INVESTIGATION OF THE RELATIONSHIP BETWEEN SLEEP PROBLEMS AND WORK INJURIES

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KNOWING IS NOT ENOUGH; WE MUST APPLY.
WILLING IS NOT ENOUGH; WE MUST DO.

– Goethe

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LIST OF ABBREVIATIONS

AHI	Apnoea hypopnea index
AIC	Akaike information criterion
BIA	Bioelectrical impedance analysis
BMI	Body mass index
Chi2	Chi-squared test
CI	Confidence interval
CPAP	Continuous positive airway pressure
DALY	Disability-adjusted life year
ED	Emergency department
EKAS	Federal Coordinating Commission for Occupational Safety
EKBB	Local ethics committee of Basel-Stadt and Basel-Land
ESI	Emergency severity index
ESS	Epworth sleepiness scale
ETH	Swiss Federal Institute of Technology, Zürich, Switzerland
ICSD-2	International classification of sleep disorders, version 2
ILO	International Labour Office
IPAQ	International physical activity questionnaire
IQR	Interquartile range
ISI	Insomnia severity index
MVC	Motor vehicle crash
MWW	Mann-Whitney-Wilcoxon test
N, n, nr	Number
OR	Odds ratio
OSAS	Obstructive sleep apnoea syndrome
p	P-value (statistical index of significance)
PAR%	Population attributable risk per cent
PSQI	Pittsburgh sleep quality index
RLS	Restless legs syndrome
Suva	Swiss National Accident Insurance Institution, Luzern, Switzerland
Swiss TPH	Swiss Tropical and Public Health Institute, Basel, Switzerland
UHB	University Hospital of Basel, Basel, Switzerland
UPK	Psychiatric University Clinics, Basel, Switzerland
UVG	Swiss federal law on accident prevention
WHO	World Health Organisation
WHR	Waist-hip ratio
x/w	Times per week

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SUMMARY

BACKGROUND

Work injuries are a major problem worldwide. Approximately 360,000 fatal occupational injuries occur yearly, and more than 960,000 workers are injured daily. The worldwide estimated cost of work injuries is over US$ 400 billion a year. In Switzerland, the number of work injuries recognised by the Swiss National Accident Insurance Institution has remained stagnant at approximately 95 work injuries per 1,000 full-time employees annually, after a decrease in work injuries in the decade before. The stagnation of the decrease and the middle rank for work injury risk in the European comparison has resulted in a demand for revising prevention measures.

A preliminary literature search on potentially important but disregarded causes of work injuries revealed that little is known about the personal factors influencing work injuries and that sleep problems may be a relevant but underestimated risk for work injury. Sleep problems are one of the most common health complaints with a varying prevalence of up to 40 % depending on the sleep problem type and examination method. Sleep problems may constrict the recovery function of sleep and lead to sleepiness during the day. Sleepiness may in turn reduce work performance and increase the risk of work injury.

The role of sleep as a potential risk factor in injury prevention is still under debate. The strong belief and consensus among specialists that sleep problems have an impact on the incidence of work injuries has never been approached systematically and pooled quantitatively. No data from Switzerland are currently available on this topic. Furthermore, it is unclear whether sleep quality, sleep duration and daytime sleepiness influence the various types of work injuries differently. Additionally, limited and conflicting evidence is available on factors that modify the relationship between sleep problems and work injuries.

OBJECTIVES

Derived from the above knowledge gaps and research needs, the overall aims of this thesis were to (i) better understand the influence of sleep problems on work injuries, (ii) identify susceptible types of work injuries and populations most at risk and (iii) investigate whether our international findings can be verified for Switzerland.

METHODS

The research questions of this thesis were addressed in the framework of two separate study parts. First, a systematic literature review was performed consisting of a search of several databases. Original articles quantifying the relationship between sleep problems and work injuries were included up to July 7th, 2011. Pooled relative risks expressed in odds ratios (OR) and 95 % confidence intervals (CI) were calculated through random effects models.

Several subgroup meta-analyses and meta-regression analyses were performed, and the population attributable risk was estimated.

Second, a case-control study including 180 cases and 551 controls was conducted at the University Hospital of Basel, Switzerland, from December 1st 2009 to June 30th, 2011. Work injuries were defined according to Swiss law. Data on sleep problems were collected using the validated German versions of the Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS). The potential confounders considered included socioeconomic, health, lifestyle, occupational and environmental factors. Data analysis was performed in two steps; work injuries were investigated first, and then, we analysed the full case-control sample.

RESULTS

Through the systematic review, we identified 27 studies reporting 54 estimates for the relationship between sleep problems and work injuries. Meta-analysis suggested that sleep problems significantly increased the risk of suffering a work injury by 62 % (OR = 1.62, 95 % CI 1.43 – 1.84). Approximately 13 % of the work injuries were attributed to sleep problems. Subgroup meta-analysis showed that every type of sleep problem was significantly related to work injury; the highest risks were observed for taking sleep medication and breathing related sleep problems. Sleep problems tended to increase the work injury severity. Additionally, work injury risks tended to be higher in workers with more severe sleep problems.

Findings from the case-control study suggested that workers with poor sleep quality had a 78 % (OR = 1.78, 95 % CI 1.01 – 3.17) higher risk of being injured at work than workers with good sleep quality. More severe sleep problems were associated with a higher work injury risk, and having sleep problems resulted in a greater history of work injuries, independent of case status. The analysis of the work injury data revealed that the work injury types most susceptible to sleep problems were falls and musculoskeletal injuries, injuries while working with or being injured by a tool or machine, and injuries while performing a side task. Sleep quality, sleep duration and daytime sleepiness were significant risk factors for at least one type of work injury. The populations identified as most at risk for sleep problem related work injuries were workers older than 30 years, sleeping 7 hours or less per night, and working 50 hours or more per week.

CONCLUSIONS AND OUTLOOK

This thesis adds further evidence that sleep problems are a considerable risk for work injuries. We not only systematically confirmed the suggested association between sleep problems and work injuries, we also quantitatively pooled the estimated risks for the first time. Furthermore, this thesis is the first comparison between international and Swiss results. Similar risks for sleep problem related work injuries were observed, and the international findings could therefore be verified for Switzerland.

The socioeconomic burden of sleep problem related work injuries was estimated as considerable. Approximately CHF 290 million are spent on the consequences of sleep problem related work injuries in Switzerland every year. Up to every fifth work injury may be prevented if sleep problems are eliminated.

The knowledge about the impact of sleep problems on work safety obliges responsible parties to take preventive action. This thesis adds valuable information on how to identify the risk of sleep problem related work injuries. The identification of the work injury types most susceptible to sleep problems may contribute to a better understanding of the injury causation and thus support a comprehensive recognition of injury causes. It may be useful to check workers involved in a fatigue related work incident for the sleep problems that are found to be associated with work injuries in this thesis to prevent them from similar events. Another approach may be to target sleep-related prevention measures to the population most at risk for sleep problem related work injuries identified in this thesis.

Future studies on this topic should be conducted in basic research and applied science. Basic research in the field of sleep problem related work injuries needs to better characterise the mechanisms involved in the ways that sleep problems affect work injuries. For this purpose, laboratory simulations and epidemiological studies are needed. Furthermore, newly proposed analysis methods should be verified, and measures to assess which injury relevant aspects of sleep in the workplace setting need improvement.

Applied science should be used to provide practical knowledge on how to protect workforces from sleep problem related work injuries. For a successful implementation of fatigue prevention measures, evidence-based information is needed along the causal chain of events potentially leading to an incident. To predict fatigue at the organisational and individual levels, behaviourally based methodologies need post-implementation research to define thresholds. The possibility for reducing the number of work injuries through sleep education needs to be evaluated for targeted injury prevention. Before launching a screening program for sleep problems, questions on feasibility or effectiveness need to be answered. Fatigue detection technologies and fatigue proofing systems need validation. Furthermore, occupational health and safety officers need to be trained in identifying fatigue-related factors that can cause injuries.

In practice, many ideas on structural and behavioural strategies for work injury prevention exist. However, there are many unanswered questions about assessing fatigue management in the workplace. These questions need to be resolved before fatigue management systems can realise their full potential for contributing to injury prevention and helping to reduce the number of work injuries.

ZUSAMMENFASSUNG

HINTERGRUND

Berufsunfälle sind weltweit ein großes Problem. Rund 360,000 tödliche Berufsunfälle geschehen jährlich, und mehr als 960,000 Beschäftigte verletzen sich täglich. Weltweit werden die Berufsunfallkosten auf über US$ 400 Milliarden pro Jahr geschätzt. In der Schweiz stagnierte die von der Schweizer Unfallversicherungsanstalt anerkannte, jährliche Zahl der Berufsunfälle bei etwa 95 Berufsunfällen pro 1,000 Vollbeschäftigten, nach einem Rückgang in den zehn Jahren davor. Die Abflachung des Rückgangs der Berufsunfallzahlen und der mittlere Rang im europäischen Vergleich ergaben einen Bedarf zur Überarbeitung der Präventionsmassnahmen.

Eine erste Literaturrecherche zu potenziell wichtigen, aber vernachlässigten Ursachen ergab, dass wenig über persönliche Faktoren bekannt ist und dass Schlafstörungen ein relevantes, aber unterschätztes Risiko für Berufsunfälle darstellen könnten. Schlafstörungen sind eine der häufigsten gesundheitlichen Beschwerden mit variierender Prävalenz von bis zu 40 %, je nach Art des Schlafproblems und der Untersuchungsmethode. Schlafstörungen können die Erholungsfunktion des Schlafs mindern und zu Tagesschläfrigkeit führen. Tagesschläfrigkeit kann wiederum die Arbeitsleistung herabsetzen und das Risiko von Berufsunfällen erhöhen.

Die Rolle des Schlafs als potenzieller Risikofaktor für die Unfallprävention ist noch nicht abschliessend geklärt. Die starke Überzeugung und Übereinstimmung der Experten, dass Schlafprobleme einen Einfluss auf das Auftreten von Berufsunfällen haben, wurde nie systematisch untersucht und quantifiziert. Ausserdem stehen keine Daten aus der Schweiz zur Verfügung. Darüber hinaus ist unklar, ob Schlafqualität, Schlafdauer und Tagesschläfrigkeit die verschiedenen Berufsunfallarten unterschiedlich beeinflussen. Zusätzlich sind nur begrenzte und widersprüchliche Erkenntnisse zu Faktoren, die die Beziehung zwischen Schlafstörungen und Berufsunfällen beeinflussen, verfügbar.

ZIELE

Abgeleitet aus den oben genannten Wissenslücken und dem Forschungsbedarf, waren die allgemeinen Ziele dieser Arbeit, (i) das Risiko von Schlafstörungen für Berufsunfälle besser zu verstehen, (ii) anfällige Berufsunfallarten sowie gefährdete Bevölkerungsgruppen zu identifizieren und (iii) zu untersuchen, ob unsere internationalen Erkenntnisse in der Schweiz bestätigt werden können.

METHODEN

Auf die Forschungsfragen dieser Arbeit wurde im Rahmen von zwei separaten Studienteilen eingegangen. Zuerst wurde eine systematische Literaturrecherche von mehreren Daten-

banken durchgeführt. Originalartikel, die die Beziehung zwischen Schlafstörungen und Berufsunfällen quantifizierten, wurden bis zum 7. Juli 2011 eingeschlossen. Globale relative Risiken (OR) und 95 % Konfidenzintervalle (CI) wurden durch Modelle mit zufälligen Effekten berechnet. Mehrere Meta-Regressionsanalysen und Meta-Analysen in Untergruppen wurden durchgeführt. Der den Schlafproblemen zuzuordnende, prozentuale Anteil an Berufsunfällen wurde abgeschätzt.

Des Weiteren wurde an der Universitätsklinik Basel, Schweiz, vom 1. Dezember 2009 bis zum 30. Juni 2011 eine Fall-Kontroll-Studie mit 180 Fällen und 551 Kontrollen durchgeführt. Berufsunfälle wurden nach schweizerischem Recht definiert. Daten zu Schlafproblemen wurden mit Hilfe der deutschen, validierten Versionen des Pittsburgh-Schlafqualitätsindexes (PSQI) und der Epworth-Schläfrigkeitsskala (ESS) erhoben. Als potenzielle Störgrössen wurden sozioökonomische, gesundheits-, lifestyle-, berufs- und umweltbedingte Faktoren betrachtet. Die Datenanalyse wurde in zwei Schritten durchgeführt, zuerst die Untersuchung ausschliesslich der Berufsunfälle und dann die Analyse der gesamten Fall-Kontroll-Stichprobe.

RESULTATE

Durch die systematische Literaturrecherche haben wir 27 Studien mit 54 Risikoschätzungen zum Einfluss von Schlafstörungen auf Berufsunfälle ermittelt. Die Meta-Analyse zeigte, dass Schlafstörungen das Risiko für einen Berufsunfall signifikant um 62 % (OR = 1.62, 95 % CI 1.43 – 1.84) erhöhen. Etwa 13 % der Arbeitsunfälle wurden Schlafproblemen zugeschrieben. Meta-Analysen in Untergruppen ergaben, dass jede Art von Schlafproblem deutlich im Zusammenhang mit Berufsunfällen steht, wobei die grössten Risiken bei Schlafmittelkonsum und atembezogenen Schlafstörungen beobachtet wurden. Weiter schienen Schlafstörungen die Unfallschwere zu erhöhen. Ausserdem tendierte das Berufsunfallrisiko dazu, in Arbeitnehmenden mit schwereren Schlafproblemen höher zu sein.

Die Fall-Kontroll-Studie zeigte, dass Arbeitnehmende mit schlechter Schlafqualität ein um 78 % (OR = 1.78, 95 % CI 1.01 – 3.17) höheres Berufsunfallrisiko hatten als Arbeitnehmende mit guter Schlafqualität. Schwerere Schlafstörungen waren mit einem höheren Berufsunfallrisiko assoziiert, und Arbeitnehmende mit Schlafstörungen hatten mehr frühere Berufsunfälle, unabhängig vom Fallstatus. Die Analyse der Berufsunfalldaten ergab, dass die für Schlafprobleme anfälligen Unfalltypen Stürze und Verletzungen des Bewegungsapparates, Unfälle mit oder durch Werkzeuge oder Maschinen, und Unfälle bei Nebentätigkeiten waren. Schlafqualität, Schlafdauer und Tagesschläfrigkeit waren signifikante Risikofaktoren für mindestens eine Art von Berufsunfall. Als vorwiegend von Schlafproblem bezogenen Berufsunfällen betroffen wurden Arbeiter identifiziert, die älter als 30 Jahre sind, 7 Stunden oder weniger schlafen pro Nacht und 50 Stunden oder mehr arbeiten pro Woche.

SCHLUSSFOLGERUNGEN UND AUSBLICK

Die vorliegende Arbeit ist ein weiterer Beleg, dass Schlafstörungen ein erhebliches Risiko für Berufsunfälle darstellen. Die angedeutete Assoziation zwischen Schlafstörungen und Berufsunfällen wurde nicht nur systematisch bestätigt, sondern zum ersten Mal auch quantitativ zusammengefasst. Darüber hinaus erlaubte diese Doktorarbeit erstmals den Vergleich zwischen internationalen und Schweizer Ergebnissen. Die internationalen Ergebnisse konnten für die Schweiz bestätigt werden, da ähnliche Risiken für Schlafproblem bezogene Berufsunfälle beobachtet wurden.

Die sozioökonomische Belastung durch Schlafproblem bezogene Berufsunfälle wurde als erheblich eingeschätzt. Rund CHF 290 Millionen werden für die Folgen von Schlafproblem bezogenen Berufsunfällen in der Schweiz jährlich aufgewendet. Schätzungsweise fast jeder fünfte Schweizer Berufsunfall könnte durch die Beseitigung von Schlafproblemen verhindert werden.

