HR 1.4	0.99	2.01	–		No effect	Moderate
			High exposure	HR 1.3	0.8	2.03				
	Huysmans et al. (2012a) (H)	0 to 4 score for high precision work during mouse use	≥4 score	RR 0.9	0.6	1.3				
Repetitive movement during non-computer work	Huysmans et al. (2012a) (H)	No repetitive movements with hands(excluding computer use)	Sometimes, often or always	OR 1.5*	1.1	1.9	–		Adverse effect	Limited
Individual worker physical factors										
Medium muscular tension	Huysmans et al. (2012b) (H)	Never tensed	Sometimes muscular tension	RR 2.78*	1.88	4.11	RR 1.82	1.14–2.90	Large adverse effect	Strong
	Paksaichol et al. (2014) (H)	Low muscular tension	Medium muscular tension	RR 1.65*	1.03	2.64				
	Wahlstrom et al.(2004) (M)	Low muscular tension	Medium muscular tension	RR 1.3	0.88	1.91				
High muscular tension	Huysmans et al. (2012b) (H)	Never tensed	Often tensed	RR 4.13*	2.75	6.20	RR 2.75	1.60–4.72	Large adverse effect	Strong
	Paksaichol et al. (2014) (H)	Low muscular tension	High muscular tension	RR 3.08*	2.02	4.71				
	Wahlstrom et al. (2004) (M)	Low muscular tension	High muscular tension	RR 1.6*	1.02	2.51				

Table 2 (continued)

Physical factors	Studies (level of study quality)	Level of exposures		Risk ratio	Confidence intervals		Result in meta-analysis	Effect (size)	Strength of evidence
Frequent physical activities during leisure time	Hush et al. (2009) (M)	<3 times of exercise per week	≥3 times	HR 0.64	0.27	1.51	–	No effect	Strong
	Brandt et al. (2004) (M)	None or <2 h of light physical activity per week, or 2 to 4 h of light physical activity per week	>4 h of light physical activity per week, 2 to 4 h of hard physical activity per week, or >4 h of hard physical activity per week	HR 1.3	0.8	2.2			
	Huysmans et al. (2012a) (H)	<1 time of playing sports involving upper extremity (excluding golf)	≥1 time per week	RR 1.0	0.8	1.2			
	Korhonen et al. (2003) (H)	≤1 h	≥2 h of physical activity per week	OR 1.25	0.37	5.0			
	Shahidi et al. (2015) (H)	Leisure activity score in range 3 to 15	Per score	OR 0.44*	0.21	0.89			
Combined Mental stress + Frequency of physical exercise	Korhonen et al. (2003) (H)	None mental stress × ≥2 times of physical exercise per week	Some/fairly much/ much mental stress × ≤1 time of physical exercise per week	OR 6.7	1.0	43.6	–	Adverse effect	Limited
Daily walking steps (per 1000 steps)	Sitthipornvorakul et al. (2015) (H)	Total number of steps divided by 1000 steps	Per unit	OR 0.86	0.74	1.00	–	No effect	Limited
Cervical flexion–extension (total range,°)	Hush et al. (2009) (M)	Active range of cervical total flexion–extension degree (°)	Per degree	HR 0.97*	0.94	0.97	–	Prevention effect	Very limited
Cervical lateral flexion (total range,°)	Hush et al. (2009)(M)	Active range of cervical lateral flexion degree (°)	Per degree	HR 1.01	0.99	1.03	–	No effect	Very limited

Table 2 (continued)

Physical factors	Studies (level of study quality)	Level of exposures		Risk ratio	Confidence intervals		Result in meta-analysis	Effect (size)	Strength of evidence
Cervical extensor endurance (s)	Shahidi et al. (2015) (H)	Time of isometric cervical extensor endurance (s)	Per second	OR 0.92*	0.87	0.97	–	Prevention effect (small)	Limited
DNIC (%)	Shahidi et al. (2015) (H)	Diffuse noxious inhibitory control (%)	Per unit	OR 0.90*	0.83	0.98	–	Prevention effect (small)	Limited
Specified cervical muscle exercise	Sihawong et al. (2014) (H)	Control group	Intervention group (muscle stretching and endurance)	HR 0.45*	0.28	0.71	–	Prevention effect (large)	Limited

The crude risk estimates or initial adjusted risk estimates the studies were not present

H high quality study, *HR* hazard ratio, *OR* odds ratio, *M* moderate quality study, *RR* risk ratio

*$P<0.05$

$I^2=0\%$) (Tornqvist et al. 2009; Huysmans et al. 2012a). However, screen height above eye level showed no significant effect on the development of neck pain (polled OR of 1.12 (CI 0.88–1.42), I^2 37%) (Jensen 2003; Huysmans et al. 2012a). Another four meta-analyses included workplace physical factors (duration of computer use, mouse use, keyboard use, and work break time) showing no effect on the development of neck pain (Fig. 2.4–7) (Brandt et al. 2004; Tornqvist et al. 2009; Huysmans et al. 2012a, b).

Individual worker physical factors

High or medium self-perceived muscular tension during computer use had a large adverse effect on the development of neck pain (High tension: RR of 2.75 (CI 1.60–4.72), I^2 74%; medium tension: RR of 1.82 (CI 1.14–290), I^2 79%) (Fig. 3) and these findings were concluded as strong evidence (Wahlstrom et al. 2004; Huysmans et al. 2012b; Paksaichol et al. 2014).

Narrative synthesis for studies not included in meta-analysis

Workplace physical factors

Moderate evidence for each long duration of mouse use and keyboard use (recorded by a software programme) were concluded showing no effect on the development of neck pain (Brandt et al. 2004; Andersen et al. 2008; Ijmker et al. 2011). Another moderate evidence was found for the performance of repetitive or precision work on the development of neck pain, however the association was not significant (Wahlstrom et al. 2004; Huysmans et al. 2012a). Majority of workplace physical factors, e.g., placement of mouse, and chair arm rest, were investigated by a single study, resulted in limited evidence for its risk relationship with neck pain (Table 2).

Individual worker physical factors

There was strong evidence for the frequency of physical activity in leisure time showing no effect on the development of neck pain (Korhonen et al. 2003; Brandt et al. 2004; Hush et al. 2009; Huysmans et al. 2012a; Shahidi et al. 2015). Although a large prevention effect of frequent leisure activity on the development of neck pain (OR 0.44 CI 0.21–0.089) was reported in one study (Shahidi et al. 2015), another four studies found no effect of leisure activity on the development of neck pain (Korhonen et al. 2003; Brandt et al. 2004; Hush et al. 2009; Huysmans et al. 2012a) (Table 2). The effect of physical condition of worker was investigated by only two cohorts (cohort 2 and cohort 11) that reported greater range of cervical flexion/extension motion (HR 0.97 CI 0.94–0.97) (Hush et al.

