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CLINICAL REVIEW

Sleep problems and work injuries: A systematic review and meta-analysis

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SUMMARY

Objectives: Sleep problems are a potential risk factor for work injuries but the extent of the risk is unclear. We conducted a systematic review and meta-analysis to quantify the effect of sleep problems on work injuries.
Methods: A systematic literature search using several databases was performed. Sleep problems of any duration or frequency as well as work injuries of any severity were of interest. The effect estimates of the individual studies were pooled and relative risks (RR) and 95% confidence intervals (CI) were calculated through random effects models. Additionally, the population attributable risk was estimated.
Results: In total, 27 observational studies ($n = 268{,}332$ participants) that provided 54 relative risk estimates were included. The findings of the meta-analysis suggested that workers with sleep problems had a 1.62 times higher risk of being injured than workers without sleep problems (RR: 1.62, 95% CI: 1.43–1.84). Approximately 13% of work injuries could be attributed to sleep problems.
Conclusion: This systematic review confirmed the association between sleep problems and work injuries and, for the first time, quantified its magnitude. As sleep problems are of growing concern in the population, these findings are of interest for both sleep researchers and occupational physicians.

Introduction

Occupational injuries are a major problem worldwide. Approximately 360,000 fatal occupational accidents occur yearly, and more than 960,000 workers become injured daily because of accidents.[1] The cost of work accidents and illness is over US$ 1,250,000 million a year.[2] To reduce the number of work injuries, it is necessary to know their risk factors. This knowledge could lead to developing countermeasures for preventing accidents.

Sleep problems may be a relevant risk factor for occupational injuries. Sleep is essential for the functioning of the human body. Disrupted sleep has numerous negative consequences, including increased mortality,[3,4] diabetes,[5,6] obesity,[7,8] burnout,[9] and poor performance.[10] Sleep problems are among the most common health complaints in the population. Estimates for the prevalence of sleep problems vary greatly. Recent reviews have indicated that 10–40% of the population suffer from insomnia,[11] 2–10% suffer from obstructive sleep apnea,[12] 4–29% suffer from restless legs syndrome,[13] and about 25% suffer from non-specific sleep-related problems.[14] Accordingly, the prevalence of sleep problems also varies in the working population, ranging from approximately 18% in Europe[15] to 23% in the United States.[16]

The role of sleep as a potential risk factor in accident prevention is still under debate. Narrative reviews reflect the strong belief and consensus among specialists that sleep problems have an impact on the occurrence of work injuries. The link between sleep restriction and on-the-job driving accidents is well established,[17–22] but evidence in other working areas is sparse.[23] Previous reviews have summarised only a few of the larger studies,[24] focused on costs[11,25] or conducted a narrative overview.[18,26,27] A systematic review was

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Abbreviations

Chi^2	Chi square (statistical test)
CI	confidence interval
ESS	Epworth sleepiness scale
I^2	statistical index of heterogeneity
IRR	incidence rate ratio
MeSH	medical subject headings
MOOSE	a proposal of reporting meta-analysis of observational studies in epidemiology
MSQ	mini sleep questionnaire
NA	not available
NOS	Newcastle-Ottawa scale
OR	odds ratio
p	*p*-value (statistical index of significance)
PAR%	population attributable risk percent
PSQI	Pittsburgh sleep quality index
RR	relative risk
STOP	obstructive sleep apnea questionnaire

published recently.[28] Reviews have focused on specific sleep disorders, such as obstructive sleep apnea,[12] insomnia,[11,25,28,29] sleep restriction,[18,30] or sleepiness.[24,26,27] However, to date, no review has quantified the impact of having any sleep problem on work injuries. Therefore, the aim of this work was to conduct a broad systematic review and a meta-analysis to quantify the relationship between sleep problems and work injuries other than work-related traffic accidents.

Methods

In conducting this review, we followed the illustrated, step-by-step guide for systematic reviews and meta-analyses by Pai et al.[31] and consulted the Cochrane handbook.[32] For reporting, we considered the guidelines for meta-analysis of observational studies in epidemiology (MOOSE).[33]

Identification of eligible studies

Electronic search

A highly sensitive search strategy was developed that allowed identification of all eligible articles published in psychological and medical journals for all years up to June 2011. The electronic search strategy combined three sets of search terms (see Appendix A). The first set was made up of terms characterising the exposure, the second set contained terms describing the outcome, and the third set specified the population. All terms within each set were combined with the Boolean operator OR, and then, the three sets were combined using AND. The Medline search was adapted to searching other databases. The search was not limited to a particular type of study design or publication language. The following electronic databases were searched on July 7th 2011 using both controlled vocabulary terms and relevant free text words:

- Medline (through PubMed; all years 1946 – present)
- Embase (through www.embase.com by Elsevier B.V. 2011; all years from 1947 – present)
- PsycInfo (through Ovid; Version: OvidSP_UI03.04.01.113, SourceID 54495, all years from 1806 – present)
- ISI Web of Science (through Web of Knowledge v.4.10, Thomson Reuters© 2010; all years from 1900 – present; SCI-EXPANDED (1899 – present) & SSCI (1898 – present))

Searching other sources

The reference lists of articles identified through database searches were examined to find additional relevant studies. Bibliographies of systematic and non-systematic review articles were also examined to identify relevant studies. We hand-searched the last year's issues of Sleep Medicine Reviews and of Occupational and Environmental Medicine as being the highest-ranking journals in the field of occupational and sleep medicine. We also hand-searched the last year's issues (between July 2010 and June 2011) of the following journals that published more than one relevant article identified by a preliminary literature search:

- Accident Analysis & Prevention (six times a year)
- Industrial Health (six times a year)
- Journal of Occupational Health (six times a year)
- Journal of Sleep Research (four times a year)
- Scandinavian Journal of Work, Environment & Health (six times a year)
- Sleep (twelve times a year)

Selection criteria

Type of studies

We included original articles from observational studies (prospective and retrospective cohort studies, case-control studies and cross-sectional studies). We did not consider case reports, case series and case only studies or analyses of single events such as the Exxon Valdez ferry disaster. Review articles and intervention studies were considered for inclusion in the discussion section. We excluded studies for which no relevant data could be extracted from the paper. For an article to be included, it was required to i) have an explicit measure of sleep problems, ii) have an explicit measure of work injury, iii) provide sufficient data to quantify the association between sleep problems and work injuries. Finally, only articles in English, French, German and Italian were selected for inclusion.