Die Erkenntnisse über die Auswirkung von Schlafstörungen auf die Arbeitssicherheit verpflichtet die Verantwortlichen zu Präventionsmaßnahmen. Die vorliegende Arbeit liefert wertvolle Informationen, wie die mit Schlafproblemen verbundenen Unfallgefahren identifiziert werden können. Durch die Identifikation von Schlafproblem anfälligen Unfallarten könnten die vorliegenden Resultate zu einem besseren Verständnis von Unfallursachen beitragen und eine umfassende Bestimmung des Unfallhergangs unterstützen. Es könnte hilfreich sein, Arbeitnehmende mit Schlafproblem bezogenem Berufsunfall auf die in dieser Dissertation ermittelten Schlafprobleme zu überprüfen, um ähnliche Ereignisse zu verhindern. Ein weiterer Ansatz könnte sein, Präventionsmassnahmen zu Schlafproblemen auf jenen Anteil der Arbeitsbevölkerung auszurichten, der in dieser Studie am stärksten für Schlafproblem bezogene Berufsunfälle gefährdet war.

Zukünftige Studien sollten sich der Erforschung von Grundlagen sowie von Anwendungen annehmen. Die Grundlagenforschung im Bereich der Schlafproblem bezogenen Berufsunfälle bedarf ein besseres Verständnis der beteiligten Mechanismen aufzubauen. Zu diesem Zweck sind Laborsimulationen und epidemiologische Studien erforderlich. Darüber hinaus sollten neu vorgeschlagene Analysemethoden überprüft und verbesserte Erhebungsmethoden im Berufsumfeld zu Unfall relevanten Aspekten des Schlafes entwickelt werden.

Angewandte Forschung sollte genutzt werden, um praktisches Wissen darüber zu liefern, wie Arbeitskräfte vor Schlafproblem bezogenen Berufsunfällen geschützt werden können. Für die erfolgreiche Umsetzung von Massnahmen zur Verhütung von Schlafproblem bezogenen Berufsunfällen werden entlang der Kausalkette von Ereignissen, die möglicherweise zu einem Berufsunfall führen könnten, evidenzbasierte Informationen benötigt. Um Müdigkeit auf organisatorischer und individueller Ebene vorhersagen zu können, braucht es Anwendungsstudien, die die Schwellenwerte von verhaltensbasierten Modellen festlegen. Das Potenzial von Schlafschulungen, die Zahl der Berufsunfälle zu reduzieren, sollte ausgewertet und die Erkenntnisse für eine gezielte Unfallprävention verwendet werden. Vor der Einführung eines Früherkennungsprogramms für Schlafprobleme sollten Fragen zur Machbarkeit und Wirksamkeit beantwortet werden. Technologien zur Erkennung von Müdigkeit und Müdigkeitsnachweissysteme müssen validiert werden. Ausserdem sollten Sicherheitsbeauftragte am Arbeitsplatz für die Erkennung von müdigkeitsbezogenen Faktoren bei der Unfallanalyse geschult werden.

In der Praxis existieren viele Ideen zur Prävention von Berufsunfällen auf der Verhältnis- und der Verhaltensebene. Allerdings sind viele Fragen, die sich bei der Einführung eines Müdigkeitsmanagementsystems am Arbeitsplatz ergeben, noch offen. Diese müssen beantwortet werden, bevor die Müdigkeitsmanagementsysteme ihr volles Potenzial zur Prävention von Berufsunfällen entfalten können und dazu beitragen, die Zahl der Berufsunfälle zu reduzieren.

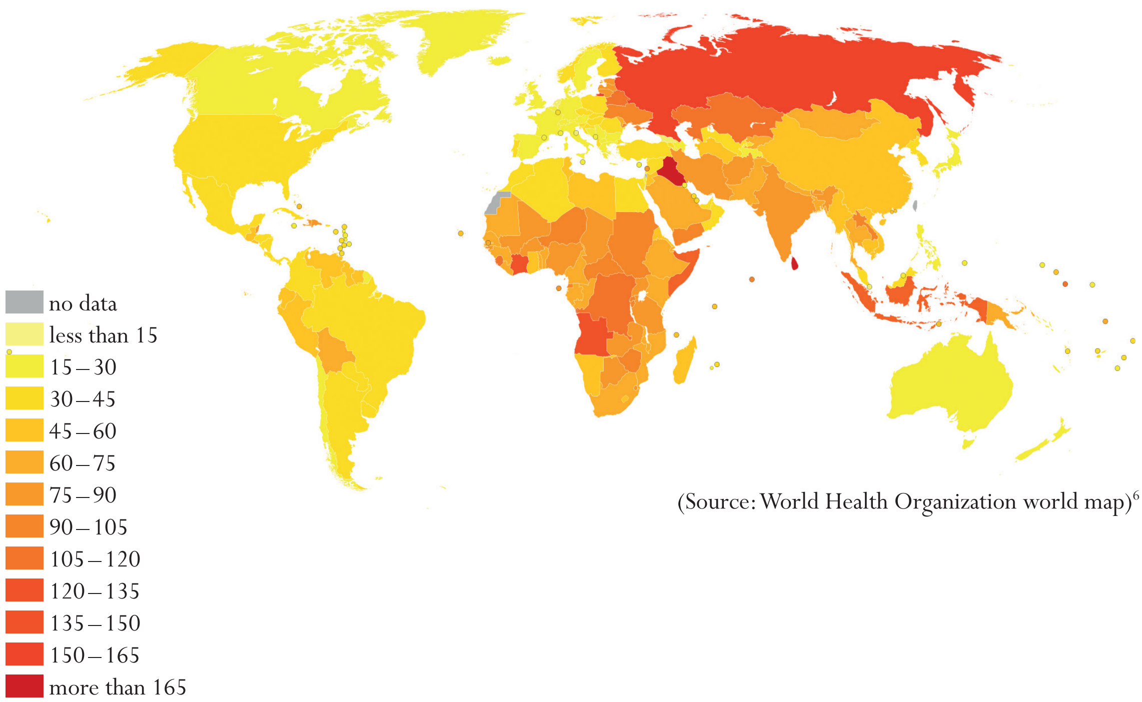
1 INTRODUCTION AND BACKGROUND

1.1 WORK INJURIES: A PUBLIC BURDEN

Worldwide, 337 million work injuries occur annually, and over 360,000 people die as a result of occupational injuries every year.[1] The International Labour Organization (ILO) estimated that the total cost of occupational injuries and work-related diseases account for 4 % of the gross domestic product and amount to approximately US$ 2,880 billion annually.[2,3] Approximately 14 % of these costs (US$ 400 billion) are caused by work injuries.[2]

The worldwide estimates are global averages and are only a rough indicator of the world cost.[2] A country with lower-than-average injury rates will lose a smaller part of its national wealth.[2] The work injury rates in Switzerland are below the international average (Figure 1) and rank in the middle in Europe.[4] In Switzerland, the work injury rate recorded by the Swiss National Accident Insurance Institution decreased by 35 % from 1990 to 2008 (Figure 2).[5] Since then, the decrease has slowed, and the rate averages approximately 270,000 work injuries per year or approximately 95 work injuries per 1,000 full-time emp-loyees yearly.[5] The risk of fatal work injury has decreased since 1985 by almost 40 % and stagnated at approximately 190 fatal work injuries per year or at five to six fatal work injuries per 100,000 full-time employees annually.[5] The work injury cost in Switzerland is approximately CHF 1,460 million every year.[5]

Figure 1: Age standardised death rates from unintentional injuries per 100,000 inhabitants by country in 2004.

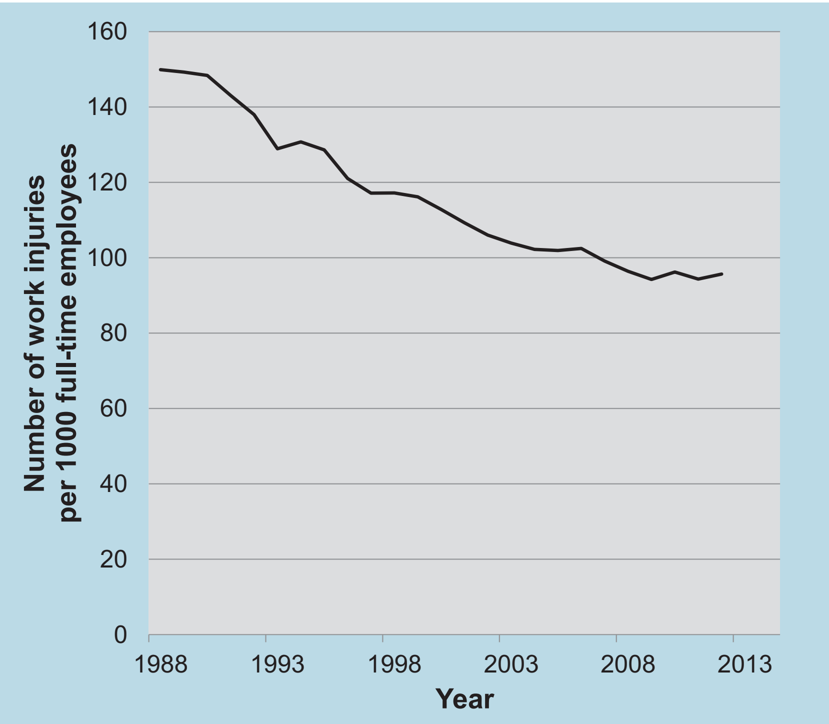


(Source: World Health Organization world map)[6]

1.2 WORK INJURY PREVENTION: THE VISION OF SAVING 250 LIVES

The stagnation of the decrease in the work injury risk and the average European comparison resulted in a need for action in Switzerland. As a consequence, the Federal Coordinating Commission for Occupational Safety (EKAS) defined new goals for work injury prevention in 2005.[7] The annual number of fatalities and the annual number of severe work injuries should be cut in half by 2015. In achieving this goal, 250 lives would be saved and 250 workers would be prevented from serious, permanent work injury consequences in a 10-year period. These objectives are in line with the European strategy promoting safety and health at work from 2007, which was targeted at reducing work injury incidence rates by 25 % over a 5-year period.[7]

Figure 2: Work injury risk in Switzerland from 1988 – 2012, illustrated by the number of newly registered work injuries per 1,000 full-time employees annually.



(Source: Swiss National Accident Insurance Institution, 2013)[8]

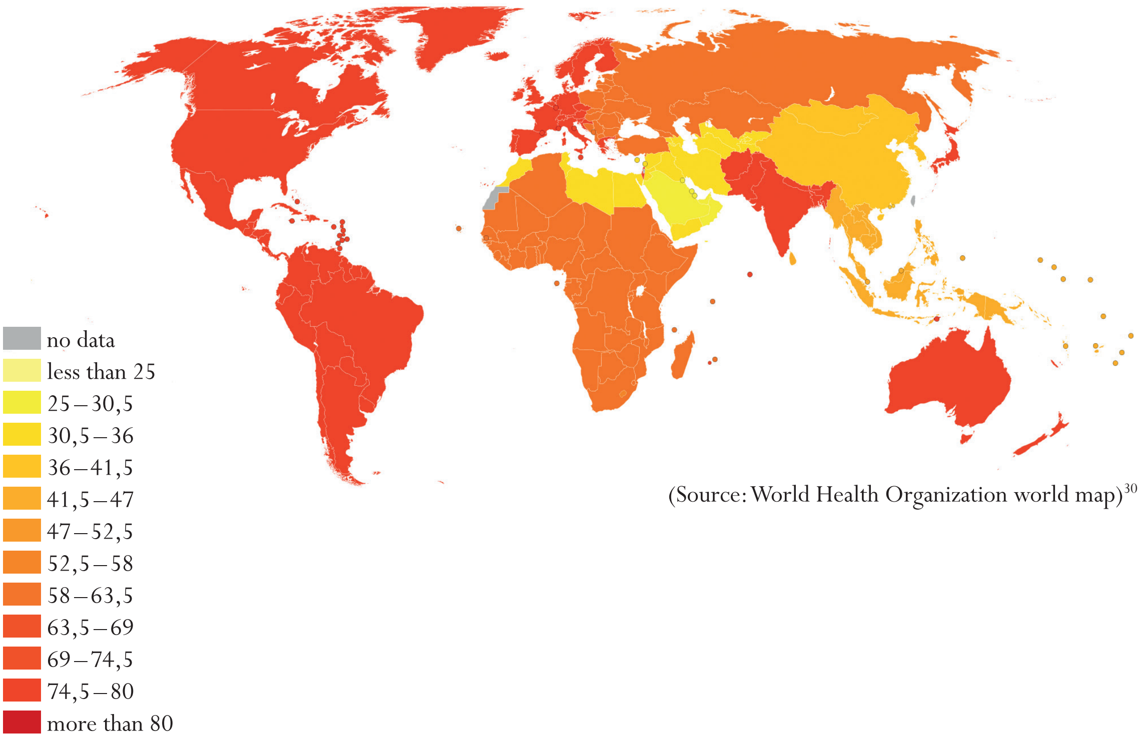
To achieve these goals, the Swiss national accident insurance companies mapped out several strategies. One is the development of new prevention measures, which requires improved knowledge about the causes of work injuries. A preliminary literature search was conducted to identify relevant but thus far disregarded risk factors for work injuries. The search topics were defined along with specialists and covered environmental, organisational, physical, psychosocial, sociodemographic and safety factors. The review revealed that little was known about personal factors[9–11] and that sleep problems may be a relevant but underestimated risk factor for work injuries.[12–14] In particular, nothing has previously been reported about the potential risk of sleep problems in Switzerland. As a consequence, the Swiss National Insurance Institution (Suva) commissioned a scientific study to investigate the relationship between sleep problems and work injuries in general and in Switzerland.

1.3 SLEEP PROBLEMS: ONE OF THE MOST COMMON HEALTH COMPLAINTS

Sleep problems are among the most common health complaints (for a definition of sleep problems, see *Chapter 2.2*).[15] A high frequency of insomnia in the general population has been observed in several international studies over the last decade, and the prevalence was estimated at 10 to 40 % depending on the methodology and insomnia definition.[16–20] Obstructive sleep apnoea syndrome (OSAS) is estimated to affect approximately 20 % of the general adult population when defined with an apnoea hypopnea index (AHI) of ≥ 5 events per hour[21] or approximately 5 % if defined as an AHI of ≥ 5 events per hour accompanied by excessive daytime sleepiness.[22] Excessive daytime sleepiness is reported by approximately 15 % of the European population.[23] Other sleep disorders are relatively rare. Restless legs syndrome (RLS) was observed in 2.5 to 10 %[24] and narcolepsy in 0.047 % of the general population.[23]

Sleep problems are more common in women[25] and in older people[26], and their prevalence varies across nations (Figure 3). The United States has a significantly higher prevalence of insomnia (39 %) than Europe (28 %) and Japan (21 %).[27] Within Europe, the prevalence of non-restorative sleep and the prevalence of excessive daytime sleepiness seem to follow a north-south pattern; the United Kingdom has the highest prevalence, and Spain has the lowest.[23,28] In Switzerland, problems falling asleep or not sleeping well were observed in 35.5 % of the general population and in 31.4 % of the working population.[29]

Figure 3: Age standardised disability-adjusted life year (DALY) rates from (primary) insomnia by country per 100,000 inhabitants in 2004.