2009), longer isometric cervical extensor endurance (OR 0.92 CI 0.87–0.97), efficient diffuse noxious inhibitory control (OR 0.90 CI 0.83–0.98) (Shahidi et al. 2015), and specified cervical muscle endurance exercise (HR 0.45 CI 0.28–0.71) (Tornqvist et al. 2009) had prevention effect on the development of neck pain (Table 2). However, those relationships were concluded as limited or very limited evidence due to insufficient number of studies.

Discussion

The findings of the meta-analysis indicate that self-perceived muscular tension, low levels of satisfaction/comfort with workplace environment, close keyboard position to the body, as well as low task variation, represented significant physical risk factors for the development of neck pain in office workers. However, a series of meta-analyses revealed no association between longer duration of computer device use (mouse and keyboard), break time and the development of neck pain. This finding of no effect of prolonged computer use is supported by the finding from the narrative synthesis in this review (software programme analysis). The strong evidence for the frequency of physical activity is derived from the narrative synthesis reporting no effect on the development of neck pain.

Comparison with previous reviews and literatures

A number of reviews with general or working populations have identified risk factors for neck pain (Hales and Bernard 1996; Ariens et al. 2000; McLean et al. 2010; Paksaichol et al. 2012), but only two of them were specifically related to the development of neck pain (McLean et al. 2010; Paksaichol et al. 2012) and only one depicted office worker focused risk factors (Paksaichol et al. 2012). The meta-analysis in this review has revealed new findings with evidence for physical risk factors previously considered as limited in previous reviews.

The strongest relationship with the development of neck pain in this review was self-perceived high muscular tension. This evidence was limited in a previous review due to fewer studies that have investigated this risk factor (Paksaichol et al. 2012). The evidence is further supported by a series of cross-sectional studies which have reported that perceived general tension, encompassing tensed muscles, sweating, hard breathing, and stomach tension, was associated with neck and shoulder symptoms (Vasseljen and Westgaard 1995; Vasseljen et al. 2001; Holte and Westgaard 2002). However, the authors of this review suggest this risk of self-perceived muscular tension for the development of neck pain is difficult to interpret. An intervention study from the same research team found that the physiotherapy and exercise intervention recorded significant reduction of pain and perceived general tension levels compared to pre-intervention, but unchanged muscle activity levels (EMG signals) in shoulder region (Vasseljen et al. 1995). One of their findings also indicated that the perceived tension increased during work and decreased during leisure time with similar time course changes for perceived stress (Holte and Westgaard 2002). This closer association to psychological stress (mental stress) rather than biological stress (EMG) may support that the perceived general tension correlates with individual psychosocial factors (Vasseljen and Westgaard 1995; Hales and Bernard 1996). Therefore, we contend that reported self-perceived muscular tension is a symptom, commonly reported in association with neck pain and raised level of mental stress, which may explain its strong relationship with the dependent variable of neck pain. It is acknowledged, however, that it may be a physical precursor to a more significant neck problem which may prompt the individual to seek remediation.

Low satisfaction or comfort with the workplace environment was also identified by the meta-analysis to have a medium adverse effect for the development of neck pain in office workers. The workplace environment was rated by workers and dichotomized into “unsatisfied” and “satisfied” using the total score from each component (e.g., lighting condition, room temperature, quality of the air, size of the working room, and acoustic conditions). This factor has been identified in previous reviews as potentially problematic but no definitive conclusions could be made due to a lack of study (Paksaichol et al. 2012). This review found strong evidence with two high quality studies and one moderate quality study for low satisfaction with ones workplace as a risk factor. Despite this finding, the validity of this subjective rating by subjects is questionable. Only one of the three studies used a validated tool to measure level of satisfaction to workstation environment and therefore may have resulted in a biased estimate. Future studies using validated measures are required to confirm this result however it does highlight the potential importance of the work environment as a predictor for the development of neck pain.

In this review, having the keyboard close to the body (less than 15 cm) was revealed as a moderate evidence which was reported as limited evidence in the previous review (Paksaichol et al. 2012). This finding is supported by several studies. Kotani et al. found that having the keyboard close to the body required greater ulnar deviation, wrist flexion, shoulder elevation, internal shoulder rotation and greater elbow flexion (Kotani et al. 2007). This altered position of upper arm may potentially create discomfort at the shoulder/neck region. The narrow space on the desk due to close keyboard position is also associated with the limited area of support for the upper arms on the desk, enabling the user to generate less torque for shoulder abduction and flexion during typing task (Onyebeke

Figure 2.1 Satisfaction/comfort of work environment as a workplace physical risk factor for the development of neck pain (adjusted pooled risk ratio by random effect model)

Study or Subgroup	log[Risk Ratio]	SE	Weight	Risk Ratio IV, Random, 95% CI	Year
Korhonen et al., 2003	0.4631	0.275	11.9%	1.59 [0.93, 2.72]	2003
Tornqvist et al., 2009	0.3274	0.1373	47.9%	1.39 [1.06, 1.82]	2009
Huysmans et al., 2012 a	0.0953	0.1499	40.2%	1.10 [0.82, 1.48]	2012
Total (95% CI)			**100.0%**	**1.28 [1.07, 1.55]**	

Heterogeneity: Tau² = 0.00; Chi² = 1.98, df = 2 (P = 0.37); I² = 0%
Test for overall effect: Z = 2.63 (P = 0.008)

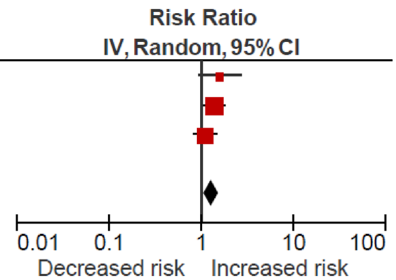

Figure 2.2 Close keyboard position as a workplace physical factor for the development of neck pain (adjusted pooled risk ratio by random effect model)

Study or Subgroup	log[Risk Ratio]	SE	Weight	Risk Ratio IV, Random, 95% CI	Year
Marcus et al., 2002	0.3075	0.2398	42.9%	1.36 [0.85, 2.18]	2002
Korhonen et al., 2003	0.4318	0.2078	57.1%	1.54 [1.02, 2.31]	2003
Total (95% CI)			**100.0%**	**1.46 [1.07, 1.99]**	

Heterogeneity: Tau² = 0.00; Chi² = 0.15, df = 1 (P = 0.70); I² = 0%
Test for overall effect: Z = 2.41 (P = 0.02)