Sleep problems

The risk factor of interest in this review was a sleep problem of any duration, frequency and severity. Previous studies used various concepts to define sleep problems.[34] In this review, we considered all sleep disorders described in the international classification of sleep disorders (ICSD-2).[35] Accordingly, we also included studies investigating symptoms described in the ISCD-2. For analysis, we grouped the results by the investigated symptoms rather than the diseases due to a lack of classified sleep disorders. Sleep quality concerned problems falling asleep, midnight awakenings, early awakenings, poor sleep sufficiency, and troubles sleeping in general. Sleep quantity described the sleep duration. Under breathing-related sleep problems symptoms like snoring, difficulties or stop breathing were subsumed. Sleep medication meant the use of sleeping pills for inducing sleep. Daytime sleepiness included difficulties waking up, problems staying awake and falling asleep during daytime. Where there was more than one symptom used to describe a sleep problem, the relative risks were pooled in the "multiple symptoms" subgroup. Not considered was non-specific fatigue or fatigue as a specific consequence from a high workload or long working hours. Articles addressing related topics such as sleep stages, shift work, time of day and circadian rhythm were included only if sleep parameters were measured directly.

Work injury

The outcome of interest was a work injury of any severity (minor, major or fatal). In this review, the Eurostat methodology was used,[36] and an accident at work was defined as described by the European agency for safety and health at work (OSHA): "An accident at work is a discrete occurrence in the course of work which leads to physical or mental harm. This includes accidents in the course of work outside the premises of one's business, even if caused by a third party (on clients' premises, on another company's premises, in a public place or during transport, including road traffic accidents) and cases of acute poisoning. It excludes accidents on the way to or from work (commuting accidents), occurrences having only a medical origin (such as a heart attack at work) and occupational diseases."[37] The Eurostat methodology is in accordance with the international labour office (ILO) resolution of 1998.[38] However, this definition of an accident at work is not based on legislation.[37] Therefore, states may have their own definition and might include for example commuting accidents in the statistics of work accidents. We excluded studies specifically addressing the relationship between sleep problems and work-related motor vehicle crashes because this topic was covered by recent reviews.[20,22,39,40] Therefore, we did not take into account studies on commercial motor vehicle or ship and aircraft crashes only. Studies that only reported errors, work performance or time loss, as well as on cumulative trauma disorders or repetitive strain injuries were not considered. The work injuries were registered by the company's administration or an official body, self-reported or diagnosed by a physician. The physicians who diagnosed the work injuries were either employed at the workplace or were external providers.

Participants and setting

The participants of the included studies were adults of both sexes in a working population ranging in age from 16 to 70 y. We considered workers in any trade. The participants had to be paid for their work (e.g., paid workers, but not students in training, were included).

Data extraction

For the study selection, two authors (AM, KU) independently assessed the titles and abstracts identified by the search strategy using EndNote X4. All potentially relevant reports were retrieved in full and assessed independently by the same two authors for inclusion. Any disagreement that could not be resolved by consensus was referred to a third author (NK). Two reviewers (KH, KU) independently extracted data on the association between sleep problems and occupational injuries, including details of the study population, setting, design, exposure, outcome, strategies for assessment of exposure and outcome, response rates, confounders considered, source of funding, conflict of interest and estimates of effect. Risk estimates (odds ratios, relative risks, etc.) were extracted with their 95% confidence intervals. The reviewers used data extraction sheets created in Access (Microsoft© Office) and were not blinded to the funding, authors or institutions. Any differences in the data extracted by KH and KU were resolved by a third author (NK).

Assessment of study quality

We used a modified version of the Newcastle-Ottawa scale (NOS) for quality assessment of the observational studies.[41,42] Two review authors (AM, KU) assessed each included study separately. Any disagreement between the two review authors was settled by consensus, or where necessary, by a third party (NK). The Newcastle-Ottawa scale includes the following three categories: selection and comparability of study groups and exposure/outcome of interest. Each numbered item within the categories of selection and exposure/outcome was awarded with a maximum of one star. A maximum of two stars could be given for comparability. High-quality papers reached 60% or more of the maximum number of stars.[43]

Statistical analysis

This review comprised binary outcomes only. We included all types of risk estimates, such as odds ratios, relative risks and incident rate ratios. Because work injuries are a rare outcome, we did not introduce a relevant artificial bias by pooling the relative risks from the cohort studies with the odds ratios from the case-control and cross-sectional studies. In the following sections, we will refer to pooled effect estimates as relative risks.

To work with consistent definitions, we reanalysed the reported risk estimates where needed. For instance, we pooled the risk estimates for nightly sleep durations of <5 h and for 5 to <6 h to a single risk estimate for <6 h spent sleeping each night.[34,44] Moreover, we converted the risk estimate for sufficient sleep into the risk estimate for insufficient sleep.[45] To conduct an overall meta-analysis without mutually overlapping the populations, we selected one risk estimate per study in the following decreasing priority, as previously defined by a sleep specialist who was not involved in the analysis (EH-T): daytime sleepiness, multiple symptoms, sleep quantity, sleep quality and sufficiency, breathing-related disorders and the use of sleep medication.

The heterogeneity of the results across studies was estimated by the Chi^2 test. Additionally, we quantified heterogeneity using I^2 statistics.[46] Publication bias was assessed by Egger's regression coefficient and visual inspection of the funnel plot.[32] The meta-estimates from the random effects models are presented. To explore potential causes of heterogeneity, subgroup analyses were conducted if four or more studies were available per subgroup. This restriction was made because we expected the results to be heterogeneous, and heterogeneity cannot be well assessed with only a few studies.[47] Moreover, a multivariate meta-regression analysis was undertaken to examine the effect of potentially influencing factors.

The population attributable risk percent was estimated (PAR%). PAR% is a standard epidemiological measure used to estimate the percentage of the outcome (work injuries) that would be prevented if the exposure (sleep problems) was eliminated.[48] It is derived from the following equation:

$$\text{PAR\%} = 100 * (P_x * (\text{RR} - 1))/(1 + (P_x * (\text{RR} - 1)))$$

where P_x is the estimate of population exposure (prevalence of sleep problems), and RR is the relative risk of the association between the sleep problems and work injuries.

All statistical analyses were performed using STATA version 10.1 software.

Results

Flow of included studies

Of the 5433 studies that were initially retrieved, 42 studies were included in the systematic review, and 27 studies were selected for the meta-analysis (Fig. 1). A total of 1716 duplicates were excluded. A total of 3604 papers clearly did not match our inclusion criteria and were excluded based on the title or abstract. Full articles were retrieved for 113 references and for seven additional studies that were identified by manually searching the bibliographies of the retrieved articles. Of these 120 full-text articles 78 were excluded according to our inclusion criteria. The main reasons for the exclusions were that sleep problems, work injuries or their association were not studied. The remaining 42 studies quantified the