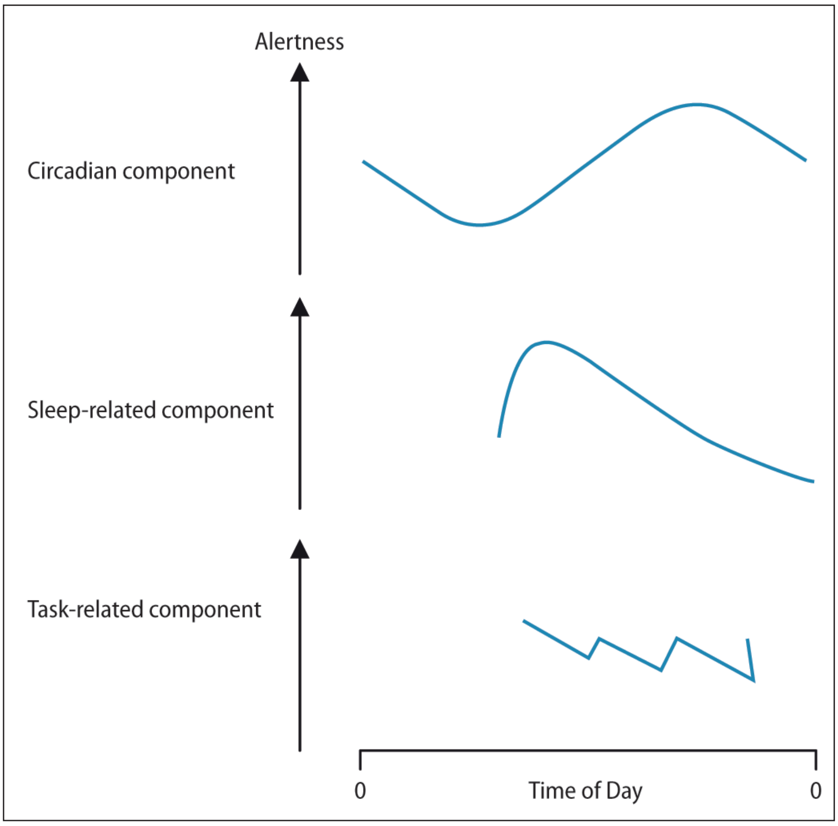


(Source: World Health Organization world map)[30]

1.4 THE OVERALL FRAMEWORK FOR EXAMINING SLEEP AND SAFETY

Sleep problems may negatively impact the recovery function of sleep and lead to sleepiness or fatigue during the day (for a definition of sleepiness and fatigue, see *Chapter 2.2*). The three main factors influencing fatigue are the circadian rhythm, the sleep-wake homeostasis and the characteristics of the task performed (Figure 4).[31] The first two components are described in the two-process model of sleep regulation.[32] The circadian rhythm influences the sleep propensity as a function of the time of the day (also known as process "C").[32] The sleep-wake homeostasis regulates the process of recovery as a function of sleep loss or time since last sleep (process "S").[32] In addition to the first two components, alertness may show a decrease during task performance, which is specific to the characteristics of that type of task.[31]

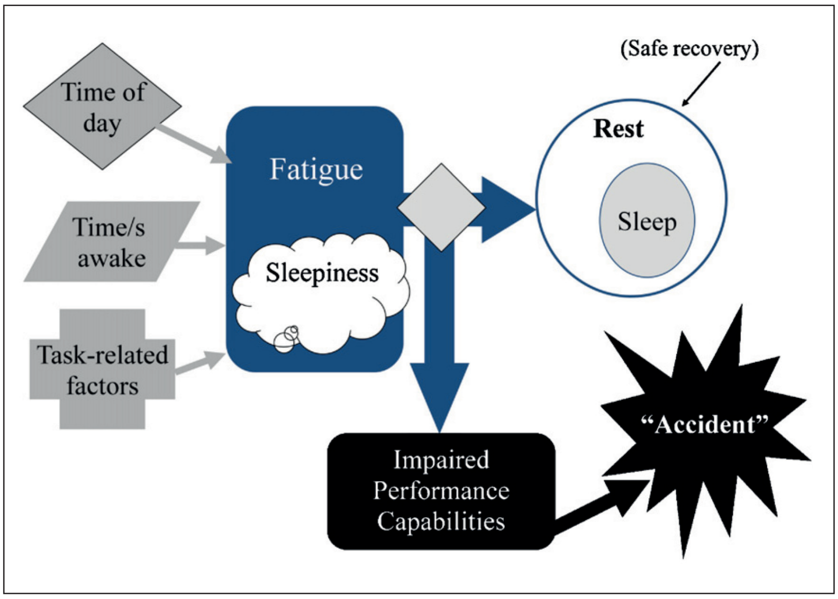
Figure 4: Three different components influencing alertness.



(Source: Gundel et al., 2007)[31]

This three component model was extended with the consequences of fatigue or sleepiness (Figure 5). Sleepiness and fatigue provide the drive for restorative rest and sleep and lead to a safe recovery.[33] To the extent that this drive remains unsatisfied, the capacity to act and the readiness for action are reduced.[34] This reduction in turn increases the risk of an adverse outcome, such as a work injury.[33] The role of sleepiness and fatigue in injury risk can be twofold. First, fatigue may reduce the ability to recognise a dangerous situation.[14] Second, fatigue may reduce the ability to respond adequately to a dangerous situation.[14]

Figure 5: Framework for examining the relationship between fatigue and safety. *Time of day* relates to the circadian component, and *time/s awake* corresponds to the sleep-related component in Figure 4.



(Source: Williamson et al., 2011)[33]

1.5 SLEEP PROBLEMS AND WORK INJURIES: STATE OF RESEARCH AND OPEN ISSUES

The role of sleep as a potential risk factor in injury 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 crashes is well established,[35–40] but there is less evidence in other working areas.[41] Previous narrative reviews have summarised only a few of the larger studies,[33] were limited to cost estimations,[42,43] or focused on specific sleep disorders, such as obstructive sleep apnoea,[44] insomnia,[42,43,45,46] sleep restriction,[38,47] or sleepiness.[33,43,48,49] However, to date, no review has quantified the impact of general sleep problems on work injuries. Therefore, there is a need for a broad, systematic review and meta-analysis that quantifies the relationship between sleep problems and work injuries other than work-related motor vehicle crashes.

The influence of different dimensions of sleep problems on work injuries is unclear and may be investigated separately. For example, the consequences of poor sleep quality may be compensated by elevated attention during work, but sleepiness might directly impair daytime performance and, therefore, be more strongly correlated with work injury. Furthermore, knowledge about the influence of sleep problems on the pattern of work injury types is limited. A French study on construction workers reported a higher risk of being injured by moving objects for workers with sleep problems compared to workers without sleep problems.[11] However, no research has thus far been undertaken that relates different dimensions of sleep problems to various types of work injuries in the general working population. Therefore, there is a need to identify potential associations between different types of work injuries and sleep quality, sleep duration and daytime sleepiness.

Limited evidence is available on the factors modifying the relationship between sleep problems and work injuries in the current literature, and existing studies show conflicting results. Evidence regarding the influence of gender is not conclusive, with studies showing higher,[50,51] lower,[52,53] or similar[54–56] rates of sleep-related work injury risk for men versus women. Our understanding of the influence of age is insufficient; one study reported higher risks in young workers[57], and two studies found no interaction between age and sleep quality with regards to work injury risk.[54,56] Concerning work-related factors, only Kling et al., 2010, stratified the association between sleep problems and work injuries by job class and shift type, showing that processing and manufacturing jobs and rotating shifts carry the highest risks for sleep problem associated work injuries in women.[52] There is limited evidence suggesting that long working hours[58–60] or reduced sleep quality[52,61] may increase work injury risk from a short sleep duration. Thus, there is a need for further studies investigating the factors that potentially modify the association between sleep problems and work injuries.

2 STUDY DESCRIPTION

The mandate of the Suva and the preliminary investigations on the current state of knowledge, which were explained in *Chapter 1*, have led to the objectives of this thesis. This chapter defines the research questions and describes the overall methods used to answer them.

2.1 AIMS AND OBJECTIVES

The overall aims of this thesis were to (i) better understand the influence of sleep problems on work injuries, (ii) identify susceptible types of work injuries and populations most at risk and (iii) investigate whether our international findings could be verified for Switzerland.

Understanding the influence of sleep problems on work injuries

To review the current knowledge on the relationship between sleep problems and work injuries, a systematic review and meta-analysis were conducted. The following questions were addressed:

1) *Are sleep problems consistently related to work injuries?*
2) *What is the pooled risk estimate of sleep problems for work injuries?*
3) *What percentage of work injuries can be attributed to sleep problems?*
4) *What types of sleep problems have the highest risks?*
5) *What factors may be underlying the overall effect of sleep problems on work injuries?*

The findings are presented in *Chapter 3: Paper 1: Sleep problems and work injuries: a systematic review and meta-analysis.*

Identifying susceptible types of work injuries and populations most at risk

To see whether certain types of work injuries are more susceptible to sleep problems than others, we analysed data from 180 work injury patients and their self-perceived sleep. The addressed research questions were:

6) *Which injury types are most susceptible to sleep problems?*
7) *What dimensions of sleep problems (sleep quality, sleep duration or daytime sleepiness) are relevant for the risk of different work injury types?*

The results are presented in *Chapter 4: Paper 2: Sleep problems and work injury types: a study of 180 patients in a Swiss emergency department.*

To identify the populations most at risk for sleep quality related work injuries, the factors potentially modifying the association between sleep problems and work injuries were assessed.

Information on the sociodemographic, work-related and health factors, including gender, age, job risk, shift or night work, nightly sleep duration, weekly working hours, and comorbid conditions, was used to address the following research question:

8) What are the most vulnerable populations at risk for poor sleep quality increasing work injuries?

The findings are presented in *Chapter 5: Paper 3: Sleep quality and the risk of work injury: a Swiss case-control study.*

Verifying our international findings for Switzerland
The relationship between sleep quality and work injury was investigated in 180 cases and 551 controls from the area of Basel. We assessed sleep problem occurrence and sleep problem severity as well as work injury occurrence and work injury history. The following research question was addressed:

9) Are the findings from Switzerland in line with the findings from the meta-analysis?

The results from Switzerland are presented in *Chapter 5: Paper 3: Sleep problems and the risk for work injuries: a Swiss case-control study).*

2.2 METHODS
The research questions of this thesis were addressed in the framework of two separate study parts. Each part is described in detail in the respective research articles *(Chapters 3 to 5)*. In this overall method section, we provide an overview of the study designs.

SYSTEMATIC REVIEW AND META-ANALYSIS
A systematic review was conducted to answer our specific research questions on the relationship between sleep problems and work injuries by identifying, selecting and synthesising all relevant research evidence.[62] This process was conducted systematically and was protocol driven. We complied with the methodical standards defined by the Cochrane Collaboration,[62] followed the step-by-step guide for systematic reviews and meta-analyses,[63] and followed the guidelines for reporting meta-analysis of observational studies in epidemiology (the MOOSE guidelines).[64] We electronically searched four relevant databases, Medline, Embase, PsycInfo, and the Web of Science, for original articles published up to July 7th, 2011, and we hand-searched the reference lists of the articles identified through database searches as well as the last year's issues of the most relevant scientific journals. Sleep problems of any duration, severity or frequency, as well as work injuries of any severity, were of interest. A meta-analysis of the systematically reviewed and extracted data was conducted to statistically synthesise the quantitative results of the eligible studies.[62] Pooled relative risks and 95 % CI were calculated

through random effects models. Additionally, meta-regression analyses were performed, and the population attributable risk was estimated. The value of systematic reviews based on meta-analyses is high, and evidence is strong because they minimise bias and increase precision.[65] Details on this methodical approach are given in *Chapter 3: Paper 1: Sleep problems and work injuries: a systematic review and meta-analysis.*

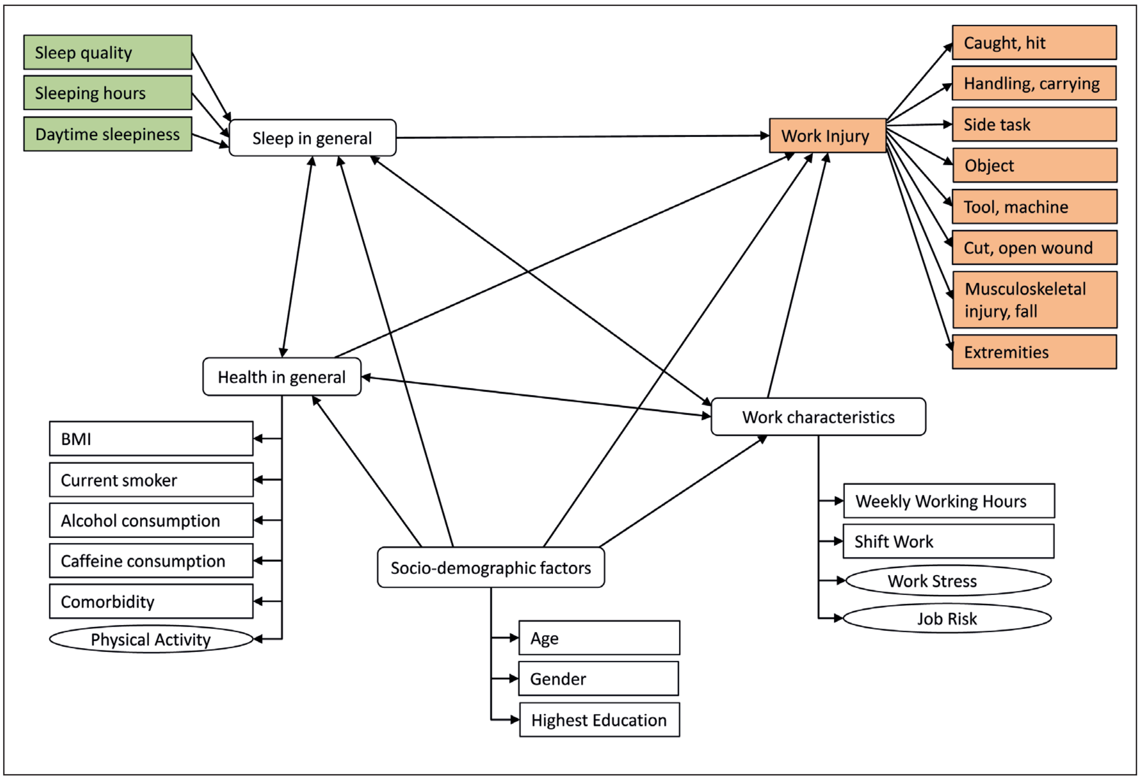
CASE-CONTROL STUDY

A case-control study design was chosen as an epidemiological approach to efficiently investigate work injury as an outcome of low incidence.[66] Case-control studies provide less evidence for causal inference than long-term cohort studies[65] but can be carried out by small teams in single facilities and are less expensive in terms of time, money and effort.[66] We had the opportunity to build this field study on an existing collaboration with the University Hospital of Basel (UHB) and to combine their knowledge with the expertise of several specialists from the University of Basel, the Swiss Tropical and Public Health Institute (Swiss TPH), the University of Bern, the Psychiatric University Clinics (UPK) in Basel, and the Swiss Federal Institute of Technology (ETH) in Zürich. Based on a power analysis for testing the relationship between sleep problems and work injuries in Switzerland, we aimed to recruit 180 cases and 360 controls at the UHB and in its catchment area, including male and female workers 18 to 65 years of age. Due to the challenging frequency matching for age, gender and job risk, we revised our sample size along the way and finally included 180 cases and 551 controls from December 1st, 2009 to June 30th, 2011. Work injuries were defined according to Swiss law,[67] which is in line with the European methodology specified by Eurostat[68] and includes injuries occurring in the course of work but excludes repetitive strain and commuting injuries. Work injury types were based on groups of work injury characteristics determined by factor analysis. Data on sleep problems were collected using the self-administered, validated German versions of the Pittsburgh Sleep Quality Index (PSQI)[69,70] and the Epworth Sleepiness Scale (ESS).[71,72] The potential confounders considered included socioeconomic, health, lifestyle, occupational and environmental factors. Data analysis was performed in two steps. For details on the work injury analyses, see *Chapter 4: Paper 2: Sleep problems and work injury types: a study of 180 patients in a Swiss emergency department.* For details on the analyses based on the case-control sample, see *Chapter 5: Paper 3: Sleep quality and the risk of work injury: a Swiss case-control study.*

THE SPECIFIC FRAMEWORK OF THE CASE-CONTROL STUDY

The concept of this case-control study was based on the model by Williamson et al., 2001, as outlined in Chapter 1.4.[33] We adopted the model to meet our research needs as follows. On the exposure side, we focused on the sleep-related component and thoroughly investigated the three dimensions of sleep problems: sleep quality, sleep duration and daytime sleepiness. On the outcome side, we focused on work injury and its various types. Furthermore, we controlled for possible influencing variables according to the literature. The specifically adapted framework for this case-control study is shown in Figure 6.