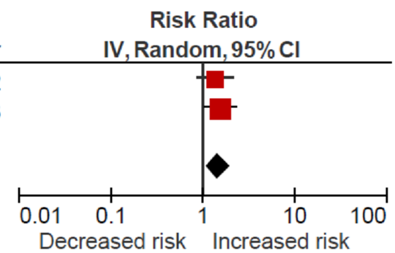

Figure 2.3 Screen height as a workplace physical factor for the development of neck pain (adjusted pooled risk ratio by random effect model)

Study or Subgroup	log[Risk Ratio]	SE	Weight	Risk Ratio IV, Random, 95% CI	Year
Jenson. 2003	0.2484	0.15	44.0%	1.28 [0.96, 1.72]	2003
Huysmans et al., 2012 a	0.003	0.1237	56.0%	1.00 [0.79, 1.28]	2012
Total (95% CI)			**100.0%**	**1.12 [0.88, 1.42]**	

Heterogeneity: Tau² = 0.01; Chi² = 1.59, df = 1 (P = 0.21); I² = 37%
Test for overall effect: Z = 0.91 (P = 0.36)

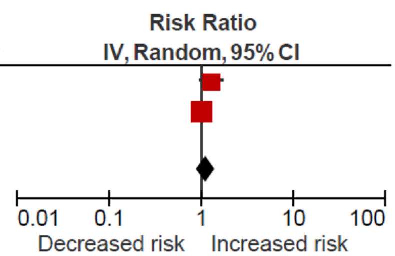

Figure 2.4 Duration of mouse use (self-reported) as a workplace physical factor for the development of neck pain (adjusted pooled risk ratio by random effect model)

Study or Subgroup	log[Risk Ratio]	SE	Weight	Risk Ratio IV, Random, 95% CI	Year
Jenson. 2003	0.0931	0.3258	21.6%	1.10 [0.58, 2.08]	2003
Tornqvist et al., 2009	-0.226	0.0898	39.8%	0.80 [0.67, 0.95]	2009
Huysmans et al., 2012 a	0.3075	0.1083	38.6%	1.36 [1.10, 1.68]	2012
Total (95% CI)			**100.0%**	**1.05 [0.69, 1.60]**	

Heterogeneity: Tau² = 0.11; Chi² = 14.47, df = 2 (P = 0.0007); I² = 86%
Test for overall effect: Z = 0.23 (P = 0.82)

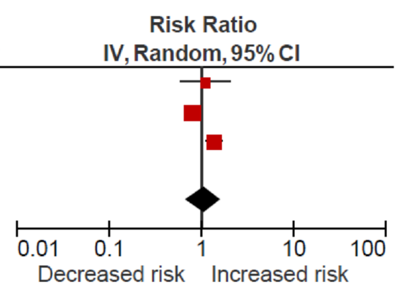

Fig. 2 *2.1–2.8* Represent risk ratio of each workplace physical factor for the development of neck pain for individual studies and pooled analysis based on random effects model. Individual risk ratio (95% CI) by each study is denoted by *rectangular box*. The pooled risk ratio for each physical factor is represented by a *diamond box*, where *diamond* width corresponds to 95% CI bounds. *Boxes* heights are inversely proportional to precision of the risk estimation. *2.1* Forest plot for the risk of low satisfaction/comfort of workplace environment on the development of neck pain from pooled analysis of three studies. *2.2* Forest plot for the risk of close keyboard position to worker's body on the development of neck pain from pooled analysis of two studies. *2.3* Forest plot for the risk of screen height above eye level compare to lower or at eye level on the development of neck pain from pooled analysis of two studies. *2.4* Forest plot for the risk of longer than 3 h of mouse use per day on the development of neck pain from pooled analysis of three studies. *2.5* Forest plot for the risk of longer than 3 h of keyboard use per day on the development of neck pain from pooled analysis of two studies. *2.6* Forest plot for the risk of longer than 4 h of computer use per day on the development of neck pain from pooled analysis of three studies. *2.7* Forest plot for the risk of prolonged work without frequent break on the development of neck pain from pooled analysis of three studies. *2.8* Forest plot for the risk of low work task variations on the development of neck pain from pooled analysis of two studies

Figure 2.5 Duration of keyboard use (self-reported) as a workplace physical risk factor for the development of neck pain (adjusted pooled risk ratio by random effect model)

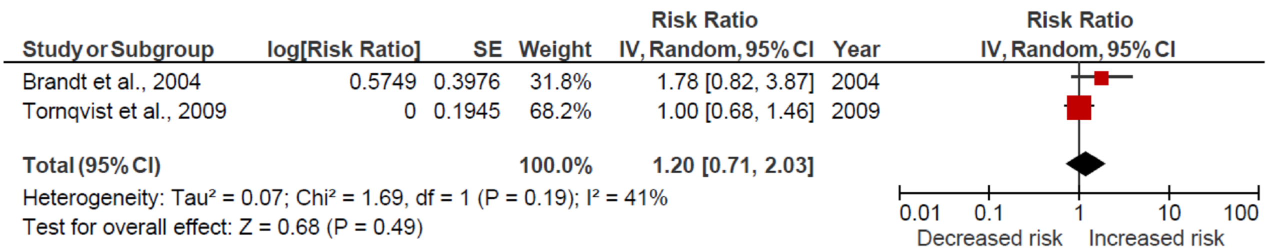

Figure 2.6 Duration of computer use (self-reported) as a workplace physical factor for the development of neck pain (adjusted pooled risk ratio by random effect model)

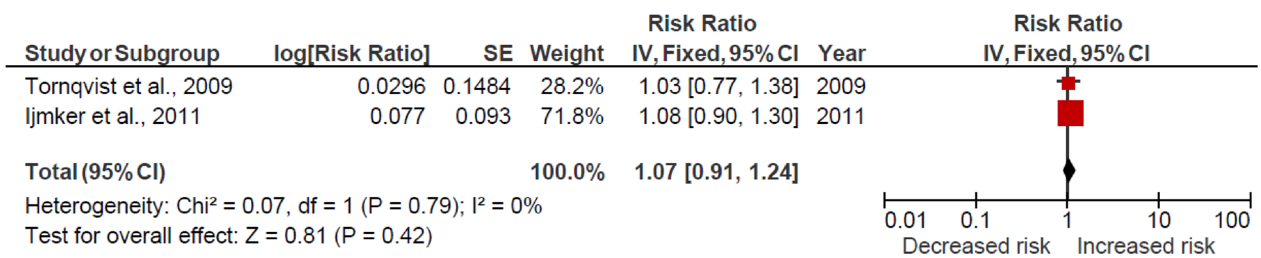

Figure 2.7 Less break time as a workplace physical factor for the development of neck pain (adjusted pooled risk ratio by random effect model)