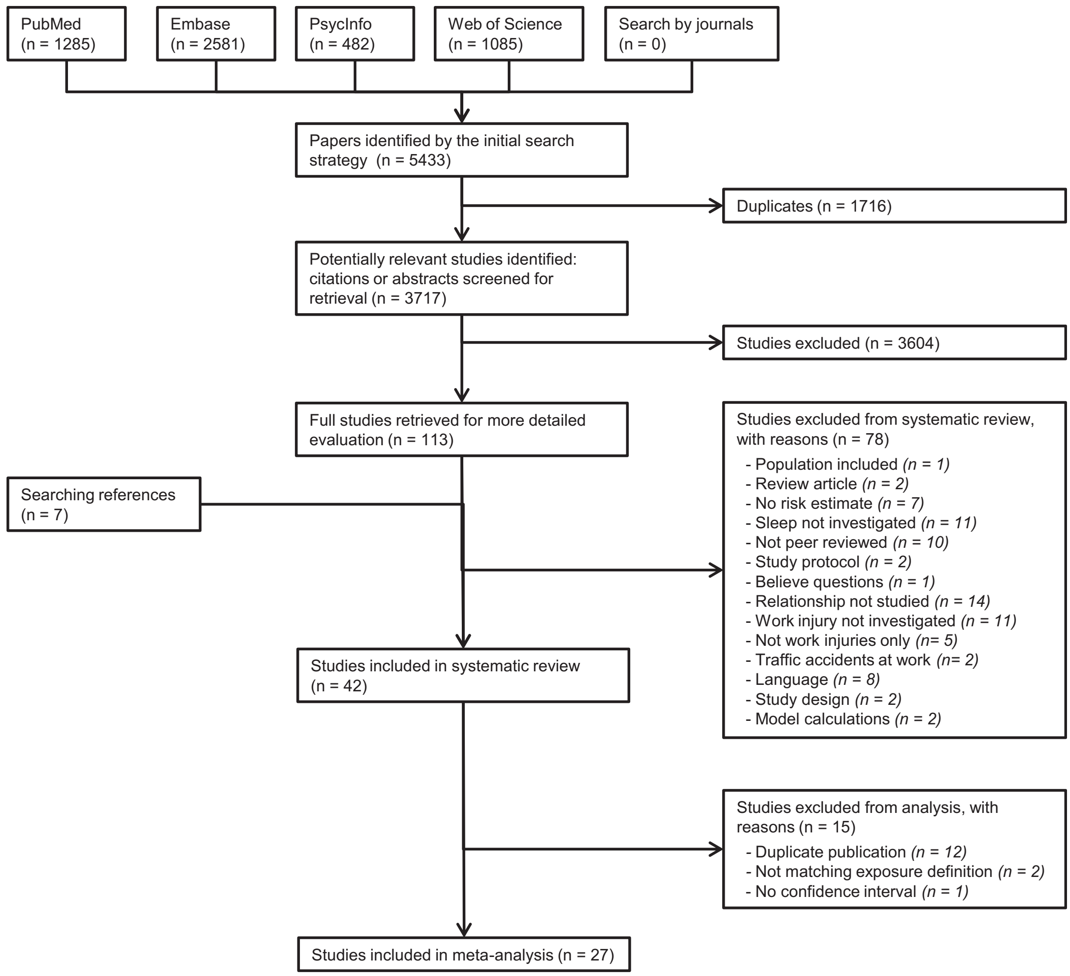

Fig. 1. Study retrieval and selection for effects of sleep problems in work injury meta-analysis. Abbreviations: n: number of studies.

relationship between sleep problems and work injuries and thus were eligible for the systematic review. For the meta-analysis, an additional 15 studies were excluded mainly due to duplicate publication, leaving 27 studies with 54 estimates for the meta-analysis.

Characteristics of eligible studies

Participants

The 27 studies included in the meta-analysis were published between 1982 and 2011 and comprised a total of 268,332 participants from five continents (Table 1). The sample sizes of the studies varied between 272 and 69,248 participants. In total, 20 studies included both sexes, six were based on males, and one was based on females only.

Settings

The studies were conducted either in the general working population (13 studies), in a certain sector, e.g., the industrial sector (five studies), or in a specific occupation, such as construction (nine studies) (Table 1).

Exposure

Sleep problems were assessed in self-reported questionnaires and interviews or were diagnosed by a physician (Table 1). There was a great diversity in the methods used to verify sleep problems. Most studies utilised self-constructed questionnaires, whereas standardised questionnaires were used in nine studies (Pittsburgh sleep quality index (PSQI),[45] Epworth sleepiness scale (ESS),[49–55] mini sleep questionnaire (MSQ),[53] obstructive sleep apnea questionnaire (STOP),[55] Jenkins sleep problems scale[56]). Somnography was used in two studies.[49,57] There were wide variations in the definition of sleep problems. Most studies reported risk estimates for individual symptoms. The use of sleep medication was addressed four times, breathing-related sleep problems were investigated seven times, sleep quality was investigated 10 times, sleep quantity was investigated nine times, and daytime sleepiness was investigated nine times. Multiple symptoms were addressed 15 times. Chau et al.[58] for example defined sleep disorders as less than 6 h of sleep per day and/or not sleeping well and/or regular consumption of sleeping pills. Regarding multiple symptoms, the predominant sleep problem could be interpreted as insomnia except for two studies which concerned breathing-related sleep problems.[52,59] The participants were exposed to sleep problems for two weeks,[60,61] four weeks,[51,56,62–64] one year[65,66] or an undefined time period in the remaining studies.

Outcome

There was also great diversity in the methods used to verify work injuries (Table 1). Most studies utilised self-reports, whereas register data were used in six studies,[53,56,57,59,61,72] and diagnostic data were used in three studies.[50,58,67] Injury severity ranged from fatal accidents[61] over injuries with sick leave,[49,56–58,67–69] to injuries with need for medical treatment.[44,50,51,54,60,71] Seven studies

Table 1
Descriptive study characteristics.