Figure 6: Study specific framework for assessing the relationship between sleep problems and work injuries.



Rectangles indicate observed variables, ellipses show latent variables/constructs, and rectangles with round corners represent their attached variables in the model. Single-headed arrows indicate directional and double-headed arrows bi-directional effects. Work injury was assessed as an outcome and is thus connected with single-headed arrows only. The considered sociodemographic factors were thought to be invariable and have directional effects only.

TERMINOLOGY OF SLEEP PROBLEMS AND WORK INJURIES

Inconsistent definitions of the terms for sleep problems and work injuries are used in the literature.[52,73] Thus, the terminology used throughout this thesis is defined in the following paragraphs.

"Sleep problems" is used as an overarching term that includes all sleep disorders described in the International Classification of Sleep Disorders (ICSD-2), including their symptoms (for detailed definition, see *Chapters 3* to *5*).[74] Insomnia, OSAS, RLS and narcolepsy are classified as intrinsic sleep disorders.[74] To date, there is no clear demarcation between "fatigue", "sleepiness" and "lethargy".[75] Sleepiness is the desire or tendency to fall asleep, lethargy is an apathetic state or lack of interest in activity, and fatigue is a sense of physical tiredness after exertions or activity.[75] Sleepiness and fatigue as a consequence of disturbed sleep are considered in this thesis, but non-specific fatigue or fatigue as a specific consequence from a high workload or long working hours are not considered here (see *Chapter 1.8)*. The term "fatigue" is widely used throughout the government, labour and the public, and overlaps with the term sleepiness.[49] Hence, we use the terms interchangeably, which is common. Related issues, such as sleep stages, shift systems, time of day and circadian rhythms, are not addressed here *(Chapter 1.8)*.

We preferred to use the term "injury" over "accident" in this thesis and thus discuss "work injury" instead of "workplace accident". For many years, safety officials and public health authorities have discouraged the use of the word "accident" because an accident is often understood to be an unpredictable, chance occurrence that is unavoidable.[76] However, most injuries and their precipitating events are predictable and preventable.[73,77,78] Hence, we used the terms "work injury" and "leisure-time injury" and referred to "motor vehicle crash".[79] In our case-control study, we defined work injuries according to the Swiss law *(Chapter 1.8)* and therefore used the Swiss term "Berufsunfall" in the questionnaires.[67] This term translates to "occupational accident". However, the German translation of work injury "Arbeitsverletzung" is hardly used and may have confused participants.

2.3 THE RELEVANCE OF THIS THESIS

By examining sleep and work injuries, we investigated two areas simultaneously, which are usually considered separately. Sleep medicine mainly addresses the association of sleep disorders with physical and mental health,[80] whereas studies on the risk factors for work injuries often consider technical[81–84] and organisational factors.[85–87] This thesis widens the perspective and goes beyond the workplace setting in the search for relevant and preventable causes of work injuries because sleep problems may not only be personal suffering but also a risk for work injuries and further incident related harm.

The expected findings of this thesis should inform governments and ministries regarding the extent of the risk of sleep problems for work injuries and the magnitude of the means spent on sleep problem related work incidents. These data will help decision-makers in determining the need to include sleep-related considerations in occupational safety programs.

The expected results of this thesis may, furthermore, support the work of occupational health and safety officers and inspecting authorities, particularly the safety-at-work experts of the Suva. The knowledge of the injury types most susceptible to sleep problems may improve injury investigation and may help prevent similar injuries in the future.

Occupational physicians and injury prevention institutions may also benefit from the knowledge generated by this thesis. A better understanding of the risk of sleep problems for work injuries and knowledge about the most vulnerable populations may help to develop target prevention measures and support the identification of workers at risk. This may, in the long-term, lead to a decrease in work injury rates.

3 PAPER 1

SLEEP PROBLEMS AND WORK INJURIES: A SYSTEMATIC REVIEW AND META-ANALYSIS

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[*] Uehli K contributed to the study conception and design, the data acquisition, analysis and interpretation, the drafting and the critical revision of the manuscript.

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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:

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

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

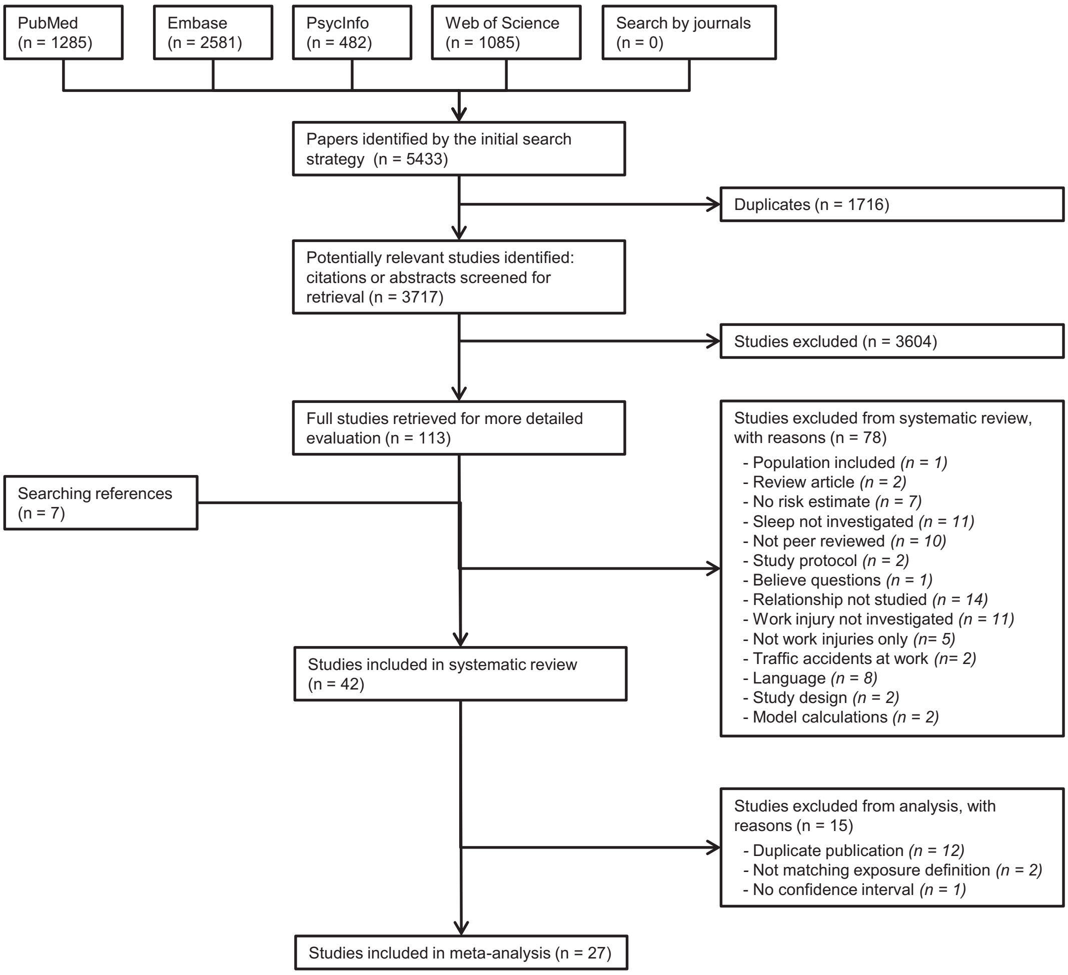

Fig. 1. Study retrieval and selection for effects of sleep problems in work injury meta-analysis. Abbreviations: n: number of studies.

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)	aOR = 1.7 [1.1–2.6]*
					Ostructive sleep apnea syndrome and/or heavy snoring in females (D)	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

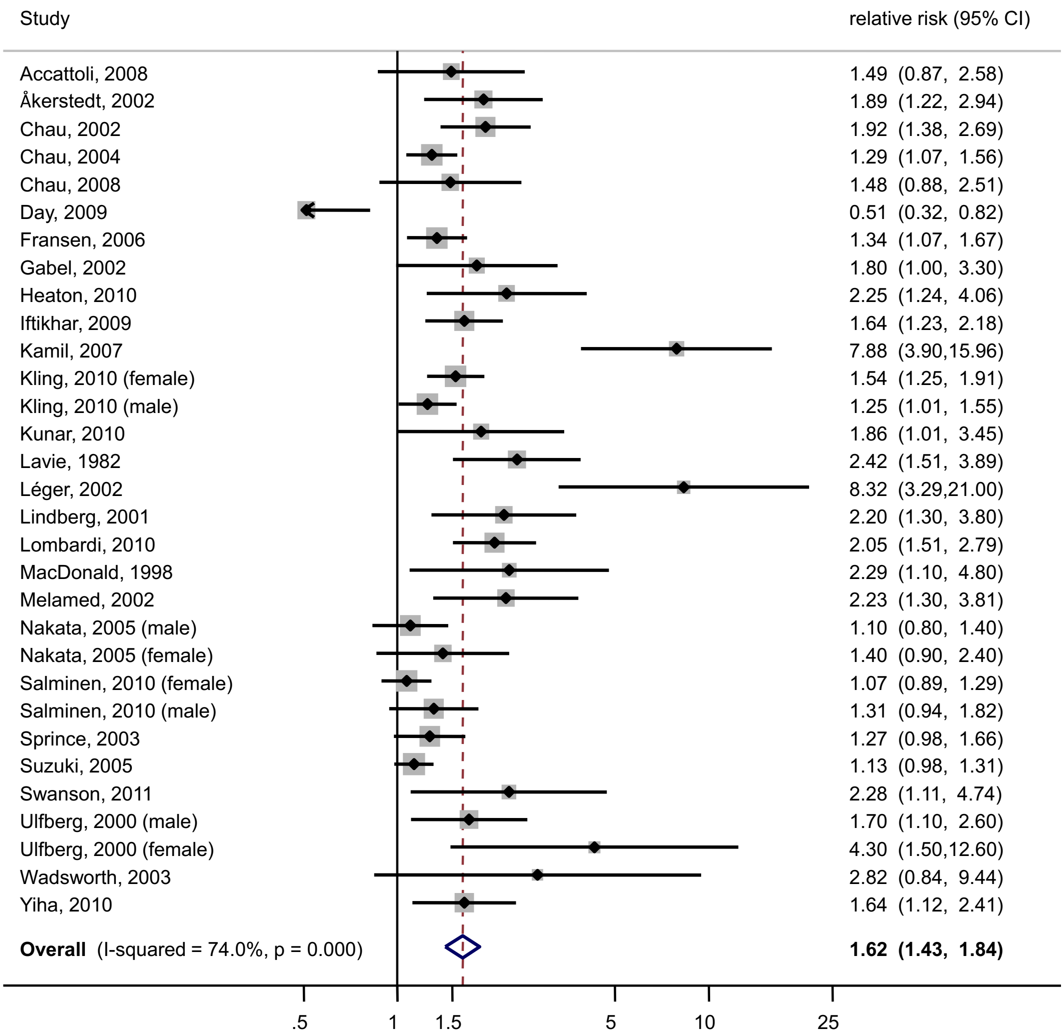

Fig. 2. Forest plot presenting the meta-analysis based on risk estimates for the effect of sleep problems on work injuries. Abbreviations: CI: confidence interval, I-squared: statistical index of heterogeneity, p: *p*-value.

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

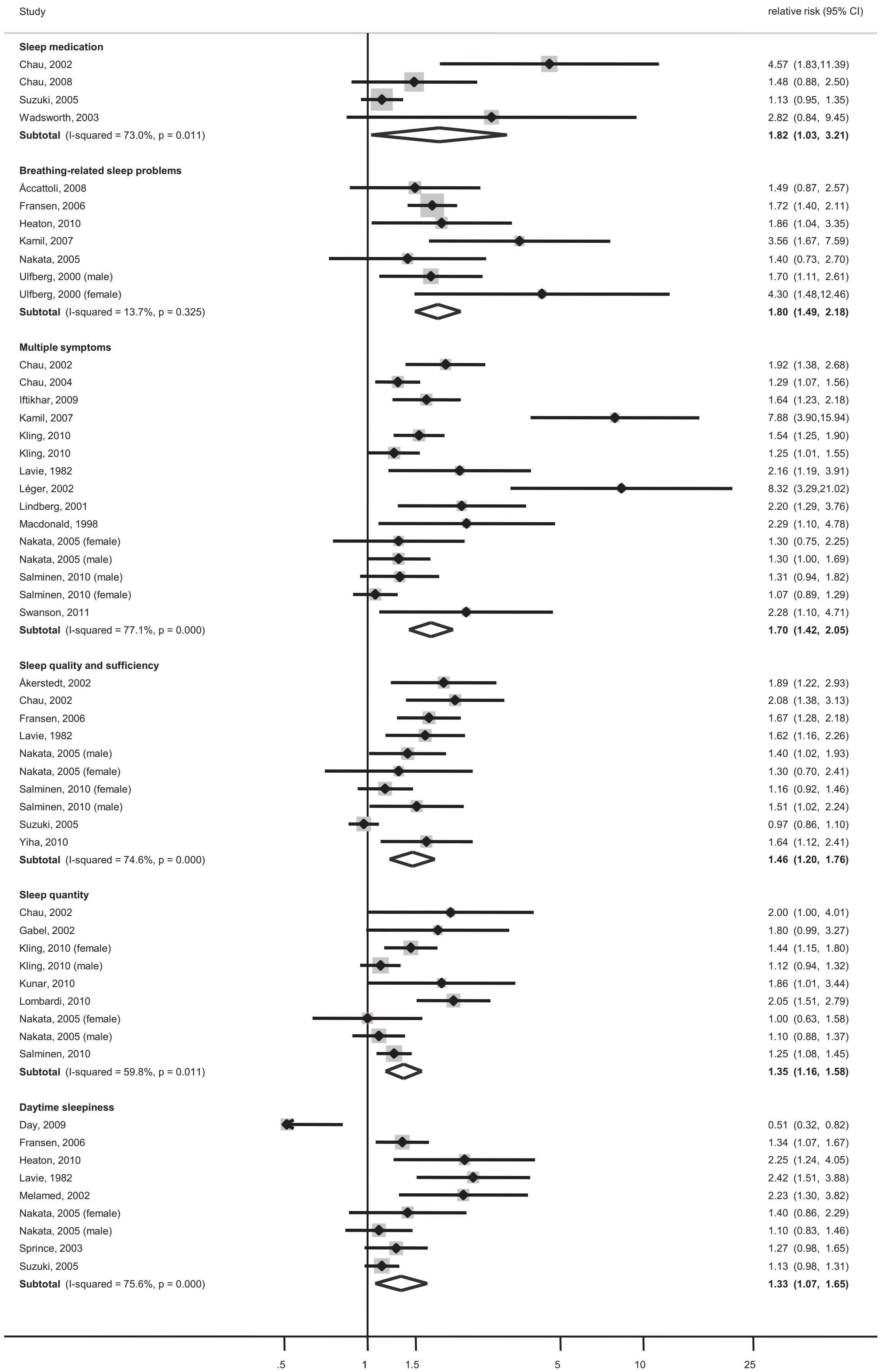

Fig. 3. Forest plot presenting the subgroup meta-analysis for the effect of different sleep problem aspects on work injuries. Abbreviations: CI: confidence interval, I-squared: statistical index of heterogeneity, p: *p*-value.