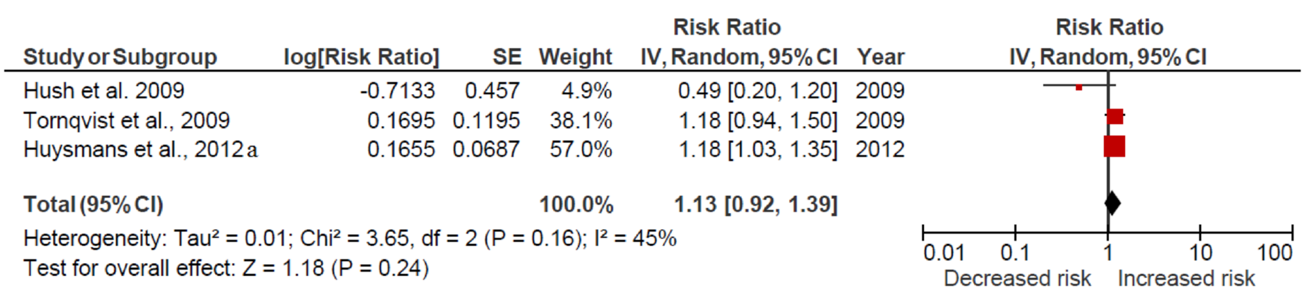

Figure 2.8 Low task variation as a workplace physical risk factor for the development of neck pain (adjusted pooled risk ratio by random effect model)

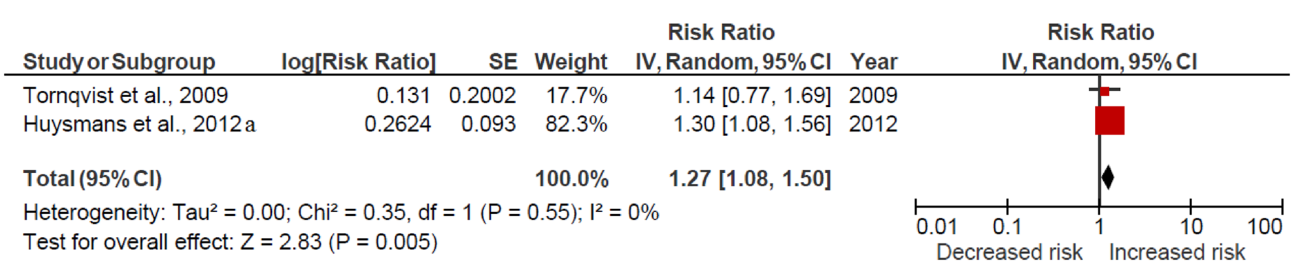

Fig. 2 (continued)

et al. 2014). A reduced incidence of neck pain (adjusted HR 0.49 CI 0.24–0.97) and significant reduction of right upper extremity discomfort were reported in an intervention group of workers being addressed a wide arm-board to support the forearms during computer work (Rempel et al. 2006; Conlon et al. 2008). Additionally, Marcus et al. in this review, characterized placement of computer devices in relation to body posture. They found that a specific angular posture may decrease or increase the risk of new episode of neck pain. For example, greater than 121° inner elbow angle when typing was shown to be less likely develop a new onset of neck pain (adjusted HR 0.16 CI 0.04–0.62) while smaller than 137° inner elbow angle when mouse use more likely develops the new onset of neck pain (adjusted HR 1.67 CI 1.09–2.55). Taken together, inadequate equipment location can negatively impact on the working posture of sufficient intensity to induce new onset of neck pain.

Low work task variation during the working day was firstly revealed as a risk factor for the development of neck pain in this review (Tornqvist et al. 2009; Huysmans et al. 2012a). Although computer work is regarded as a ubiquitous task in a similar office environment, different tasks that workers complete with a computer vary and require different patterns of movement and muscle activity of the upper extremities (Dennerlein and Johnson 2006). For example, Dennerlein and Johnson found that tasks requiring mouse intensive work (Graphical work or web browsing) were associated with greater shoulder flexion, abduction and external rotation posture while tasks involving keyboard intensive work (typing) were associated with less shoulder movement but greater ulnar deviation (Dennerlein and Johnson 2006). Therefore, performing such tasks for prolonged periods induce sustained low level muscle activity and static posture in specific body regions, resulting in the development of neck pain (Jensen et al. 1993). Quantifying and characterizing variation of work tasks is challenging in field-based research; thus, further investigations in this aspect are required.

Undertaking frequent physical activity has been argued as a preventive factor for neck pain. However, a systematic review of the association between physical activity and neck pain for general population found no association due to limited evidence (Sitthipornvorakul et al. 2011). This is in accordance with the finding of another systematic review within the office worker population (Paksaichol et al. 2012). Our review found that one study showed a strong preventive effect (OR 0.44, CI 0.21–0.89) (Shahidi et al. 2015), while four studies reported no effect of physical activity on the development of neck pain (Korhonen et al. 2003; Brandt et al. 2004; Hush et al. 2009; Huysmans et al. 2012a). Of those four studies, one study (Hush et al. 2009) showed a relatively strong tendency of decreased neck pain (HR 0.64) for the group with frequent physical activities although the relationship was not significant. This discrepancy may exist because of diverse definition for physical activities and different cut-off points for frequency of activities. Therefore, we contend that as the evidence for physical activity on the development of neck pain is insufficient or controversial, future research should be undertaken with a standardized risk assessment.

There were also several factors that showed limited (based on evaluation from single studies) significant evidence of a relationship with the development of neck pain in office workers. Individuals using a telephone shoulder rest were found to be two times more likely to develop neck pain (HR 2.05, CI 1.14–3.71) (Marcus et al. 2002). The interaction between self-reported postural risk and psychosocial risk were associated with a greater risk of neck pain in female workers only (risk estimates are presented in Table 2). Similarly, combined reduced physical activity and high mental stress and less physical activities were presented (cohort 9). The findings from these cohort indicated that adverse psychosocial work environment might affect physical work condition and vice versa. This review did also identify a significant relationship between increased cervical range of motion, greater cervical extensor endurance, and that undertaking a program of neck muscular training (Hush et al. 2009; Sihawong et al. 2014; Shahidi et al. 2015) are all associated with reduced incidence of future neck pain. These findings are consistent with observed improvements in neck pain with rehabilitation programmes aimed to strengthen neck muscles and improve joint mobility (Bertozzi et al. 2013).