Authors, year, reference number	Study design (study quality)	Sample N (location)	Population (mean age or age range in years)	Definition of work injury (source)	Definition of sleep problem (source)	Impact of sleep problems on work injury
Accattoli et al. 2008[49]	Case-control study (low)	431 (Italy)	Working population (33.4–60.1)	Work accident due to sleepiness or inattention with sick leave since start of symptoms (cases) or in the past 14.3 y (controls) (Q)	Obstructive sleep apnea syndrome (D)	cOR = 1.49 [0.87–2.58]
Åkerstedt et al. 2002[61]	Prospective cohort study (high)	47,860 (Sweden)	Working population (16 to >50)	Fatal occupational accidents (R)	Sleeping difficulties during the last two weeks (PI)	aRR = 1.89 [1.22–2.94]*
Chau et al. 2002[58]	Case-control study (high)	1760 (France)	Male construction workers (<30 to >50)	Non-fatal occupational accidents with medical treatment and sick leave over two years (D)	<6 h of sleep per day (PI) Regular consumption of sleeping pills (PI) <6 h of sleep per day and/or not sleeping well and/or regular consumption of sleeping pills (PI)	cOR = 2.00 [1.02–4.11]* cOR = 4.57 [1.98–12.3]* aOR = 1.92 [1.38–2.69]*
Chau et al. 2004[67]	Case-control study (high)	2610 (France)	Male railway workers (NA)	Non-fatal occupational accident with sick leave over one year (D)	<6 h of sleep per day and/or not sleeping well and/or regular consumption of sleeping pills (PI)	aOR = 1.29 [1.07–1.56]*
Chau et al. 2008[68]	Cross-sectional study (low)	2888 (France)	Working population (15 to >50)	At least one occupational injury with sick leave during the previous two years (Q)	Frequent use of sleeping pills (Q)	cOR = 1.48 [0.88–2.51]
Day et al. 2009[50]	Case-control study (high)	756 (Australia)	Male farmers (49, 17–88)	Serious farm work related unintentional injury over three years (D)	Epworth sleepiness scale >10 (TI)	aOR = 0.51 [0.32–0.82]*
Fransen et al. 2006[51]	Cross-sectional study (low)	15,365 (New Zealand)	Working population recruited from blood donors (16 to >40)	Injury at work with medical treatment in the past 12 mo (Q)	Apnea/choke (Q) Epworth sleepiness scale >10 (Q) Sleep difficulties ≥ 5 nights per month (Q)	cRR = 1.72 [1.40–2.11]* aRR = 1.34 [1.07–1.67]* aRR = 1.67 [1.28–2.18]*
Gabel et al. 2002[63]	Case-control study (high)	643 (USA)	Veterinarians (24–80)	Animal-related injury over one year (Q)	Average sleep duration per night ≤ 6 h (Q)	aRR = 1.8 [1.0–3.3]*
Heaton et al. 2010[62]	Cross-sectional study (high)	742 (USA)	Older farmers (64.7, 41–87)	Farm injury in the past year (TI)	Cessation of breathing while asleep (TI) Trouble staying awake during daytime in the past month (TI)	aOR = 1.861 [1.035–3.346]* aOR = 2.246 [1.244–4.055]*
Iftikhar et al. 2009[65]	Cross-sectional study (high)	272 (Pakistan)	Industrial workers (16–62)	Occupational injury including minor ones (Q)	Insomnia symptoms (Q)	aOR = 1.64 [1.23–2.18]*
Kamil et al. 2007[52]	Cross-sectional study (low)	699 (Malaysia)	Working population (49, 30–70)	Workplace accident due to sleepiness (PI)	Snoring ≥ 3 nights per week (PI) Obstructive sleep apnea syndrome (snoring, breathing pauses and excessive daytime sleepiness) (PI)	cOR = 3.56 [1.67–7.60]* cOR = 7.88 [3.90–15.96]*
Kling et al. 2010[34]	Cross-sectional study (high)	32,604 male, 34,043 female (Canada)	Working population (15–64)	Work injury (Q)	Having trouble going to sleep or staying asleep most of the time in males (Q) Having trouble going to sleep or staying asleep most of the time in females (Q)	aOR = 1.25 [1.01–1.55]* aOR = 1.54 [1.25–1.91]*
Kunar et al. 2010[69]	Case-control study (high)	575 (India)	Male coalmine workers (43.5, 18–60)	Occupational injury with sick leave (NA)	<6 h of sleep daily (PI)	aOR = 1.86 [1.01–3.45]*

(*continued on next page*)

Table 1 (*continued*)

Authors, year, reference number	Study design (study quality)	Sample N (location)	Population (mean age or age range in years)	Definition of work injury (source)	Definition of sleep problem (source)	Impact of sleep problems on work injury
Lavie et al. 1982[70]	Cross-sectional study (low)	1022 (Israel)	Industrial workers (NA)	Work accident (PI)	Excessive daytime sleepiness (PI) Midsleep awakenings (PI) Midsleep awakenings and difficulties falling asleep and excessive daytime sleepiness (PI)	cOR = 2.42 [1.51–3.89]* cOR = 1.62 [1.16–2.25]* cOR = 2.16 [1.19–3.90]*
Léger et al. 2002[64]	Cross-sectional study (high)	631 (France)	Working population (NA)	Work-related injury (Q)	Severe insomnia for at least 1 mo (Q)	cOR = 8.32 [3.29–21.00]*
Lindberg et al. 2001[59]	Prospective cohort study (high)	2009 (Sweden)	Male working population (42.7, 30–64)	Occupational accident with or without sick leave (R)	Snoring and excessive daytime sleepiness (Q)	aOR = 2.2 [1.3–3.8]*
Lombardi et al. 2010[44]	Cross-sectional study (high)	69,248 (USA)	Working population (40.6, 18–74)	At least one work injury requiring medical attention in prior three months (PI)	<6 h of sleep daily (PI)	aOR = 2.05 [1.51–2.79]*
Macdonald et al. 1998[71]	Cross-sectional study (low)	825 (Canada)	Working population (<30 to >45)	Work injury requiring medical attention in the prior year (Q)	Sometimes or often have trouble getting to sleep or staying awake (Q)	cOR = 2.29 [1.10–4.80]*
Melamed et al. 2002[53]	Retrospective cohort study (high)	532 (Israel)	Industrial workers (44.5)	At least one occupational injury including minor ones over two years (R)	Epworth sleepiness scale score >10 (Q)	aOR = 2.23 [1.30–3.81]*
Nakata et al. 2005[66]	Cross-sectional study (high)	1970 male, 792 female (Japan)	Industrial workers (45, 16–83)	Occupational injuries including minor ones in the previous year (Q)	Insomnia symptoms in men (Q) Insomnia symptoms in women (Q) <6 h of daily sleep in men (Q) <6 h of daily sleep in women (Q) Considerable/somewhat difficulty waking up in the morning in men (Q) Considerable/somewhat difficulty waking up in the morning in women (Q) Sleeping very poorly or not so well at night in men (Q) Sleeping very poorly or not so well at night in women (Q) Difficulty breathing during sleep more than once per week in men (Q)	aOR = 1.3 [1.0–1.7]* aOR = 1.3 [0.7–2.1] aOR = 1.1 [0.9–1.4] aOR = 1.0 [0.6–1.5] aOR = 1.1 [0.8–1.4] aOR = 1.4 [0.9–2.4] aOR = 1.4 [1.0–1.9]* aOR = 1.3 [0.7–2.4] aOR = 1.4 [0.7–2.6]
Salminen et al. 2010[56]	Prospective cohort study (high)	8051 male, 32,335 female (Finland)	Public sector workers (44.8)	Registered occupational injuries during the year subsequent to the survey (R)	<7 h of sleep per day and night (Q) Any sleep disturbances in males (Q) Any sleep disturbances in females (Q) Non-refreshing sleep in males (Q) Non-refreshing sleep in females (Q)	aOR = 1.25 [1.08–1.45]* aOR = 1.31 [0.94–1.82] aOR = 1.07 [0.89–1.29] aOR = 1.51 [1.02–2.24]* aOR = 1.16 [0.92–1.46]
Sprince et al. 2003[54]	Case-control study (high)	903 (USA)	Farmers (48.75, 22 to >65)	Farm work related injury during past 12 mo (TI)	Epworth sleepiness scale >15 (>7 on standard scale) (TI)	aOR = 1.27 [0.98–1.66]
Suzuki et al. 2005[45]	Cross-sectional study (low)	4137 (Japan)	Female hospital nurses (30.3, 20 to >50)	Needle stick injuries over previous 12 mo (Q)	Excessive daytime sleepiness (Q) Subjectively sufficient sleep (Q) Use of medication for inducing sleep (Q)	aOR = 1.13 [0.98–1.31] aOR = 1.03 [0.91–1.17] aOR = 1.13 [0.90–1.28]
Swanson et al. 2011[55]	Cross-sectional study (high)	1000 (USA)	Working population (47, 18–91)	Occupational accidents in past year (TI)	Insomnia symptoms (TI)	aOR = 2.28 [1.11–4.74]*