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.

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

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.

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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SUPPLEMENT

SEARCH IN PUBMED

1 „accidents“[Mesh] OR accident*[Title/Abstract]
2 „wounds and injuries“[Mesh] OR injur*[Title/Abstract]
3 accident prevention [Mesh]
4 /OR #1 – #3
5 „work“[Mesh] OR work[Title/Abstract]
6 „workplace“ [Mesh] OR workplace[Title/Abstract]
7 \occupations“[Mesh] OR occupation*[Title/Abstract]
8 „industry“[Mesh] OR industrial[Title/Abstract]
9 /OR #5 – #8
10 /AND #4, #9
11 „accidents, occupational“[Mesh]
12 /OR #10, #11
13 „sleep“[Mesh] OR sleep*[Title/Abstract]
14 „sleep disorders“[Mesh]
15 („fatigue“[Mesh] OR fatigue[Title/Abstract]) NOT depression[Title/Abstract])
16 „snoring“[Mesh] OR snoring[Title/Abstract]
17 drows*[Title/Abstract]
18 asleep[Title/Abstract]
19 /OR #13 – #18
20 /AND #12, #19
21 #20 AND „Animals“ [Mesh:noexp]
22 /NOT #20, #21

Hits: 1,285

SEARCH IN EMBASE

1 accident/exp OR accident*:ab,ti
2 injury/exp OR injur*:ab,ti
3 ‚accident prevention‘/exp
4 ‚occupational safety‘/exp
5 /OR #1 – #4
6 ‚work‘/exp OR ‚work‘:ab,ti
7 ‚workplace‘/exp OR ‚workplace‘:ab,ti
8 occupation/exp OR occupation*:ab,ti
9 ‚industry‘/exp or industrial:ab,ti
10 /OR #6 – #9

11 /AND #5, #10
12 ‚occupational accident‘/exp
13 /OR #11, #12
14 sleep/exp OR sleep*:ab,ti
15 ‚sleep disorder‘/exp
16 fatigue/exp OR fatigue:ab,ti NOT ‚depression‘/exp
17 ‚snoring‘/exp
18 drows*:ab,ti
19 asleep:ab,ti
20 /OR #14–#19
21 /AND #13, #20
22 #21 AND ‚animal‘/exp
23 #21 NOT #22

Hits: 2,581

SEARCH IN PSYCINFO

1 accidents/or accident*.ab. or accident*.ti.
2 injuries/or injur*.ab. or injur*.ti.
3 accident Prevention/
4 occupational Safety/
5 /OR #1–#4
6 work.ab. or work.ti.
7 workplace.ab. or workplace.ti.
8 occupation*.ab. or occupation*.ti.
9 business/
10 industrial.ab. or industrial.ti.
11 /OR #6–#10
12 /AND #5, #11
13 exp industrial accidents/
14 /OR #12, #13
15 sleep/ or sleep*.ab. or sleep*.ti.
16 exp sleep disorders/
17 sleepiness/
18 sleep apnea/
19 sleep deprivation/
20 (fatigue.sh. or fatigue.ab. or fatigue.ti.) not depression.af.
21 snoring/

22 drows*.ab. or drows*.ti.
23 asleep.ab. or asleep.ti.
24 /OR #15 - #23
25 /AND #14, #24

Hits: 482

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1 Topic=(accident*)
2 Topic=(injur*)
3 Topic=(„accident prevention“)
4 Topic=(„occupational safety“)
5 /OR #1 – #4
6 Topic=(work)
7 Topic=(workplace)
8 Topic=(occupation*)
9 Topic=(industrial)
10 /OR #6 – #9
11 /AND #5, #10
12 Topic=(sleep*)
13 Topic=(fatigue) NOT Topic=(depression)
14 Topic=(snoring)
15 Topic=(drows*)
16 Topic=(asleep)
17 /OR #12 – #16
18 /AND #11, #17
19 #18 AND Topic=(animal)
20 /NOT #18, #19

Hits: 1,085
Total hits: 3,723
(cleaned from duplicates)

4 PAPER 2

SLEEP PROBLEMS AND WORK INJURY TYPES: A STUDY OF 180 PATIENTS IN A SWISS EMERGENCY DEPARTMENT

This paper has been published:
Katrin Uehli[1,2,3,*], David Miedinger[2,3,4], Roland Bingisser[2,5], Selina Dürr[4], Edith Holsboer-Trachsler[2,6], Sabrina Maier[4], Amar J Mehta[1,2,7], Roland Müller[8], Christian Schindler[1,2], Stefanie Zogg[4], Nino Künzli[1,2], Jörg D. Leuppi[2,4]. Sleep problems and work injury types: a study of 180 patients in a Swiss emergency department. *Swiss Medical Weekly,* 2013;143:w13902.

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Sleep problems and work injury types: a study of 180 patients in a Swiss emergency department

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Summary

INTRODUCTION: Sleep problems present a risk for work injuries and are a major occupational health concern worldwide. Knowledge about the influence of sleep problems on work injury patterns is limited. Therefore, the aim of this study was to identify potential associations between different types of work injuries and sleep quality, sleep duration, and daytime sleepiness.

METHODS: In this hospital-based study, 180 male and female patients with work injuries were recruited at the Emergency Department of the University Hospital Basel, Switzerland, from December 1st 2009 to June 30th 2011. The data on work injury characteristics, sleep problems, and potential confounders, such as demographic, health, lifestyle, occupational and environmental factors, were collected. Multivariable logistic regression analyses were performed to investigate the relationship between sleep problems and various types of work injury.

RESULTS: Each dimension of sleep problems – sleep quality, sleep duration and daytime sleepiness – was a significant risk factor for at least one type of work injury. The strongest association was found for musculoskeletal injuries and falls with short sleep duration (odds ratio [OR] 5.41, 95% confidence interval [CI] 1.81–16.22). The standardised scores of the Pittsburgh sleep quality index (PSQI) and the Epworth sleepiness scale (ESS) did not discriminate between injury types.

CONCLUSION: Employees with sleep problems were more likely to suffer from certain types of work injuries. This should be considered by employers monitoring work injuries and implementing prevention measures in the company's health and safety management.

Key words: *occupational health and safety; work injuries; occupational accidents; sleep disorders; sleep quality; sleep duration; daytime sleepiness*

Abbreviations

BMI body mass index
ED emergency department
ESI emergency severity index
ESS Epworth sleepiness scale
PSQI Pittsburgh sleep quality index
OR odds ratio
CI confidence interval

Introduction

Sleep problems present a risk for work injuries and are a major occupational health concern worldwide. Sleep problems were found to increase the risk of work injuries by 1.6–fold in a systematic review and meta-analysis that we

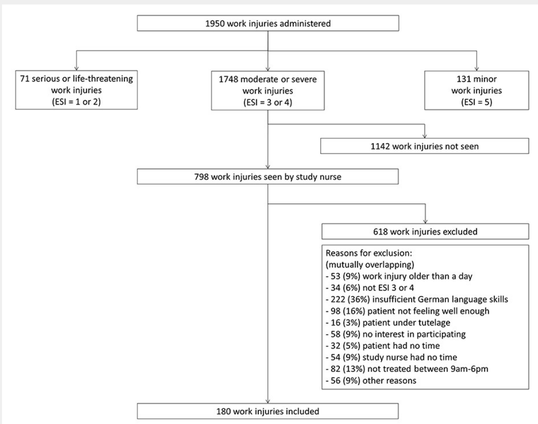

Figure 1

Flow chart of participants.
ESI = emergency severity index.

conducted recently [1]. Moreover, there was a high prevalence of sleep problems among workers in Europe (18%) and in the United States (23%) in 2011 [2, 3].

Knowledge about the influence of sleep problems on work injury patterns is limited. There is evidence that sleep-related work injuries are associated with longer absences from work and more frequent hospital treatments [4]. In an investigation of various types of work injuries, sleep disorders in construction workers were associated with an increased risk of injury by moving objects [5]. However, no information is available concerning a general working population.

Different dimensions of sleep problems are involved in the physiological pathway and may be investigated separately. Poor sleep quality or short sleep duration limit the recovery function of sleep and can lead to sleepiness during the day. In turn, sleepiness may reduce the ability of people to process information about dangerous situations and may reduce their ability to respond adequately [6]. However, no research has thus far been undertaken that relates different dimensions of sleep problems to various types of work injuries. Therefore, the aim of this hospital-based study was to identify potential associations between different types of work injuries and sleep quality, sleep duration and daytime sleepiness.

Methods

In this study, 180 male and female work injury patients were recruited from the Emergency Department (ED) of the University Hospital of Basel, Switzerland, between December 1st 2009 and June 30th 2011 (fig. 2). Patients were eligible to participate in the study if they suffered from a moderate to severe work injury (emergency severity index [ESI] 3 or 4) (fig. 1) [7, 8], were admitted to hospital on the day or the day after injury occurred, were between 18 and 65 years old, were in an adequate general mental state, had sufficient language skills to complete the questionnaire, and agreed to participate. Data were collected through standardised, self-administered, questionnaires in German, administered in a preset procedure by a trained study nurse, who also took all standardised measurements. Work injuries were defined in accordance with Swiss law [9], which is consistent with the European methodology defined by Eurostat [10]. Work injury types were defined on the basis of groups of work injury variables that had been identified by factor analysis. Sleep problems were assessed using the total score of the Pittsburgh sleep quality index (PSQI) [11, 12], its subscales (see Supplement A), and the Epworth sleepiness scale (ESS) [13, 14]. Potential confounders considered included socioeconomic, health, lifestyle, occupational and environmental factors. Quantitative variables were di- or tri-chotomised as appropriate. Chi-squared tests or Fisher's exact tests were used to describe the study population. To assess the relationship between injury type and sleep problems, multivariable logistic regressions were conducted, adjusted for age, sex, socioeconomic status and job risk. The stability of the regression models was tested trough sensitivity analysis. For a detailed description of the study methods, please see Supplement B.

The study protocol was approved by the local ethics committee (reference number 37/09).

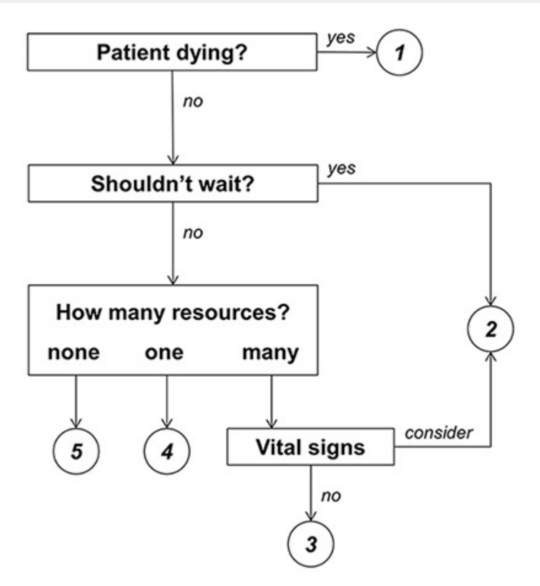

Figure 2

Emergency severity index conceptual algorithm, version 4. Adapted from Gilboy, et al. 2005 [7]

Results

Study participants

A total of 180 emergency patients with work injuries were recruited (fig. 1). Of the 1,950 work-injury patients attending the ED of the University Hospital of Basel during the 19–month study period, 798 (41%) were seen by our study nurses. Of those seen, 618 (77%) were excluded because at least one of the inclusion criteria were not met (n = 423, 68%), the patient was not interested in participating (n = 58,9%), or for administrative reasons (n = 168, 27%). The most frequent exclusion criterion was insufficient German language skills (n = 222, 35%). The patients included were compared with a subsample of excluded patients (n = 498, 81%) and the two groups were found to be similar regarding age, gender and perception of daytime sleepiness on the day of accident, but the excluded patients had lower perceptions of general health, general work satisfaction, general subjective sleep quality, sleep quality the night before the accident, concentration on the day of accident, and actual pain (data not shown). When the study population was compared with only the patients excluded owing to language barriers, the same picture emerged, except that excluded foreigners were more often male than the included cases (data not shown).

Sample details

The majority of the population was male (n = 144, 80%), older than 30 years (n = 106, 59%), and high job risk workers (n = 112, 62%) (table 1). Age ranged from 18 to 63 years with a mean age of 35.5 years (standard deviation [SD] 11.5). Most work injuries happened during a work-related task rather than a side task (n = 128, 71%). In almost all work injuries, a tool, machine, or object was involved (n = 172, 96%). Extremities were injured most frequently (n = 149, 83%). No injury involved occupational driving. Most participants exhibited normal sleep characteristics and the most frequently observed sleep problem was poor sleep quality as measured with the PSQI (n = 35, 21%). For study characteristics stratified by gender, please see Supplement C.

Characteristics of work injury types

Certain work injury types were more susceptible to particular risk factors than other types (table 1). Injuries while handling or carrying loads and work injuries during side tasks were significantly more often observed in workers with low sleep efficiency, as compared with workers with high sleep efficiency. Musculoskeletal injuries or falls and work injuries during side tasks were significantly more frequent in short and long sleepers than in normal sleepers. Being injured by, or while working with, a tool or machine was significantly more likely to happen to workers with problems staying awake than to their counterparts. The other work injury types were not significantly associated with the sleep variables investigated.

Relationship between sleep problems and work injury type

Sleep problems were associated with certain work injury types, even after control for age, gender, socioeconomic status, and job risk (table 2). Workers with low sleep efficiency had a greater risk for injuries during side tasks than workers with high sleep efficiency (OR = 2.43, 95% CI = 1.05–5.62). Workers with less than 6 hours of sleep per night had a more than 5–fold increased risk for both side task and falls or musculoskeletal injuries (OR = 5.17, 95% CI = 1.70–15.70; OR = 5.41, 95% CI = 1.81–16.22, respectively). The relationship with sleep duration was U-shaped and indicated an elevated risk also for those injuries in workers sleeping 8 hours and more per night (OR = 2.32, 95% CI = 0.98–5.50 for side task work injuries; OR = 3.45, 95% CI = 1.52–7.79 for musculoskeletal injuries or falls). Workers with problems staying awake at least once a week had a 3.7–fold increased risk of being injured by, or while working with, a tool or machine (OR = 3.73, 95% CI =

Table 1: Distribution of different work injury types according to various individual characteristics (n = 180).