Strengths and weakness of the study

This is the first systematic review and meta-analysis specifically addressing physical risk factors for the development of neck pain in office workers. The review summarised the findings of 20 prospective studies, which is the greatest number of studies among reviews in this field. This review also selected strict inclusion criteria for the choice of risk estimates only from confounding adjusted analysis model. Therefore, we could minimize the biased conclusion that can be derived from unadjusted model and have also established less biased evidence for our findings. The purpose of this review was to identify physical risk factors to assist health professionals and researchers to minimise the negative impact of working with computer. It was evident from previous reviews that non-physical factors such as high work demands, low job authorities, and poor social support, female gender, and history of neck pain are strongly predictive of the development of neck pain from the previous reviews (Hales and Bernard 1996; Ariens et al. 2000; Linton et al. 2002; McLean et al. 2010; Kraatz et al. 2013). However, the findings of this review benefit workers as well as policy makers by providing valuable evidence for physical factors.

There were some limitations of this review. We included only studies published in English and as such potential publication and language bias may exist. Additionally, we did not report crude factor-outcome relationships which may have additional meaningful information for the relationship with the development of neck pain. There were some methodological issues in combining the findings of multiple studies. Inconsistency and a lack of standardisation between studies regarding the assessment and measurement of variables and outcome, hindered data synthesis, as a result, this review was able to conclude only five strong

Figure 3.1 Self-perceived high muscular tension as a individual physical factor for the development of neck pain (adjusted pooled risk ratio by random effect model)

Study or Subgroup	log[Risk Ratio]	SE	Weight	Risk Ratio IV, Random, 95% CI
Huysmans et al., 2012b	1.4183	0.2075	34.0%	4.13 [2.75, 6.20]
Paksaichol et al., 2014	1.1262	0.2161	33.4%	3.08 [2.02, 4.71]
Wahlstro¨m et al 2004	0.47	0.2297	32.6%	1.60 [1.02, 2.51]
Total (95% CI)			**100.0%**	**2.75 [1.60, 4.72]**

Heterogeneity: Tau² = 0.18; Chi² = 9.64, df = 2 (P = 0.008); I² = 79%
Test for overall effect: Z = 3.67 (P = 0.0002)

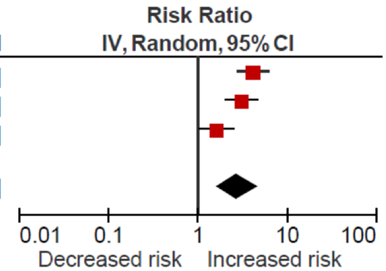

Figure 3.2 Self-preceived medium muscular tension as a individual physical risk factor for the development of neck pain (adjusted pooled risk ratio by random effect model)

Study or Subgroup	log[Risk Ratio]	SE	Weight	Risk Ratio IV, Random, 95% CI	Year
Wahlstro¨m et al 2004	0.2624	0.1987	34.5%	1.30 [0.88, 1.92]	2004
Huysmans et al., 2012b	1.0225	0.1996	34.4%	2.78 [1.88, 4.11]	2012
Paksaichol et al., 2014	0.5008	0.2404	31.0%	1.65 [1.03, 2.64]	2014
Total (95% CI)			**100.0%**	**1.82 [1.14, 2.90]**	

Heterogeneity: Tau² = 0.12; Chi² = 7.54, df = 2 (P = 0.02); I² = 73%
Test for overall effect: Z = 2.52 (P = 0.01)

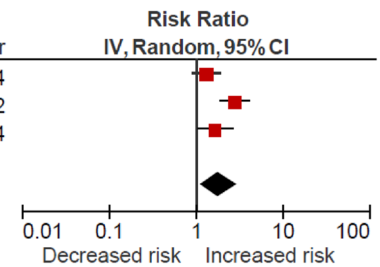

Fig. 3 *3.1, 3.2* Represent risk ratio of each individual physical factor for the development of neck pain for individual studies and pooled analysis based on random effects model. Individual risk ratio (95% CI) by each study is denoted by *rectangular box*. The pooled risk ratio for each physical factor is represented by a *diamond box*, where *diamond* width corresponds to 95% CI bounds. *Boxes* heights are inversely proportional to precision of the risk estimation. *3.1* Forest plot for the risk of self-perceived high intensity muscular tension on the development of neck pain from pooled analysis of three studies. *3.2* Forest plot for the risk of self-perceived medium intensity muscular development of neck pain from pooled analysis of three studies

and seven moderate evidences for physical factors. The 42 investigated risk factors in the previous studies have been still remained limited evidence.

Implications

Future studies need to incorporate a more comprehensive range of potential physical risk factors with standardized methods of measurement to further clarify of physical risk factors for the development of neck pain in office workers. This review indicates that low satisfaction with the physical work environment, close keyboard position to the body, low work task variation, as well as perceived muscular tension are predictive for developing a new episode of neck pain in office workers. Yet current evidence is inconclusive with regard to many other potentially important physical workplace and individual variables. Further study in this field is essential as many of these variables are potentially modifiable and therefore informative for the prevention of neck pain in office workers.

Conclusions

Although a number of individual and workplace physical factors were identified as risks for neck pain in this review, there was either limited or conflicting evidence for many of the physical factors previously reported to be a potential risk factor for neck pain in this population. One of the major findings of the study was the paucity of prospective studies investigating the association between the physical work environment, the individuals work practices, physical condition of the worker, and the development of neck pain. Another important finding is the need to develop standardised risk and outcome assessments. Therefore, studies in the future will need to consider more comprehensive physical variables, as well as develop standardised methods for measurement and case definition when investing this area of health care for the integrated preventive of neck pain in office workers.

Appendix A

See Table 3.

Appendix B

See Table 4.