Ulfberg et al. 2000[57]	Cross-sectional study (high)	855 male, 429 female (Sweden)	Working population (30–64)	Occupational accident due to inattention with sick leave over 10-y period (R)	Ostructive sleep apnea syndrome and/ or heavy snoring in males (D) Ostructive sleep apnea syndrome and/ or heavy snoring in females (D)	aOR = 1.7 [1.1–2.6]* aOR = 4.3 [1.5–12.6]*
Wadsworth et al. 2003[60]	Cross-sectional study (high)	1535 (UK)	Working population (49.84, 19–97)	Work accidents requiring medical attention during past 12 mo (Q)	Taking sleeping pills in the last 14 d (Q)	aOR = 2.82 [0.84–9.44]
Yiha et al. 2010[72]	Cross-sectional study (high)	810 (Ethiopia)	Farm workers (31.7, 17 to >30)	Any occupational injury, disease or death in the past one year (R)	Sleeping disorder (PI)	aOR = 1.64 [1.12–2.41]*

Abbreviations: N: number of participants, OR: odds ratio, RR: relative risk, IRR: incidence rate ratio, c: crude, a: adjusted, Q: written questionnaire, PI: personal interview, TI: telephone interview, *: significant, R: register data, D: diagnosis, NA: not available.

included minor injuries also.[34,45,53,59,65,66,72] Injury severity was not clearly defined in six studies.[52,55,62–64,70] Commuting accidents were explicitly excluded in five of the reports.[45,59,62,63,69] The period in which the work injuries had to occur ranged from three months[44] to 10 years.[59]

Study design and quality

In all, 16 cross-sectional, seven case-control, one retrospective and three prospective cohort studies were found (Table 1). Of these, 20 were considered to be of high quality, and seven were of poor quality based on the Newcastle-Ottawa scale (NOS).[41] The poor-quality studies all had a cross-sectional design except for one case-control study.[49] The deficits were mainly selection bias related to sampling, insufficient adjustment for core confounders and measurements solely based on self-reporting. All of the included articles were written in English except one that was written in Italian,[49] and all were published in peer-reviewed journals.

Meta-analysis

Having sleep problems significantly increased the relative risk of being injured at work by 1.62-fold (Fig. 2). The relative risks ranged from 1.07[56] to 4.3[57] with one low outlier at 0.51[50] and two high outliers at 7.88[52] and 8.32.[64] Removing these three outliers from the meta-analysis reduced the pooled relative risk (RR) only marginally (RR = 1.53, 95% CI = 1.39–1.69). Significant heterogeneity (I^2 = 74.0%, $p < 0.001$) and publication bias were found (Egger's regression coefficient = 2.64, $p < 0.001$). Visual inspection of the funnel plot confirmed that weaker effects were less often published in smaller studies. By removing the three outliers, heterogeneity decreased (I^2 = 55.1%, $p < 0.001$), but it remained significant, indicating that these outliers were not the source of the heterogeneity.

To explore the potential reasons for the heterogeneity we conducted several subgroup meta-analyses (Fig. 3 and Table 2). Significant differences across the subgroups were not reported in any of the subgroup meta-analyses; however, tendencies could be observed. Analysing the different aspects of sleep problems (Fig. 3), the highest relative work injury risks were noted for using sleep medication or breathing-related sleep problems, followed by multiple symptoms. For sleep quality and sufficiency and for sleep quantity, intermediate relative work injury risks were found. Suffering from daytime sleepiness was associated with the lowest relative work injury risk. Excluding the outlier,[50] the relative risk (RR) for daytime sleepiness was also intermediate (RR = 1.42, 95% CI = 1.18–1.71). Despite the different magnitudes, each aspect of the sleep problems was independently significantly associated with work injuries.

In the analyses of additional subgroups (Table 2), workers with sleep problems tended to be at a higher risk for more severe injuries. Likewise, workers with sleep disorders classified by an international classification such as the international classification of sleep disorders (ICSD-2)[35] tended to report higher relative risks for work injuries than people with sleep problems not classified as sleep disorders. Interestingly, daytime sleepiness had the lowest association with work injuries, nighttime problems were moderately associated with work injuries, and night- and daytime problems had the highest association with work injuries. Unexpectedly, the risk of having a work injury due to sleep problems was higher in the general working population than in the groups corresponding to specific occupations, such as farmers, miners or construction workers, or among workers from certain sectors, such as the industrial sector. Studies from all continents tended to report similar relative risks for work injuries due to sleep problems. Interestingly, case-control studies tended to report lower relative risks for work