	Number of subjects	Caught, hit	Handling, carrying	Side task	Tool, machine	Object	Cut, open wound	Musculo-skeletal injury, fall	Extremity
	n	%	%	%	%	%	%	%	%
Total	180	24.4	15.6	28.9	47.2	48.3	50.0	34.4	82.8
Socioeconomic factors									
Gender									
Female	36	22.2	22.2	30.6	41.7	41.7	47.2	38.9	91.7
Male	144	25.0	13.9	28.5	48.6	50.0	50.7	33.3	80.6
Age									
18–30 years	74	17.6	10.8	25.7	56.8 *	40.5	55.4	33.8	86.5
31–65 years	106	29.2	18.9	31.1	40.6	53.8	46.2	34.9	80.2
Socioeconomic status									
Low	87	25.0	15.2	20.7 *	60.9 ‡	50.0	57.6 *	33.7	83.7
Middle/high	92	24.1	16.1	37.9	32.2	47.1	41.4	35.6	81.6
Job risk									
Low	68	27.9	19.1	38.2 *	30.9 †	48.5	38.2 *	39.7	86.8 *
High	112	22.3	13.4	23.2	57.1	48.2	57.1	31.3	80.4
Sleep subscales and total scores									
Sleep efficiency[a]									
Normal (≥85%)	149	24.8	18.1 *	25.5 *	49.0	49.7	49.7	33.6	83.2
Low (<85%)	31	22.6	3.2	45.2	38.7	41.9	51.6	38.7	80.6
Sleep duration									
Short (<6h)	17	23.5	5.9	58.8 †	35.3	35.3	29.4	64.7 ‡	76.5
Normal (6–7h)	131	25.2	18.3	22.9	51.1	48.9	55.0	26.0	84.0
Long (≥8h)	31	19.4	9.7	35.5	38.7	51.6	38.7	54.8	83.9
Problems staying awake[b]									
Normal (<1 times/week)	163	25.2	15.3	30.1	44.2 *	49.1	49.1	35.0	82.8
High (≥1 times/week)	17	17.6	17.6	17.6	76.5	41.2	58.8	29.4	82.4
PSQI									
Normal (≤5 points)	131	24.4	18.3	27.5	47.3	48.9	48.9	33.6	84.0
High (>5 points)	35	22.9	8.6	31.4	45.7	42.9	51.4	40.0	85.7
ESS									
Normal (≤10 points)	151	25.2	15.9	28.5	46.4	49.0	49.0	34.4	81.5
High (>10 points)	28	21.4	14.3	28.6	50.0	46.4	53.6	35.7	89.3

Work injury types were defined on the basis of groups of variables that had been identified by factor analysis. They are not mutually exclusive. Differences in different categories were assessed using the Chi-squared test or Fisher's exact test, as appropriate. ESS = Epworth sleepiness scale; PSQI = Pittsburgh sleep quality index. Job risk = risk for a work injury compared with the average Swiss relative work injury risk in the 3 years available prior to study start (2005–2007) influenced by sex, age and job category. [a] a measure of sleep quality; [b] a measure of daytime sleepiness; *p <0.05, †p <0.01, ‡p <0.001: statistically significant association.

1.10–12.69). No significant associations between PSQI or ESS and the various work injury types were found. Sensitivity analysis confirmed the stability of the estimates. The results presented are a selection of analyses. The complete results are given in Supplement A.

Discussion

Summary of the main results

The findings of this hospital-based study, investigating 180 work injuries, suggested that workers with sleep problems had a 2- to 5-fold higher risk of certain types of work injury. The work injury types that were more likely to occur in workers with sleep problems included those that occurred while performing a side task, while working with, or being injured by, a tool or machine, and falls or musculoskeletal injuries. Moreover, each dimension of the sleep problems – sleep quality, sleep duration and daytime sleepiness – significantly increased the risk for at least one work injury type. However, the summary scores of the PSQI and the ESS were not significantly related to injury types and therefore could not discriminate between them.

Sleep problems and their risk for certain types of work injuries

Poor sleep quality, measured as low sleep efficiency, was significantly associated with injury during side tasks. Side tasks were therefore more susceptible for performance reduction by poor sleep quality than work-related tasks. Performance may be maintained through high attention despite sleep deprivation [15]. Thus, poor sleep quality might affect performance during side tasks more than during work-related tasks, if attention was higher during work-related tasks.

Short sleep duration was also significantly related to injuries during side tasks. Mechanisms similar to those that occur with low sleep efficiency could explain this relationship. Inattention may also account for the fact that short sleep duration was significantly more often present in patients with slips, trips and falls resulting in sprains, dislocations and fractures. Concerning the association between sleep duration and these work injuries, we observed a U-shaped pattern, with both short and long sleepers being at higher risk than normal sleepers. The observation that long sleepers were at higher risk than normal sleepers may be explained by underlying factors, such as overweight or smoking, that are more frequent in long sleepers [16, 17] and are related to problems in posture stabilisation, which could potentially lead to falls [5, 18–21]. In this study, being overweight and smoking tended to be more frequent in long sleepers but did not influence the relationship between sleep problems and work injuries as tested by sensitivity analysis.

Daytime sleepiness, measured as problems staying awake, was significantly related to injuries while working with, or being injured by, a tool or machine. This may indicate that if sleep is severely disturbed and sleep problems result in daytime sleepiness, complex tasks such as working with tools or machines may also be affected by performance reduction.

The ESS and the PSQI scores were not related to any of the work injury types and therefore were not sensitive enough to distinguish between different types of work injuries. Statistically, total scores are more reliable than single items if the relevant dimensions are captured [22]. However, to detect workers at risk for certain work injury types, specific characteristics of sleep problems may need to be asked about.

Table 2: Relationship between sleep problems and types of work injury: adjusted ORs and 95% CI calculated with multivariable logistic regression.

	Caught, hit		Handling, carrying		Side task		Tool, machine		Object		Cut, open wound		Musculoskeletal injury, fall		Extremities	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Low sleep efficiency (<85%)[a]	0.71	(0.27–1.91)	0.15	(0.02–1.13)	2.43	(1.05–5.62)*	0.65	(0.28–1.50)	0.65	(0.29–1.46)	0.97	(0.44–2.17)	1.32	(0.59–2.98)	1.03	(0.35–2.98)
Short sleep duration (<6 h)[b]	0.70	(0.20–2.40)	0.23	(0.03–1.87)	5.17	(1.70–15.70)†	0.57	(0.18–1.78)	0.45	(0.15–1.33)	0.37	(0.12–1.14)	5.41	(1.81–16.22)†	0.65	(0.19–2.27)
Long sleep duration (≥8 h)[b]	0.74	(0.29–1.92)	0.43	(0.12–1.55)	2.32	(0.98–5.50)	0.49	(0.21–1.16)	1.06	(0.48–2.35)	0.52	(0.23–1.17)	3.45	(1.52–7.79)†	0.88	(0.32–2.46)
Problems staying awake (≥1x/w)[c]	0.70	(0.19–2.63)	1.19	(0.30–4.70)	0.58	(0.16–2.20)	3.73	(1.10–12.69)*	0.75	(0.27–2.13)	1.23	(0.43–3.50)	0.84	(0.28–2.56)	0.98	(0.26–3.76)
PSQI (>5)[d]	0.84	(0.33–2.11)	0.30	(0.08–1.13)	1.16	(0.50–2.70)	1.06	(0.47–2.37)	0.73	(0.33–1.59)	1.18	(0.54–2.58)	1.24	(0.56–2.73)	1.07	(0.36–3.16)
ESS (>10)[e]	0.89	(0.33–2.41)	0.96	(0.30–3.08)	1.08	(0.43–2.71)	1.03	(0.44–2.43)	0.95	(0.42–2.16)	1.11	(0.49–2.56)	1.10	(0.47–2.57)	1.93	(0.54–6.97)

Work injury types were defined on the basis of groups of variables that had been identified by factor analysis. They are not mutually exclusive.
Adjusted for age, sex, socioeconomic status, and job risk.
CI = confidence interval; ESS = Epworth sleepiness scale; OR = odds ratio; PSQI = Pittsburgh sleep quality index; x/w = times per week
Reference groups were (a) normal sleep efficiency (≥85%) as a measure of sleep quality, (b) normal sleep duration (6–7 h), (c) rare problems staying awake (<1x/w) as a measure of daytime sleepiness, (d) normal PSQI (≤5), and (e) normal ESS (≤10)
*p <0.05, †p <0.01, ‡p <0.001: Statistically significant association.

Strengths and limitations

The strength of this study was the detailed information obtained on the work injuries, which was sufficient to categorise the injuries into different types and analyse them separately for their susceptibility to sleep problems. Sleep problems were assessed using standardised measures, facilitating comparisons across studies. Furthermore, detailed information was obtained regarding several potentially influencing factors, thereby allowing us to confirm the stability of the results by controlling for confounders and performing sensitivity analysis.

Methodological issues must be considered when interpreting the findings of this study. The study participants were recruited from the area of Basel City and may not be representative of Switzerland at large (see Supplement D). Concerning work injury types, this study observed more injuries during side tasks, more injured extremities, and fewer injuries from being caught or hit than reported in the Swiss national work injury statistics [23, 24]. This may be explained by the exclusion of serious to life-threatening work injuries, which may be more likely to happen during dangerous work processes than during side tasks, such as changing clothes or taking a break, which may more often affect the head or trunk than the extremities, and which may more often be a result of being hit, for example, by a heavy load. Additionally, the exclusion of minor injuries may amplify the under-representation of work injuries from being hit, if, for example, they result in bruises only limiting mobility and lead to work absence but not to medical treatment at a hospital. Serious or life-threatening injuries were excluded because those patients were not suitable for questioning. Minor injuries were excluded because the prevalence of minor injuries in the ED depends mainly on factors other than the need for treatment, such as the patient's concerns or the availability of a general practitioner. Furthermore, sleep problems were slightly less frequent in the present study sample than in the general Swiss population, most likely owing to a more strict definition of sleep problems in this study [25]. However, for sociodemographic and occupational factors, the study sample was similar to the Swiss working population and the population of Swiss employees with work injury in gender, age, type of worker, socioeconomic status, job risk, shift work and occupational experience [26]. This may be surprising since injured workers were recruited only during weekdays and daytime.

A further limitation reflects the potential selection bias introduced by including only a small proportion of persons in relation to the population of interest. The most frequent reason for exclusion was the use of a German questionnaire. The main language of the study area was German, but many other languages are spoken in this area because of the large proportion of foreigners working in the Basel area (40% foreigners, of whom approximately 50% are from Germany) [27, 28]. Analysis of the exclusions showed that the nonparticipants were more likely to suffer from poor sleep quality than participants. However, we lack the information on their injury types needed to make a statement on how estimates might have been influenced. Additionally, the relatively small number of participants limited statistical power to detect significant associations. Thus, only strong relationships could be detected, and some weaker associations might have been missed.

Comparison of our results with those of other studies

This study investigated the impact of sleep problems on different types of work injuries – a topic addressed in only a few studies. An industry-based study on work injuries in French construction workers reported a 2.2–fold risk of being involved in an injury by moving objects for workers with sleep disorders compared with their colleagues without sleep disorders [5]. These results could not be replicated in our study, perhaps because of the different definition of sleep problems or study populations. Other hospital-based studies were not comparable because they either reported the relationship with other injury types, such as road traffic accidents [29], or did not investigate sleepiness as a risk factor for work injuries [30].

Implications for research and practice

To better understand the consequences of sleep problems, it would be of interest to explore whether these findings could be replicated in larger studies and also whether they applied to minor or fatal work injuries. Little is known about the effect of sleep problems on work injury severity. Chau and coworkers observed that sleep problems increased the risk for work injuries, with longer sick leave and hospitalisation, in male construction workers [4]. However, to the authors' knowledge, there is no evidence as to whether those associations might be true for every work injury type or for certain types only. Furthermore, it would be beneficial to learn more about the factors influencing the relationship between sleep problems and work injuries to better understand the mechanisms by which sleep problems affect work injuries. Our current knowledge about influencing factors is very limited, even for age [31], gender [32–35], and job parameters [32]. Additionally, intervention studies may improve the understanding of how sleep-related work injuries might be prevented. Melamed and Oksenberg [36] observed a decreased injury rate in workers with excessive daytime sleepiness 1 year after providing workers with their assessment results and with information on the implications of excessive daytime sleepiness for safety. However, further interventional studies are needed to learn more about the effectiveness and applicability of such programmes.

In practice, employers and work accident investigators may be recommended to examine work injuries more closely for factors related to sleepiness and sleep problems – mainly falls or musculoskeletal injuries, injuries incurred while working with, or being injured by, a tool or machine, and injuries incurred while carrying out a side task. Employees and occupational physicians should be aware that sleep problems could be a contributory cause for such injuries and represent an important hazard for safety.

Regarding the potential for prevention, the public health burden of sleep-related work injuries is high and thus the potential for prevention is large. Approximately 13% of work injuries could be prevented by eliminating sleep problems [1]. In Switzerland, this approximation translates into 35,000 work injuries and costs of approximately CHF 190 million per year [23]. To identify workers most at risk for certain injury types, specific questions should be asked, such as “Have you had problems staying awake in everyday life during the last four weeks?” rather than calculating commonly used scores. Workers with identified sleep problems could then specifically and individually be coached in taking steps to reduce sleep problems and/or in adopting safety behaviours to prevent injuries.

Conclusion

Sleep quality, sleep duration and daytime sleepiness were significant risk factors for at least one type of work injury. Work injuries that occurred while carrying out a side task, while working with, or being injured by, a tool or machine, and falls or musculoskeletal injuries were highly correlated with sleep problems. Employees and occupational physicians should be aware that sleep problems are a risk factor for certain types of work injuries, and employers may include sleep-related aspects in their health and safety management.

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Supplement A

Table Supplement A: Relationship between each subscale of Pittsburgh sleep quality index (PSQI) and each type of work injury: adjusted ORs and 95% CI calculated by multivariable logistic regression.

PSQI subscales	Caught, hit		Handling, carrying		Side task		Object		Tool, machine		Cut, open wound		Musculoskeletal injury, fall		Extremities	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Bad subjective sleep quality	0.68	(0.23–1.99)	0.39	(0.08–1.79)	1.37	(0.54–3.51)	1.13	(0.46–2.74)	0.41	(0.16–1.03)	0.84	(0.35–2.01)	1.33	(0.55–3.21)	0.60	(0.21–1.70)
Time to fall asleep (>30 min)	0.98	(0.29–3.33)	0.67	(0.14–3.30)	0.69	(0.20–2.35)	1.03	(0.33–3.16)	1.46	(0.50–4.25)	0.88	(0.30–2.61)	1.36	(0.47–3.94)	1.18	(0.24–5.71)
Not asleep within 30 min (≥1x/w)	0.71	(0.30–1.69)	0.90	(0.34–2.42)	0.78	(0.34–1.78)	1.18	(0.55–2.53)	2.17	(1.03–4.55)*	0.98	(0.47–2.03)	1.28	(0.61–2.67)	0.66	(0.26–1.68)
Poor sleep latency[a]	0.88	(0.34–2.28)	0.72	(0.22–2.32)	0.84	(0.34–2.10)	1.00	(0.43–2.35)	2.22	(0.96–5.14)	1.06	(0.45–2.41)	1.01	(0.44–2.33)	0.80	(0.27–2.35)
Short sleep duration (<6 h)	0.70	(0.20–2.40)	0.23	(0.03–1.87)	5.17	(1.70–15.70)†	0.57	(0.18–1.78)	0.45	(0.15–1.33)	0.37	(0.12–1.14)	5.41	(1.81–16.22)†	0.65	(0.19–2.27)
Long sleep duration (≥8 h)	0.74	(0.29–1.92)	0.43	(0.12–1.55)	2.32	(0.98–5.50)	0.49	(0.21–1.16)	1.06	(0.48–2.35)	0.52	(0.23–1.17)	3.45	(1.52–7.79)†	0.88	(0.32–2.46)
Low sleep efficiency (<85%)	0.71	(0.27–1.91)	0.15	(0.02–1.13)	2.43	(1.05–5.62)*	0.65	(0.28–1.50)	0.65	(0.29–1.46)	0.97	(0.44–2.17)	1.32	(0.59–2.98)	1.03	(0.35–2.98)
Disturbed sleep (≥1x/w)	1.74	(0.46–6.57)	0.27	(0.03–2.41)	1.86	(0.52–6.66)	2.53	(0.67–9.60)	0.29	(0.07–1.15)	1.76	(0.49–6.27)	0.87	(0.25–3.19)	0.52	(0.12–2.29)
Sleep medication (≥1x/w)	1.74	(0.26–11.62)	2.35	(0.34–16.25)	0.61	(0.06–6.10)	0.28	(0.03–2.83)	–		1.73	(0.26–11.54)	1.16	(0.18–7.62)	–	
Problems staying awake (≥1x/w)	0.70	(0.19–2.63)	1.19	(0.30–4.70)	0.58	(0.16–2.20)	3.73	(1.10–12.69)*	0.75	(0.27–2.13)	1.23	(0.43–3.50)	0.84	(0.28–2.56)	0.98	(0.26–3.76)
Not enough swing	0.87	(0.36–2.13)	0.81	(0.28–2.37)	1.19	(0.52–2.71)	1.05	(0.48–2.28)	1.09	(0.52–2.30)	1.51	(0.71–3.23)	0.88	(0.40–1.93)	0.75	(0.29–1.97)
Daytime sleepiness[b]	1.18	(0.45–3.10)	0.59	(0.16–2.19)	1.26	(0.49–3.20)	1.84	(0.75–4.52)	0.71	(0.30–1.68)	1.66	(0.69–3.96)	0.63	(0.25–1.60)	0.60	(0.21–1.70)

Work injury types were defined on the basis of groups of variables that had been identified by factor analysis. They are not mutually exclusive. PSQI subscales values ranged from 0–4 points and were dichotomised into good (0–1 point) and poor (2–3 points), except for sleep duration which was trichotomised (long: 0 points; normal: 1 point; short: 2–3 points).
Adjusted for age, sex, socio-economic status, and job risk.CI = confidence interval; OR = odds ratio;
PSQI subscales were defined from the 19 items according to the Pittsburgh sleep quality index protocol;
[a] sleep latency was calculated as average of “time to fall asleep” and “not asleep within 30 min”;
[b] daytime sleepiness was calculated as average of “troubles staying awake” and “not enough swing”; min: minutes; x/w: times per week;
*p <0.05, †p <0.01, ‡p <0.001: statistically significant association; -: not available.