Table 3 Search keywords from the five databases

Keywords	Pubmed	CINAHL	Embase	Psycinfo	Proquest
Office worker	"Office worker" OR "office workers" OR "white collar"	(MH "White Collar Workers") OR "office worker" OR "computer work" OR "office"	'Office worker'/exp OR 'white collar worker'/exp OR 'office workers'	{White Collar Workers} OR "office worker" OR "white collar"	"Office worker" OR "white collar" OR "office"
Computer	"Computers"[Mesh] OR "visual display unit" OR "visual display terminal" OR "keyboard" OR "Computer Peripherals"[Mesh] OR "Computer Terminals"[Mesh] OR "computer" OR	(MH "Computer Peripherals") OR "computer" OR (MH "Computers, Portable") "visual display unit" OR (MH "Keyboards") OR "keyboard" OR "Computer Peripherals" OR (MH "Computer Terminals") OR (MH "Mouse (Computer)")	"Computer interface"/exp OR "keyboard"/exp OR "computer mouse"/exp OR "computer input device"/exp OR "computer terminal"/exp	{Computer Peripheral Devices} OR {Computer Usage} OR {Computers} OR {Visual Displays} OR {Keyboards}	Computer OR "visual display unit" OR "visual display terminal" OR "keyboard" OR "computer peripherals"
Physical capacity	"Physical capacity" OR Physical Endurance[Mesh] OR "Muscle Strength"[Mesh] OR Pliability[Mesh] OR Range of Motion, Articular[Mesh] OR "functional capacity" OR "functional ability" OR "Physical ability"	(MH "Physical Examination") OR "physical capacity" OR (MH "Physical Performance") OR (MH "Exercise Tolerance") OR (MH "Maximum Tolerated Dose") OR (MH "Exercise Test, Muscular") OR (MH "Exercise Test") OR (MH "Isometric Exercises") OR (MH "Isokinetic Exercises") OR (MH "Isotonic Exercises") OR (MH "Physical Endurance") OR (MH "Physical Restraint (Iowa NIC)") OR (MH "Muscle Strength") OR "functional capacity" OR (MH "Functional Assessment") OR (MH "Functional Assessment Inventory") OR (MH "Range of Motion") OR (MH "Joint Movement: Passive (Iowa NOC)") OR (MH "Joint Movement: Active (Iowa NOC)") OR (MH "Pliability")	"Physical activity, capacity and performance"/exp OR "strength"/exp OR "range of motion"/exp OR "physical performance"/exp	{Endurance} OR {Physical Endurance} OR {Physical Examination} OR {Physical Fitness} OR {Physical Health} OR {Physical Mobility} OR {Physical Restraint} OR {Physical Strength} OR "physical capacity"	"Physical capacity" OR "Exercise Tolerance" OR "Endurance" OR "Strength" OR "Physical Examination" OR "Range of Motion" OR "functional capacity" OR "functional ability" OR "Physical ability""
Physical activity	"Exercise"[Mesh] OR Leisure Activities[Mesh] OR "Jogging"[Mesh] OR "Sports"[Mesh] OR Health Behavior[Mesh] OR "physical activity" OR "sedentary work" OR "Sedentary Lifestyle"[Mesh]	(MH "Life Style, Sedentary") OR (MH "Physical Activity") OR (MH "Physical Activity (Omaha)") OR (MH "Health Behavior") OR (MH "Health Behavior (Iowa NOC) (Non-Cinahl)") OR (MH "Sports") OR (MH "Jogging") OR (MH "Leisure Activities") OR (MH "Motor Vehicles")	'Exercise'/exp OR 'sport'/exp OR 'health behavior'/exp OR 'sedentary lifestyle'/exp	{Behavior} OR {Exercise} OR {Leisure Time} OR {Physical Activity} OR {Sports} OR "health behavior"	"Exercise" OR "Leisure Activities" OR "Sports" OR "Health Behavior" OR "physical activity"

Table 3 (continued)

Keywords	Pubmed	CINAHL	Embase	Psycinfo	Proquest
Physical exposure and risk factors	“Posture”[Mesh] OR “posture” OR “Occupational Exposure”[Mesh] OR “physical exposure” OR “physical factors” OR “Risk Factors”[Mesh]	(MH “Posture”) OR “Posture” OR (MH “Body Positions”) OR (MH “Occupational Exposure”) OR “Occupational Exposure” OR “physical exposure” OR (MH “Risk Factors”) OR “Risk Factors”	‘Body posture’/exp OR ‘abnormal posture’/exp OR ‘occupational exposure’/exp OR ‘physical exposure’ OR ‘physical factor’ OR ‘risk factor’/exp	{Human Factors Engineering} OR {Occupational Exposure} OR {Posture} OR “ ergonomics” OR {Risk Factors} OR “physical factors” OR “risk factor”	Posture OR “Occupational Exposure” OR “physical exposure” OR “physical factors” OR “Risk Factors”
Workload	“Physical workload” OR “physical job demands” OR “Workload”[Mesh] OR “workload”	“physical workload” OR (MH “Workload”) OR “physical factors” OR (MH “Stress, Occupational”) OR (MH “Stress, Mechanical”)	Workload’/exp	“Job demand” OR “job strain” OR {Stimulus Duration} OR {Work Load} OR “workload” OR “work stress”	“Physical workload” OR “physical job demands” OR “Workload”
Environment	“Work environment”	(MH “Workload Measurement”) OR (MH “Work Environment”) OR (MH “Computer Environment”) OR	Work environment’/exp	{Working Conditions}	“Work environment”
Neck pain	“Neck pain” OR “Neck Pain”[Mesh] OR “neck ache” OR “Shoulder Pain” OR “Shoulder Pain”[Mesh] OR “shoulder ache”	(MH “Neck Pain”) OR “neck pain” OR (MH “Neck Muscles”) OR (MH “Neck”) (MH “Shoulder Pain”) OR “Shoulder Pain” OR (MH “Referred Pain”) OR (MH “Muscle Pain”)	‘Neck pain’/exp OR ‘neck pain’ OR ‘shoulder pain’	“Neck pain” OR “shoulder pain”	“Neck pain” OR “shoulder pain”
Work-related disorders	“Work-related disorders” OR “Musculoskeletal Diseases”[Mesh] OR “musculoskeletal disease” OR “Occupational Diseases”[Mesh] OR “occupational diseases” OR “work-related disorders” OR “Cumulative Trauma Disorders”[Mesh] OR “musculoskeletal disorders”	(MH “Occupational-Related Injuries”) OR “work-related disorders” OR (MH “Musculoskeletal Diseases”) OR “Musculoskeletal Diseases” OR (MH “Muscular Diseases”) OR (MH “Occupational Diseases”) OR “occupational diseases” OR (MH “Cumulative Trauma Disorders”) OR “Cumulative Trauma Disorders”	‘Musculoskeletal disease’/exp OR ‘cumulative trauma disorder’/exp OR ‘musculoskeletal pain’/exp OR ‘work-related disorders’	“Work-related disorders” OR “occupational disease” OR “cumulative trauma disorders” OR {Musculoskeletal Disorders}	“Work-related disorders” OR “Musculoskeletal disorders” OR “Musculoskeletal disease” OR “occupational disease” OR “cumulative trauma” OR “occupational disorders”

Table 4 Results from quality assessment using the Epidemiological Appraisal Instruments (20 articles assessed)

Studies	Cohort 1				Cohort 2	Cohort 3	Cohort 4		Cohort 5		Cohort 6
	Wahlstrom (2004)	Hagberg et al. (2007)	Tornqvist et al. (2009)	Lindegard et al. (2012)	Hush et al. (2009)	Jensen (2003)	Lapointe et al. (2009)	Lapointe et al. (2009)	Brandt et al. (2004)	Andersen et al. (2008)	Ijmker et al. (2011)
Q1. Reported study aim/objective clearly	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q2. Risk factors related to neck pain are clearly defined	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q3. Neck pain clearly defined	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q4. Reported study design	Y	Y	Y	Y	Y	p	Y	Y	Y	Y	Y
Q5. Reported source of subject population	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q6. Reported inclusion criteria	N	N	Y	N	Y	Y	Y	Y	N	N	Y
Q7. Reported participation rate	NA	NA	NA	NA	Y	Y	Y	Y	Y	Y	Y
Q8. Reported participant characteristics	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q9. Reported participant lost characteristics	P	P	P	P	N	N	Y	Y	P	Y	Y
Q10. Reported adverse reactions	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Q11. Reported individual confounders and covariates	Y	Y	Y	P	Y	Y	Y	Y	Y	Y	Y