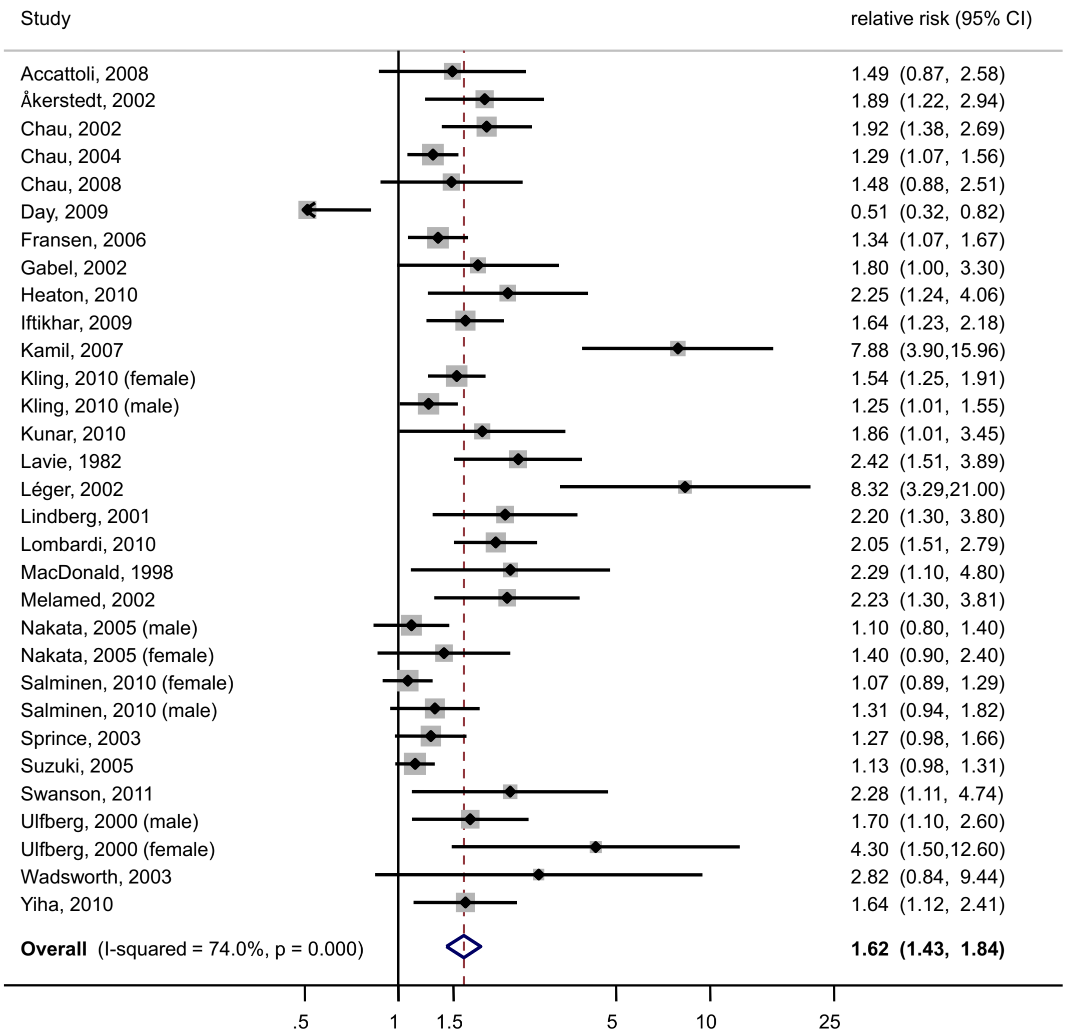

Fig. 2. Forest plot presenting the meta-analysis based on risk estimates for the effect of sleep problems on work injuries. Abbreviations: CI: confidence interval, I-squared: statistical index of heterogeneity, p: *p*-value.

injuries due to sleep problems than cross-sectional or cohort studies. Looking at the temporal relationship, prospective studies tended to show lower relative risks than non-prospective studies. As expected, the risk of having a work injury due to sleep problems tended to be lower in the high-quality studies than in the low-quality studies.

Meta-regression analysis

To examine the potential influence of different factors on the natural logarithm of the odds ratio between sleep problems and work injuries, we conducted a multivariate meta-regression analysis (Table 3). None of the studied factors were statistically significant.

Population attributable risk percent

The PAR% suggested that approximately 13% of the work injuries were due to sleep problems, using the average prevalence of sleep problems in the populations of the included studies ($P_x = 24.76\%$) and the pooled relative risk (RR = 1.62).

Discussion

Summary of the main results

The findings of the present meta-analysis, comprising 27 observational studies, suggested that workers with sleep problems had a 1.62 times higher risk of being injured at work compared to workers without sleep problems. Moreover, each aspect of the sleep problems significantly increased the risk for work injuries. A subsequent meta-analysis among studies using the same sleep problem measure revealed the largest effects for the use of sleep medication and for breathing-related sleep problems, the smallest effect was observed for daytime sleepiness, and intermediate effects were reported for multiple symptoms, sleep quality and sufficiency, and sleep quantity. Approximately 13% of the work injuries could be attributed to sleep problems.

Effect of sleep problems on work injuries (meta-analysis)

Overall, sleep problems significantly increased the work injury risk (Fig. 2); each aspect of the sleep problems also significantly increased the work injury risk, but the effects were not equally strong (Fig. 3). Using sleep medication seemed to be a high risk factor for work injuries. This finding could be explained in two