Supplement B

Study population

This study uses data collected in the Emergency Department (ED) of the University Hospital of Basel, Switzerland (fig. 1). The hospital's catchment area has 0.5 million inhabitants. During the study period, 67,925 patients were seen in the ED, of whom approximately 1,950 were seen for work injuries. We enrolled male and female patients from December 1st 2009 to June 30th 2011 who met the following inclusion criteria: (1.) age between 18 and 65 years; (2.) admitted to hospital owing to a work injury on the day or the day after the injury occurred; (3.) moderate to severe injury severity (emergency severity index [ESI] = 3 to 4) (fig. 2) [7, 8]; (4.) sufficient German language skills to complete the questionnaire; (5.) adequate general mental condition to complete the questionnaire and (6.) agreement to participate. Potential cases were identified in the following three ways: (1.) communication from the personnel of the Administration Department where all patients are required to register; (2.) notification by the treating physicians or nurses; and (3.) trained study nurses examining the internal medical administration system (ISMed). The following data collection procedure was performed throughout: Trained study nurses, who were either part of the permanent medical research team at the hospital or master students at the university and who were specifically hired for this purpose, were on site during normal business hours from Monday to Friday, 9 a.m. to 6 p.m. Work injury patients were approached and informed about the study in the waiting room. After having signed the informed consent, the participants were given a questionnaire to complete while waiting. Measurements were taken, and questions about the accident were asked in a private compartment within the emergency room. The data were verified for completeness, and recording was finished when patients were transferred internally or left the hospital. Participants were recruited consecutively until 180 work injury patients were included for analysis. The study protocol was approved by the local ethics committee (reference number 37/09).

Questionnaires and measurements

Work injuries were defined in accordance with Swiss law [9], which is consistent with the European methodology defined by Eurostat [10] and excludes repetitive strain injuries and commuting accidents. In accordance with Swiss national accident statistics, the following information on work injuries was collected: (1.) the task in process at the time of injury; (2.) the course of injury; (3.) objects involved in the accident; (4.) injured body parts; and (5.) injury diagnosis [23, 24]. The data on work injuries were collected by a trained study nurse, who completed a paper-based questionnaire. Injury severity was classified by hospital physicians using the ESI, a standard procedure in the management of the ED [7, 8].

Sleep problems were assessed using two standardised self-administered questionnaires. We used the German version of the Pittsburgh sleep quality index (PSQI) to retrospectively collect information on the subjective sleep quality during the previous 4 weeks [11, 12]. The PSQI consists of 19 self-reported items used to calculate the total sore and subscales, three of which are sleep duration, subjective sleep efficiency and problems staying awake. Values ranged from 0–3 points and were dichotomised into good (0–1 point) and poor (2–3 points), except for sleep duration which was trichotomised (long: 0 points; normal: 1 point; short: 2–3 points). Total scores range from 0 to 21, high values indicating reduced sleep quality. Bad sleep quality was defined as a PSQI total score higher than five, according to the protocol. We also used the German version of the Epworth sleepiness scale (ESS), which retrospectively measures subjective sleep propensity in daily situations over the previous weeks using eight items [13, 14]. Total scores ranged from 0 to 24, high values indicating increased sleep propensity. Excessive daytime sleepiness was defined as an ESS total score higher than ten, according to the protocol.

Information on potential confounders was collected using specific measuring instruments or validated self-administered questionnaires in German. Questions on demographic factors included sex, age, highest education (compulsory primary school, apprenticeship as a skilled worker, secondary school, general qualification for university entrance, higher professional education and university), occupational status (in training, without relevant professional experience, unskilled or semi-skilled worker, worker with apprenticeship, employee without particular education, employee with particular education, middle grade employee, self-employed small-scale trader, farmer, executive employee, entrepreneur, and director) and primary job (manager, scientist, technician, office worker, service occupation, skilled personnel for farming and fishery, craftsman, machine operator or assembler, and helpers). Questions on health and lifestyle factors included chronic diseases (present or not present), alcohol consumption (never, once to several times a month, once a week, several times a week, once a day and several times a day), smoking status (currently smoking or nonsmoking), and caffeine sensitivity based on nightly symptoms as a result of caffeine consumption after 4 p.m. (present or not present). Questions regarding occupational and environmental factors included noise, lighting, temperature, available or functional tools, spatial conditions, job hazards, physical workload, monotonous posture (very bad, quite bad, so-so, quite good, very good, or not applicable), shift or night work (present or not present), years in present occupation, and date of injury occurrence. Additionally, height (m), weight (kg), and waist and hip circumference (m) were measured by a trained study nurse. Furthermore, the study nurse researched the relative work injury risk based on the patient's age, sex and primary job from the Swiss national accident statistics 2007 [24]. The average Swiss relative work injury risk in the 3 years available prior to the start of the study (2005–2007) was 68 work accidents per 1,000 fulltime employees annually [24]. The patient's job risk was classified as high if his relative work injury risk was greater than the 3-year Swiss average. Blue-collar workers were technicians, service occupations, skilled personnel for farming and fishery, craftsmen, machine operators or assemblers, and labourers. Working conditions were considered to be adverse if the average total rating of occupational and environmental factors was mediocre or poorer. Socioeconomic status was determined as the average of education and occupational status and classified as low if the average was below one third of the maximum score. Body mass index (BMI) was calculated by dividing the weight by height squared, and overweight was classified as a BMI of at least 25 kg/m^2 [37]. Waist-hip ratio (WHR) was calculated by dividing the waist by the hip circumference, and abdominal obesity was classified as a WHR of at least 0.85 or 0.90 for women or men, respectively [38].

Questionnaires were scanned using Sphinx software (Plus2 Sphinx Lexica edition, version 5.1.0.3.), and data were completed and checked by a trained study nurse. Independent, trained staff double-checked data and, if necessary, corrected entries. Data cleaning was performed using Stata software (version 10.1) following general research guidelines [39].

Statistical analysis

Of the comprehensive information on work injuries (94 items), we defined eight mutually nonexclusive work injury types. First, we summarised selected items into 11 binary characteristics based on conceptual concordance and frequency distributions. Then, we conducted a factor analysis based on those 11 binary characteristics, identifying four factors. By also considering the signs of the variable loadings, eight work injury types were defined: (i.) Being caught, hit, crushed, or struck; (ii.) handling or carrying loads by hand or using a handling device; (iii.) carrying out a side task such as walking around, cleaning, tidying, changing clothes or taking a break; (iv.) involving a tool or machine i.e., for cutting, assembling, forming, lifting, or digging; (v.) involving an object i.e., obstacles, inventory, ladders, or building parts; (vi.) being cut or open wound; (vii.) musculoskeletal injury or slip, trip, or fall; (viii.) extremity i.e., hands, arms, legs, or feet.

To describe the characteristics of the study population, we used standard descriptive statistics. To assess differences between male and female participants and between subjects with and without a given injury characteristic, the Chi-squared test or the Fisher's exact test was used, as appropriate. To assess the relationship between a given injury type and each sleep variable individually, multivariable logistic regressions were performed with adjustment for age, sex, socioeconomic status and job risk. The stability of these regression models was tested in a sensitivity analysis, adding further potential confounding variables ($p < 0.2$ in the bivariate analysis) one by one to the corresponding model. The degree of correlation between all variables was assessed. To facilitate interpretation, quantitative variables were dichotomised. However, if the relationship between the logit of the respective injury characteristic and a quantitative predictor variable was nonlinear, three categories were introduced. All statistical analyses were performed using STATA software (version 10.1).

Supplement C

Table Supplement C: Characteristics of participants who presented with work injury by gender (n = 180).

Characteristics	Male		Female		Total		p-value
	n	%	n	%	n	%	
Socioeconomic characteristics							
Gender	144	80.0	36	20.0	180	100.0	**–**
Age							0.226
18–30 years	56	38.9	18	50.0	74	41.1	
31–65 years	88	61.1	18	50.0	106	58.9	
Socioeconomic status							0.093
Low	65	45.5	22	61.1	87	48.6	
Middle/high	78	54.5	14	38.9	92	51.4	
Type of worker							**0.018**
White collar	17	12.0	10	27.8	27	15.2	
Blue collar	125	88.0	26	72.2	151	84.8	
Injury characteristics							
Caught, hit	36	25.0	8	22.2	44	24.4	0.729
Handling, carrying	20	13.9	8	22.2	28	15.6	0.217
Side task	41	28.5	11	30.6	52	28.9	0.805
Tool, machine	70	48.6	15	41.7	85	47.2	0.455
Object	72	50.0	15	41.7	87	48.3	0.371
Cut, open wound	73	50.7	17	47.2	90	50.0	0.709
Musculoskeletal injury, fall	48	33.3	14	38.9	62	34.4	0.530
Extremity	116	80.6	33	91.7	149	82.8	0.114
Sleep subscales and total scores							
Sleep efficiency[a]							0.617
Normal (≥85%)	121	84.0	29	80.6	150	83.3	
Low (<85%)	23	16.0	7	19.4	30	16.7	
Sleep duration							0.502
Short (<6h)	15	10.5	2	5.6	17	9.5	
Normal (6–7h)	102	71.3	29	80.6	131	73.2	
Long (≥8h)	26	18.2	5	13.9	31	17.3	
Problems staying awake[b]							0.702
Normal (<1 times/week)	131	91.0	32	88.9	163	90.6	
High (≥1 times/week)	13	9.0	4	11.1	17	9.4	
PSQI							**0.021**
Normal (≤5 points)	110	82.7	22	64.7	132	79.0	
High (>5 points)	23	17.3	12	35.3	35	21.0	
ESS							0.746
Normal (≤10 points)	120	83.9	31	86.1	151	84.4	
High (>10 points)	23	16.1	5	13.9	28	15.6	
Health and lifestyle factors							
Overweight							0.131
Normal (BMI <25 kg/m^2)	59	41.5	20	55.6	79	44.4	
Overweight (BMI ≥25 kg/m^2)	83	58.5	16	44.4	99	55.6	
Abdominal obesity							**0.039**
Normal (WHR ≤0.85 or 0.90)	62	44.6	23	63.9	85	48.6	
High (WHR >0.85 or 0.90)	77	55.4	13	36.1	90	51.4	
Chronic diseases							
No chronic disease	80	57.1	20	57.1	100	57.1	1.000
Chronic disease(s) (at least one)	60	42.9	15	42.9	75	42.9	
Alcohol consumption							0.129
Rarely (≤1 times/week)	106	74.1	31	86.1	137	76.5	
Sometimes (>1 times/week)	37	25.9	5	13.9	42	23.5	
Current smoker							0.062
Not smoking	67	46.5	23	63.9	90	50.0	
Smoking	77	53.5	13	36.1	90	50.0	
Caffeine sensitivity							0.388
Not sensitive	94	79.0	20	71.4	114	77.6	
Sensitive (at least one symptom)	25	21.0	8	28.6	33	22.4	

Occupational and environmental factors							
Job risk							**0.000**
Low	37	25.7	31	86.1	68	37.8	
High	107	74.3	5	13.9	112	62.2	
Working conditions							0.329
Good	65	58.0	21	67.7	86	60.1	
Adverse	47	42.0	10	32.3	57	39.9	
Shift or night work							**0.002**
No shift or night work	127	88.2	24	66.7	151	83.9	
Shift or night work	17	11.8	12	33.3	29	16.1	
Work experience							0.673
High (>5 years in present occupation)	83	57.6	20	55.6	83	57.6	
Low (≤5 years in present occupation)	61	42.4	16	44.4	61	42.4	
Season of injury occurrence							0.469
Spring/Summer	101	70.1	23	63.9	124	68.9	
Autumn/Winter	43	29.9	13	36.1	56	31.1	

Differences between males and females were assessed using the Chi-squared or the Fisher's exact test, as appropriate. Work injury types were defined on the basis of groups of variables that had been identified by factor analysis. They are not mutually exclusive. Job risk is the risk for a work injury compared to the average Swiss relative work injury risk in the three years available previous to study start (2005–2007) influenced by sex, age and job category; working conditions: conditions concerning work environment, work setting and physical work load. BMI: body mass index; PSQI: Pittsburgh sleep quality index; ESS: Epworth sleepiness scale; WHR: waist-hip ratio for women and men, respectively. [a] a measure of sleep quality; [b] a measure of daytime sleepiness.

Supplement D

Table Supplement D: Characteristics of participants compared with general populations.

	Study sample (%)		**Work injuries in Switzerland (%) [23]**	
Caught, hit	24		48	
Handling, carrying loads	16		12	
Side task	15		29	
Tool, machine	47		55	
Object	48		45	
Cut, open wound	47		50	
Musculoskeletal injury, fall	34		38	
Extremity	83		29	
	Study sample (%)		**Swiss employees with work injuries (%) [26]**	
Gender (male)	80		77	
Age (30 years or less)	41		49	
Type of worker (blue collar)	85		82	
	Study sample (%)		**Swiss working population (%) [26]**	
Low socioeconomic status	51		57	
High job risk	62		62	
Shift work	16		16	
Less than 5 years in present job	42		46	
	Study sample (%)		**General Swiss population (%) [25]**	
	Male	**Female**	**Male**	**Female**
Sleep problems	9–21	6–35	29	41
Daily alcohol consumption	6	3	20	10
Overweight (body mass index ≥25 kg/m^2)	59	44	38	21
Currently smoking	54	36	32	24

[23]: Swiss accident statistics 2012 (a total of 242,099 work injuries); [25]: Swiss health statistics 2012 (representative sample of 18,760 people); [26]: Swiss labour statics 2011 (representative sample of 126,000 people). For reference details, please see reference list of main paper.