Table 4 (continued)

Studies	Cohort 1				Cohort 2	Cohort 3	Cohort 4		Cohort 5		Cohort 6
	Wahlstrom (2004)	Hagberg et al. (2007)	Tornqvist et al. (2009)	Lindegard et al. (2012)	Hush et al. (2009)	Jensen (2003)	Lapointe et al. (2009)	Lapointe et al. (2009)	Brandt et al. (2004)	Andersen et al. (2008)	Ijmker et al. (2011)
Q12. Reported environmental confounders and covariates	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y
Q13. Reported statistical methods	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q14. Reported all basic data for neck pain	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q15. Reported variability in data (95% CI or SD)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q16. Reported statistical parameters	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q17. Reported sample size calculations	N	N	N	N	P	N	N	N	N	N	Y
Q18. Comparability of case/control groups	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	P
Q19. Adequate participation rate	Y	Y	Y	Y	N	P	P	P	P	N	N
Q20. Same recruitment period	UTD	UTD	UTD	UTD	P	NA	N	N	UTD	UTD	UTD
Q21. Non-responder characteristics described	N	N	N	N	Y	N	Y	Y	P	P	Y

Table 4 (continued)

Studies	Cohort 1				Cohort 2	Cohort 3	Cohort 4		Cohort 5		Cohort 6
	Wahlstrom (2004)	Hagberg et al. (2007)	Tornqvist et al. (2009)	Lindegard et al. (2012)	Hush et al. (2009)	Jensen (2003)	Lapointe et al. (2009)	Lapointe et al. (2009)	Brandt et al. (2004)	Andersen et al. (2008)	Ijmker et al. (2011)
Q22. New incident case analysis	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Q23. Subject randomisation	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Q24. Randomisation concealment	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Q25. Reported reliability of physical risk factor measures	UTD	N	N	UTD	N	UTD	UTD	UTD	N	Y	UTD
Q26. Reported validity of physical risk factor measures	UTD	N	N	UTD	UTD	UTD	UTD	UTD	N	UTD	UTD
Q27. Reported standardisation of physical risk factor measures over all groups	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	N
Q28. Physical risk factor measure prior to new event of neck pain	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q29. Observer blinding	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Q30. Subject blinding	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Q31. Reported reliability of neck pain measures	UTD	UTD	UTD	UTD	P	Y	Y	Y	UTD	UTD	Y

Table 4 (continued)

Studies	Cohort 1				Cohort 2	Cohort 3	Cohort 4		Cohort 5		Cohort 6
	Wahlstrom (2004)	Hagberg et al. (2007)	Tornqvist et al. (2009)	Lindegard et al. (2012)	Hush et al. (2009)	Jensen (2003)	Lapointe et al. (2009)	Lapointe et al. (2009)	Brandt et al. (2004)	Andersen et al. (2008)	Ijmker et al. (2011)
Q32. Reported validity of neck pain measures	UTD	UTD	UTD	UTD	P	Y	Y	Y	UTD	UTD	Y
Q33. Reported standardisation of neck pain measures	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q34. Observation time comparability	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q35. Reported prior disease/history	N	N	N	N	NA	Y	Y	Y	N	N	Y
Q36. Adjustment for individual confounders and covariates	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q37. Adjustment for environmental confounders and covariates	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y
Q38. Is follow-up time adequate	P	P	P	P	Y	Y	Y	Y	Y	Y	Y
Q39. Follow-up time differences	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q40. Reported data for ≥ 3 levels of associated factors	Y	Y	Y	Y	P	Y	Y	Y	Y	N	Y

Table 4 (continued)

Studies	Cohort 1				Cohort 2	Cohort 3	Cohort 4		Cohort 5		Cohort 6
	Wahlstrom (2004)	Hagberg et al. (2007)	Tornqvist et al. (2009)	Lindegard et al. (2012)	Hush et al. (2009)	Jensen (2003)	Lapointe et al. (2009)	Lapointe et al. (2009)	Brandt et al. (2004)	Andersen et al. (2008)	Ijmker et al. (2011)
Q41. Reported data for subgroups of subjects (e.g. by gender or age)	Y	N	N	N	N	Y	Y	Y	N	Y	N
Q42. Generalisability of results to study population (participation rate)	UTD	UTD	N	UTD	N	P	P	P	P	N	N
Q43. Generalisability of results to other populations (random sampling)	UTD	UTD	N	UTD	N	P	P	P	P	N	N
Overall Quality score (range 0 to 2)	1.33 (M)	1.11 (M)	1.33 (M)	1.14 (M)	1.36 (M)	1.61 (H)	1.68 (H)	1.70 (H)	1.38 (M)	1.38 (M)	1.54 (H)

Studies	Cohort 6		Cohort 7	Cohort 8	Cohort 9		Cohort 10	Cohort 11	Cohort 12	Studies scoring yes or NA
	Huysmans et al. (2012a)	Huysmans et al. (2012b)	Marcus et al. (2002)	Korhonen et al. (2003)	Paksaichol et al. (2014)	Sitthipornvorakul et al. (2015)	Gerr et al. (2005)	Shahidi et al. (2015)	Sihawong et al. (2014)	
Q1. Reported study aim/objective clearly	Y	Y	Y	Y	Y	Y	Y	Y	Y	20
Q2. Risk factors related to neck pain are clearly defined	Y	Y	Y	Y	Y	P	Y	Y	Y	19
Q3. Neck pain clearly defined	Y	Y	Y	Y	Y	Y	Y	Y	Y	20

Table 4 (continued)