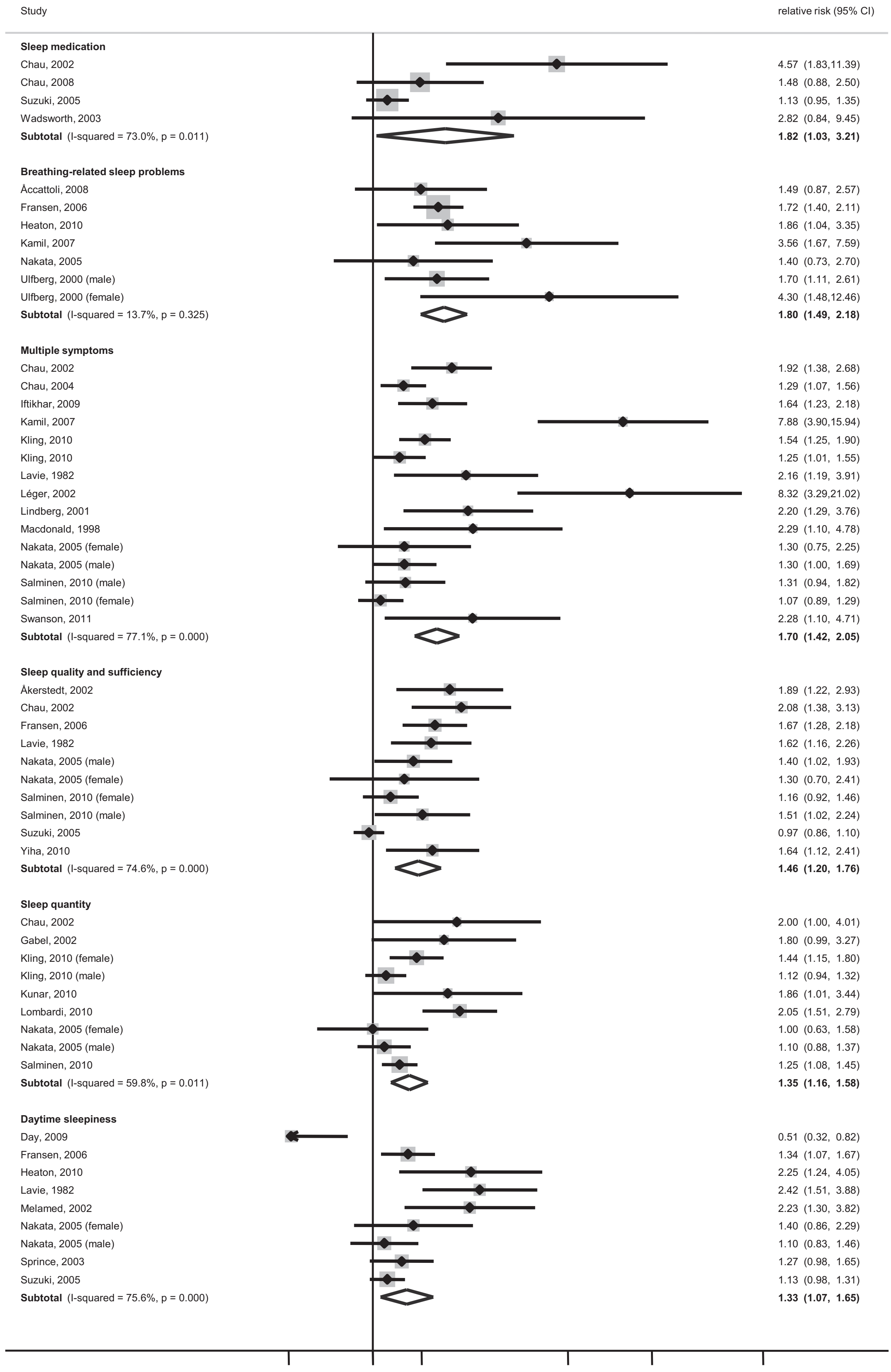

Fig. 3. Forest plot presenting the subgroup meta-analysis for the effect of different sleep problem aspects on work injuries. Abbreviations: CI: confidence interval, I-squared: statistical index of heterogeneity, p: *p*-value.

Table 2
Pooled relative risks from subgroup meta-analyses for the effect of sleep problems on work injury.

Subgroup	N	Relative risk	(95% CI)
Consequences of work injury			
Fatal	1	1.89	(1.22, 2.93)
Sick leave	9	1.46	(1.22, 1.75)
Medical treatment	6	1.37	(0.95, 2.00)
From minor to fatal	15	1.84	(1.50, 2.26)
Classified sleep disorders			
OSAS	4	2.88	(1.34, 6.16)
Insomnia	3	2.87	(1.23, 6.73)
No international classification	24	1.46	(1.30, 1.64)
Daytime vs. nighttime problems			
Daytime sleepiness	9	1.33	(1.07, 1.65)
Nighttime problems	16	1.69	(1.47, 1.95)
Night-and daytime problems	6	2.10	(1.28, 3.45)
Population			
General working population	14	2.00	(1.59, 2.50)
Workers from certain sectors	7	1.44	(1.15, 1.80)
Specific occupations	10	1.42	(1.15, 1.75)
Continent			
Europe, North America, Australia, New Zealand	24	1.62	(1.40, 1.87)
Asia	6	1.68	(1.17, 2.40)
Africa	1	1.64	(1.12, 2.41)
Study design			
Case-control studies	7	1.33	(1.01, 1.75)
Cross-sectional studies	19	1.79	(1.50, 2.13)
Cohort studies	5	1.57	(1.14, 2.16)
Temporality			
Non-prospective studies	27	1.66	(1.44, 1.91)
Prospective studies	4	1.46	(1.06, 2.02)
Study quality			
Low quality	7	1.87	(1.31, 2.65)
High quality	24	1.57	(1.37, 1.80)

Abbreviations: N: number of relative risk estimates, CI: confidence interval.

ways. First, people with severe sleep problems might be more likely to take sleeping pills and cause more accidents due to their more severe sleep problem. Or, people may not recover fully from the narcotic effect and therefore cause more accidents due to their medication. Furthermore, breathing-related sleep problems showed a strong relationship too, an association that was previously described in a review for motor vehicle accidents.[12] This strong effect could be due to breathing-related sleep problems seriously disturbing the sleep architecture. However, the relative risk of using sleep medication and breathing-related sleep problems included the fewest references, had the largest confidence intervals and comprised the highest proportion of low-quality studies and crude estimates. Interestingly, daytime sleepiness showed the lowest association with work injuries, although it was described as a symptom of obstructive sleep apnea.[73] This result could be explained by sleepy people being aware of their limitations at the time of risk and therefore adopting coping strategies. However, excluding the outlier,[50] the relative risk for daytime sleepiness was similar to the intermediate relative risk of sleep quality, indicating that daytime difficulties are equally hazardous. The quality of sleep seemed more important than the quantity; however, the relationship between sleep quantity and work injuries could be masked by inter-person differences in the need for sleep hours.

Heterogeneity could not be explained by subgroup meta-analyses (Table 2), leaving the lack of standardisation in exposure and outcome assessment as a plausible reason. However, people with sleep problems tended to be at a higher risk for more severe work injuries including fatal accidents. These results are in line with the theory that sleepy workers may not adequately react in dangerous situations. Additionally, classified and therefore more severe sleep disorders tended to result in a higher risk for work injuries compared to non-classified sleep problems. Accordingly, more far-reaching impacts of sleep problems (from daytime problems over nighttime to night- and daytime problems) tended to show higher risks for work injuries also. These dose-response relationships would support a causal interpretation of the findings.

Table 3
Results of meta-regression analysis examining potential effects of different factors on the natural logarithm of the odds ratio between sleep problems and work injuries.

Meta-regression variables	Risk for work injury			
	Univariate analysis		Multivariate analysis	
	Coef.	*p*-Value	Coef.	*p*-Value
Proportion females (in %)	0.035	0.912	0.171	0.656
Mean age (in years)	0.012	0.444	0.012	0.491
Sample size (in number of people)	−0.000	0.678	−0.000	0.825
Quality rating (in %)	−0.006	0.262	0.001	0.905
Adjusted risk estimate (vs. crude)	−0.417	0.093	−0.424	0.277

Potentially influencing factors (meta-regression analysis)

None of the tested factors significantly influenced the effect size between sleep problems and work injuries (Table 3); thus, the meta-analytic estimate reflects an appropriate estimate of the general association. The power to explain the heterogeneity with statistical significance was limited. However, the heterogeneity due to adjustment was close to statistical significance, underscoring the need for proper multivariate modelling approaches. Additionally, studies with a higher proportion of females and a higher mean age tended to result in higher risks for occupational injury. Contrarily, studies with a larger sample size, a higher quality rating and with adjusted risk estimates tended to show lower risk for work injuries.

Our results compared with other reviews on the topic

The findings of this systematic review and meta-analysis are in line with previous reviews on the topic and advance the actual state of knowledge. This is the first meta-analysis to quantify the association between sleep problems and work injuries. The only previous systematic review on the topic found that insomnia symptoms elevated the risk for workplace accidents.[28] Confirming this association, several narrative reviews focused on specific types of sleep related accidents, such as farm injuries,[30] industrial accidents[18] or injuries in the maritime domain.[39] Concerning the impact of sleep problems on economics, two narrative reviews declared that the costs of insomnia related to work accidents were enormous.[25,29] Supporting the relationship, several reviews reported that obstructive sleep apnea,[74] insomnia,[11] hypersomnias,[75] and sleepiness[17–20,23,24] increased the risk of work-related traffic accidents in commercial drivers. In general, sleep problems cause a two- to seven-fold increased risk of traffic accidents.[22] According to the European statistics on accidents at work (ESAW), road traffic accidents constituted 9.6% of all accidents at work in 2007.[76] By excluding studies specifically addressing work-related motor vehicle crashes from our meta-analysis, we might have therefore underestimated the relative risk of sleep problems. Commuting accidents are excluded from the work injury statistics according to the definition of Eurostat,[36] and were therefore not considered for this meta-analysis. However, how the authors dealt with commuting accidents was not always clear. None of the reports explicitly included commuting accidents, but they might have been part of the work injury statistics in some studies. However, the number of commuting accidents is small compared to all work accidents.[77] If commuting accidents were included, they might not have noticeably influenced the estimated relative risk.