Studies	Cohort 6		Cohort 7	Cohort 8	Cohort 9		Cohort 10	Cohort 11	Cohort 12	Studies scoring yes or NA
	Huysmans et al. (2012a)	Huysmans et al. (2012b)	Marcus et al. (2002)	Korhonen et al. (2003)	Paksaichol et al. (2014)	Sitthipornvorakul et al. (2015)	Gerr et al. (2005)	Shahidi et al. (2015)	Sihawong et al. (2014)	
Q4. Reported study design	Y	Y	Y	Y	Y	Y	Y	Y	Y	19
Q5. Reported source of subject population	Y	Y	Y	Y	Y	Y	Y	P	Y	19
Q6. Reported inclusion criteria	Y	Y	Y	Y	Y	Y	Y	Y	Y	15
Q7. Reported participation rate	Y	Y	Y	Y	Y	Y	NA	Y	Y	20
Q8. Reported participant characteristics	Y	Y	Y	Y	Y	Y	Y	Y	Y	20
Q9. Reported participant lost characteristics	Y	N	Y	Y	Y	P	Y	Y	Y	11
Q10. Reported adverse reactions	NA	NA	NA	NA	NA	NA	N	NA	N	18
Q11. Reported individual confounders and covariates	Y	Y	Y	Y	Y	Y	Y	Y	Y	19
Q12. Reported environmental confounders and covariates	Y	Y	Y	Y	Y	N	Y	N	Y	15
Q13. Reported statistical methods	Y	Y	Y	Y	Y	Y	Y	Y	Y	20

Table 4 (continued)

Studies	Cohort 6		Cohort 7	Cohort 8	Cohort 9		Cohort 10	Cohort 11	Cohort 12	Studies scoring yes or NA
	Huysmans et al. (2012a)	Huysmans et al. (2012b)	Marcus et al. (2002)	Korhonen et al. (2003)	Paksaichol et al. (2014)	Sitthipornvorakul et al. (2015)	Gerr et al. (2005)	Shahidi et al. (2015)	Sihawong et al. (2014)	
Q14. Reported all basic data for neck pain	Y	Y	Y	Y	Y	Y	Y	Y	Y	20
Q15. Reported variability in data (95% CI or SD)	Y	Y	Y	Y	Y	Y	Y	Y	Y	20
Q16. Reported statistical parameters	Y	Y	Y	Y	Y	Y	Y	Y	Y	20
Q17. Reported sample size calculations	Y	Y	Y	N	N	N	N	N	Y	5
Q18. Comparability of case/control groups	Y	Y	Y	Y	Y	Y	Y	Y	Y	19
Q19. Adequate participation rate	N	N	P	Y	Y	Y	NA	Y	Y	9
Q20. Same recruitment period	UTD	Y	N	Y	UTD	UTD	UTD	UTD	UTD	2
Q21. Non-responder characteristics described	Y	Y	Y	P	Y	Y	Y	Y	Y	12
Q22. New incident case analysis	NA	NA	NA	NA	NA	NA	NA	NA	NA	20
Q23. Subject randomisation	NA	NA	NA	NA	NA	NA	Y	NA	Y	20
Q24. Randomisation concealment	NA	NA	NA	NA	NA	NA	N	NA	Y	19

Table 4 (continued)

Studies	Cohort 6		Cohort 7	Cohort 8	Cohort 9		Cohort 10	Cohort 11	Cohort 12	Studies scoring yes or NA
	Huysmans et al. (2012a)	Huysmans et al. (2012b)	Marcus et al. (2002)	Korhonen et al. (2003)	Paksaichol et al. (2014)	Sitthiporn-vorakul et al. (2015)	Gerr et al. (2005)	Shahidi et al. (2015)	Sihawong et al. (2014)	
Q25. Reported reliability of physical risk factor measures	UTD	UTD	Y	N	Y	P	NA	Y	NA	4
Q26. Reported validity of physical risk factor measures	UTD	UTD	Y	N	N	UTD	NA	Y	NA	2
Q27. Reported standardisation of physical risk factor measures over all groups	Y	Y	Y	Y	Y	Y	NA	Y	NA	18
Q28. Physical risk factor measure prior to new event of neck pain	Y	Y	Y	Y	Y	Y	NA	Y	NA	20
Q29. Observer blinding	NA	NA	NA	NA	NA	NA	N	NA	Y	19
Q30. Subject blinding	NA	NA	NA	NA	NA	NA	N	NA	N	18
Q31. Reported reliability of neck pain measures	Y	Y	Y	N	Y	Y	UTD	Y	Y	11
Q32. Reported validity of neck pain measures	Y	Y	UTD	N	Y	Y	UTD	Y	Y	10
Q33. Reported standardisation of neck pain measures	Y	Y	Y	Y	Y	Y	Y	Y	Y	20

Table 4 (continued)

Studies	Cohort 6		Cohort 7	Cohort 8	Cohort 9		Cohort 10	Cohort 11	Cohort 12	Studies scoring yes or NA
	Huysmans et al. (2012a)	Huysmans et al. (2012b)	Marcus et al. (2002)	Korhonen et al. (2003)	Paksaichol et al. (2014)	Sitthipornvorakul et al. (2015)	Gerr et al. (2005)	Shahidi et al. (2015)	Sihawong et al. (2014)	
Q34. Observation time comparability	Y	Y	UTD	Y	Y	Y	Y	Y	Y	19
Q35. Reported prior disease/history	Y	Y	NA	N	Y	Y	Y	Y	Y	11
Q36. Adjustment for individual confounders and covariates	Y	Y	Y	Y	Y	Y	Y	Y	Y	19
Q37. Adjustment for environmental confounders and covariates	Y	Y	Y	Y	Y	Y	Y	N	Y	16
Q38. Is follow-up time adequate	Y	Y	Y	Y	Y	Y	Y	Y	Y	16
Q39. Follow-up time differences	Y	Y	UTD	Y	Y	Y	Y	Y	Y	19
Q40. Reported data for ≥ 3 levels of associated factors	N	P	P	N	P	N	NA	N	NA	12
Q41. Reported data for subgroups of subjects (e.g. by gender or age)	N	N	N	N	N	N	N	N	N	5

Table 4 (continued)

Studies	Cohort 6		Cohort 7	Cohort 8	Cohort 9		Cohort 10	Cohort 11	Cohort 12	Studies scoring yes or NA
	Huysmans et al. (2012a)	Huysmans et al. (2012b)	Marcus et al. (2002)	Korhonen et al. (2003)	Paksaichol et al. (2014)	Sitthiporn-vorakul et al. (2015)	Gerr et al. (2005)	Shahidi et al. (2015)	Sihawong et al. (2014)	
Q42. Generalisability of results to study population (participation rate)	N	N	P	P	P	P	Y	Y	Y	3
Q43. Generalisability of results to other populations (random sampling)	N	N	P	P	P	P	Y	P	P	1
Overall Quality score (range 0 to 2)	1.57 (H)	1.59 (H)	1.61 (H)	1.49 (H)	1.68 (H)	1.54 (H)	1.49 (H)	1.62 (H)	1.76 (H)	

H high quality study, *L* low quality study, *M* moderate quality study, *N* no, *NA* not applicable, *P* partial, *UTD* unable to determine, *Y* yes

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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