Study limitations

Several methodological issues must be considered when interpreting the findings of this meta-analysis.

First, as with any meta-analysis, one limitation relates to the potential bias introduced in the paper selection process. Following the recommendations in the Cochrane handbook[32] whenever possible helped minimize the selection bias. However, only peer-reviewed articles were searched for, and only English, French, German and Italian articles were considered during the full-text review (language bias).

Second, a further limitation reflects the possible bias introduced by the individual studies that were included. The designs of the included studies were rated low for assigning the grade of evidence.[78] In the absence of controlled studies, we relied exclusively on observational studies, and only three were of a prospective nature. However, the subgroup meta-analysis did not show a significant difference between the prospective and non-prospective studies, indicating that the reported overall estimate properly reflects the general effect. In addition to study design, the poor quality of the included studies could introduce possible bias. We included both high- and low-quality studies in the meta-analysis to avoid influencing the pooled estimate due to the type of scale used to assess the quality.[79] The subsequent subgroup meta-analysis did not show a significant difference between the high- and low-quality studies, indicating that the study quality might not have influenced the overall estimate. This assumption is supported by the meta-regression analysis, where the study quality did not turn out to be a significant factor.

Third, there was considerable variation between the studies in the assessment methods used to verify sleep problems and work injuries, introducing moderate heterogeneity. This heterogeneity raised some questions about the comparability of results across studies. According to our research question, we focused on a broad concept of sleep problems based on having any sleep problem symptoms. Thus, we pooled the different sleep problem symptoms because we assumed a common underlying concept. This assumption was based on several reviews that consistently related all types of sleep problems, such as insomnia,[11,25,28,29] impaired or shortened sleep,[18,30] sleepiness,[18,26,27] fatigue[24] or sleep apnea,[12] to work injuries. Additionally, heterogeneity remained in the subgroup meta-analysis of the sleep problems and also of the internationally classified sleep disorders, indicating that its source was not between the different aspects of sleep problems, but within each aspect, possibly due to a subjective assessment, the lack of standardisation or failure to control for somatic and psychiatric co-morbidities.

Finally, as in any meta-analysis, publication bias may have affected the representativeness of the included studies by over-reporting significant findings. Egger's regression test and visual analysis of the distribution of the relative risks using a funnel plot showed a moderate under-representation of weaker effects in smaller studies. This impression was supported by the fact that the studies excluded from this meta-analysis due to not presenting a risk estimate were mainly smaller studies with population sizes ranging from 95 to 826 participants.[80–85]

Further studies and implications

It would be of interest to explore whether these findings also apply to injury frequency or severity and to sleep problem severity to better understand the mechanisms involved in the ways that sleep problems affect work injuries. The relationship between sleep problems and injury frequency is still unclear, with only one study reporting the number of subjects with sleep problems in the subgroups of people with 0, 1, 2, 3 or more work accidents.[70] Additionally, the association between sleep problems and injury severity remains unclear with only one study showing workers with sleep problems having a higher risk for being injured in a more severe work accident (with hospitalisation or with sick leave of more than 30 d).[86] Furthermore, the link between sleep problem severity and work injuries is still unknown, with only two studies examining this relationship, suggesting that more severe sleep problems (more symptoms) resulted in a higher risk for work injuries.[58,59]

It would be beneficial to know better the population at highest risk for planning countermeasures to prevent sleep-related work injuries. Our understanding of age or gender differences, amplifying factors and differences in jobs or the types of sleep problems is insufficient. Age was rarely investigated with only one study suggesting that younger workers are at a higher risk for work injuries due to sleep problems.[69] This was contrary to the results of this meta-regression analysis, where risk tended to increase with age. Gender differences were addressed in several studies, but the evidence is non-conclusive with studies showing both lower[56,66] and – as in this meta-regression analysis – higher risks in women.[34,57] Several factors could amplify or weaken the relationship between sleep problems and work injuries, but only Kling et al. showed stratified results by job class, shift type and hours worked per week.[34] Regarding job type, it was suggested to investigate a broad range of occupations and not just trade or transportation,[34] taking into account that blue collar workers seemed to be more affected than white collar workers.[59] Further research is needed regarding the findings of this meta-analysis concerning the presumably strong impact of sleep medication or obstructive sleep apnea and the surprisingly weak indicator "daytime sleepiness", with wide consequences for preventive measures.

It would be desirable to achieve greater standardisation in sleep and injury measures to facilitate comparisons across studies and to improve the interpretability of findings. In addition to a recent review on fatigue risk management[87] and a study carrying out sleep disorders education,[53] future intervention studies may improve the understanding of how sleep-related work injuries might be prevented. The public health relevance was underscored by the high PAR%, suggesting that approximately 13% of the work injuries could be prevented. That means, the preventable burden of sleep problems in work injuries was similar to that in traffic accidents (PAR% = 10–15%).[88]

Practice points

1. There is accumulating evidence that sleep problems elevate the risk of injury in the workplace.
2. Sleep disorders, poor sleep quality and quantity, daytime sleepiness and sleep medication increase the work injury risk.
3. The risk for sleep-related work injuries is increased by a factor of 1.62.
4. Approximately 13% of work injuries were due to sleep problems.
5. General practitioners and occupational physicians should be aware of the role of sleep problems in work injuries and inform patients.
6. Prevention of sleep problems and fatigue management in the workplace are needed.

Research agenda

1 More information on the impact of sleep problems on work injuries according to the nature of the sleep problems (obstructive sleep apnea, sleep quality, sleep quantity, daytime sleepiness, sleep medication) is needed.
2 The impact of sleep problems on the frequency and the severity of work injuries needs to be assessed.
3 Driving and non-driving accidents should be distinguished in the workplace setting.
4 The use of standardised measures and procedures for the assessment of sleep problems and work injuries is important to compare results in the future.
5 More prospective studies to verify causality and first intervention studies to understand the impact of treating sleep problems on work injury risk are needed.
6 The mechanism underlying the impact of sleep problems on work injuries needs to be explained.
7 An understanding of how people at risk can be better identified would improve safety.

Conclusion

In conclusion, this comprehensive, systematic review not only confirmed the association between sleep problems and work injuries but also quantified this relationship for the first time. As sleep problems are of growing concern in the population, sleep medicine needs to further assess the implications and preventive measures, and occupational physicians should be aware of this risk and its effects on employees.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.smrv.2013.01.004.

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