Figures (large format)

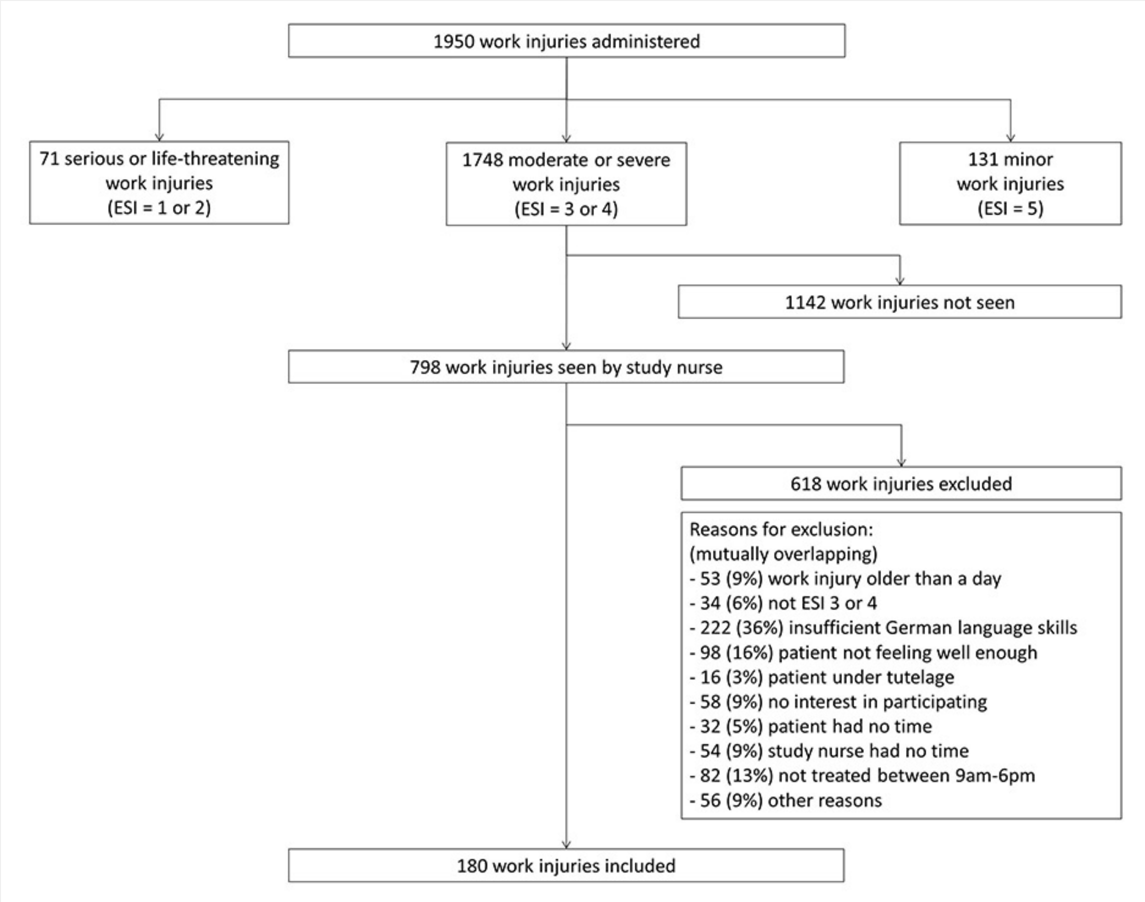

Figure 1

Flow chart of participants.
ESI = emergency severity index.

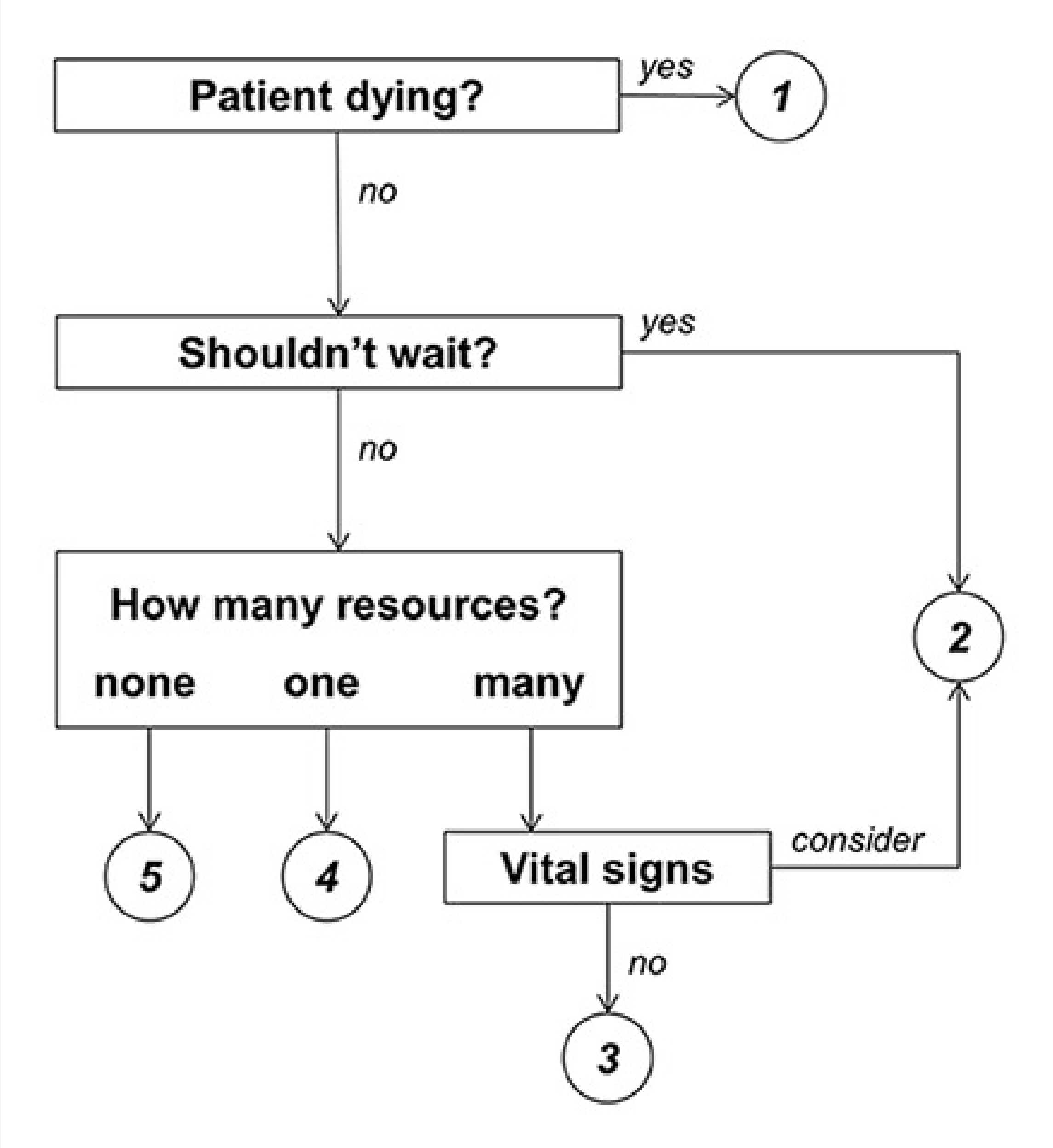

Figure 2

Emergency severity index conceptual algorithm, version 4.
Adapted from Gilboy, et al. 2005 [7]

5 PAPER 3

SLEEP QUALITY AND THE RISK OF WORK INJURY: A SWISS CASE-CONTROL STUDY

This paper has been published:
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Sleep quality and the risk of work injury: a Swiss case–control study

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Keywords
effect modification, frequency, occupational accidents, occupational health and safety, severity, sleep disorders

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SUMMARY

Sleep problems are a well-known risk factor for work injuries, but less is known about which vulnerable populations are most at risk. The aims of this study were to investigate the association between sleep quality and the risk of work injury and to identify factors that may modify the association. A case–control study including 180 cases and 551 controls was conducted at the University Hospital in Basel, Switzerland, from 1 December 2009 to 30 June 2011. Data on work injuries and sleep quality were collected. Adjusted odds ratios and 95% confidence intervals of the association between sleep quality and work injury were estimated in multivariable logistic regression analyses and were stratified by hypothesized effect modifiers (age, gender, job risk, shift work, sleep duration and working hours). Poor sleep quality was associated significantly with work injury of any type ($P < 0.05$) and with being caught in particular ($P < 0.05$). The association between poor sleep quality and work injury was significantly higher for workers older than 30 years (odds ratio$_{>30}$ 1.30 versus odds ratio$_{\leq 30}$ 0.91, $P < 0.01$), sleeping 7 h or less per night (odds ratio$_{\leq 7}$ 1.17 versus odds ratio$_{>7}$ 0.79, $P < 0.05$) and working 50 h or more per week (odds ratio$_{\geq 50}$ 1.79 versus odd ratio$_{<50}$ 1.10, $P < 0.01$). Work injury risk increased with increasing severity of sleep problems ($P < 0.05$). Prior work injury frequency increased with decreasing sleep quality ($P < 0.05$). Older age, short sleep duration and long working hours may enhance the risk of work injuries associated with sleep quality.

INTRODUCTION

Epidemiological research indicates that poor sleep quality is a risk factor for work injuries. A recent systematic review and meta-analysis, pooling data from 27 observational studies, estimated that sleep problems increase the risk of being injured at work by 62% 2014(Uehli *et al.*, 2014). This relationship was confirmed for various sleep problems (e.g. poor sleep quality, short sleep duration or daytime sleepiness), consequences (e.g. minor or fatal work injuries) and occupations (e.g. a specific profession or the general working population).

A number of factors may modify the relationship between sleep quality and work injuries. Women have more sleep problems but fewer work injuries than men (Laflamme and Eilert-Petersson, 2001; Zhang and Wing, 2006). Older people complain about sleep problems more often but are at lower risk for work injuries (Roepke and Ancoli-Israel, 2010; Salminen, 2004). People working shifts or long hours are at higher risk for sleep problems and work injuries (Dembe *et al.*, 2005; Folkard and Tucker, 2003; Metlaine *et al.*, 2005). Work injuries are more common in blue-collar workers, whereas there are conflicting results for the prevalence of sleep problems in occupational categories (Metlaine *et al.*, 2005; Smith and DeJoy, 2012). Short sleeping hours, medication and comorbid conditions were related to poor sleep quality and to work injuries (Ashton, 2004; Cameron *et al*., 2005; Hayashino *et al*., 2010; Keklund and Åkerstedt, 1997; Uehli *et al*., 2014; Voaklander *et al*., 2009).

Modifying factors regarding the association between sleep quality and work injuries have rarely been investigated, and existing studies show conflicting results. Evidence regarding the influence of gender is not conclusive, with studies showing higher, lower (Kling *et al*., 2010) or similar (Kessler *et al*., 2012) rates of sleep-related work injury risk for men compared to women. Our understanding of the influence of age is insufficient, with one study reporting higher risks in young workers (Kunar *et al*., 2010) and other studies finding no interaction between age and sleep quality with regard to work injury risk (Kessler *et al*., 2012). Only Kling *et al.* (2010) stratified the associations between sleep problems and work injuries by job class and shift type, showing that processing and manufacturing jobs and rotating shifts carry the highest risks for sleep problem-associated work injuries in women. There is limited evidence to suggest that long working hours (Arlinghaus *et al*., 2012; Swanson *et al*., 2011) or reduced sleep quality (Kling *et al*., 2010; Nakata, 2011) may increase work injury risk from short sleep duration.

The aim of this study was to provide further evidence for the relationship between sleep quality and work injury and to identify factors that may modify this association. Factors considered for the effect modification were gender, age, job risk, shift or night work, sleep duration, weekly working hours and comorbid conditions.

MATERIALS AND METHODS

Study population

This case–control study included 180 cases and 551 controls (Fig. 1). Cases were recruited through the emergency department of the University Hospital in Basel, Switzerland, from 1 December 2009 to 30 June 2011 (Uehli *et al*., 2013). We enrolled male and female cases who fulfilled the following inclusion criteria: (1) age between 18 and 65 years, (2) admission to hospital from a work injury on the day or the day following an injury, (3) moderate to serious injury severity [Emergency Severity Index (ESI) 3–4] (Gilboy *et al*., 2005; Grossmann *et al*., 2009), (4) sufficient German language skills and (5) an adequate general mental condition to complete the questionnaire. During the same period, controls were recruited from the working population of Basel City through other hospital departments, through the blood donation centre and through workplaces in the hospital's catchment area. Controls who were recruited at the hospital were seeing the physician due to minor local problems that did not affect their body system, e.g. vaccinations against bee sting allergy or excision of warts. Controls met the same inclusion criteria as the cases, but had declared that they had not suffered from an injury during the previous 3 months. Frequency matching was used to ensure that controls were similar to cases with respect to the distribution of age, gender and job risk. The study protocol was approved by the local ethics committee (EKBB, reference number 37/09). Participants were informed of the study objectives and gave their written informed consent prior to their inclusion.

Questionnaires and measurements

Sleep characteristics

Sleep quality was assessed using the German version of the Pittsburgh Sleep Quality Index (PSQI) measuring sleep quality in the 4 weeks prior to work injury with high values

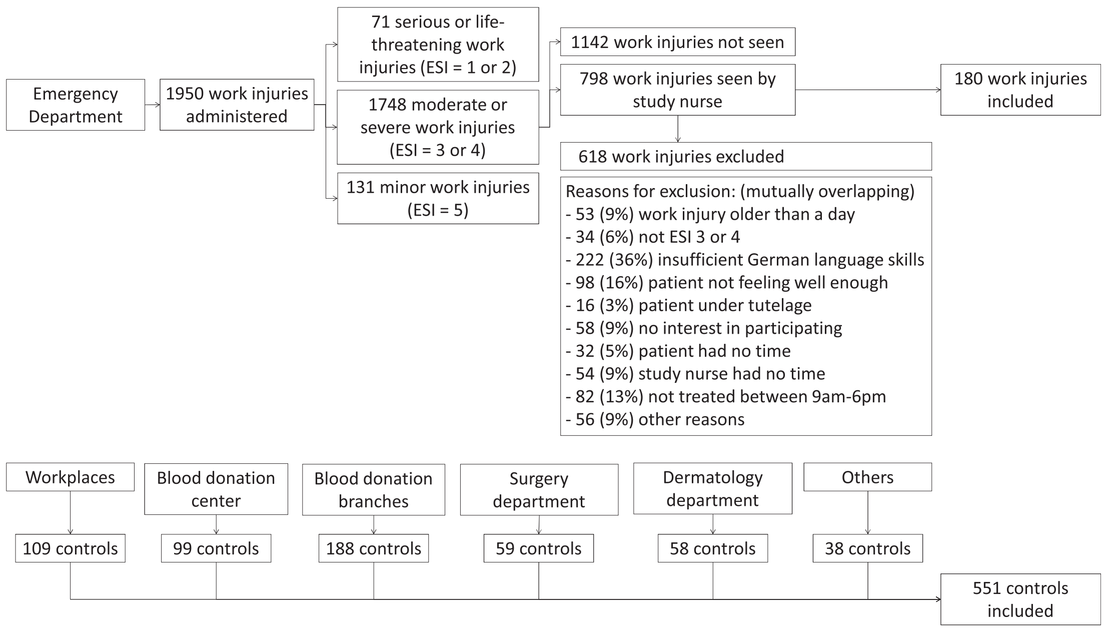

Figure 1. Flowchart of study participants (Abbreviations: ESI, Emergency Severity Index).

indicating poor sleep quality (Buysse *et al.*, 1989; Riemann and Backhaus, 1996). One of the self-reported items measures average sleep duration, which was also treated separately. Sleep disorders, based on self-reported physician's diagnoses within the last 3 months, were obtained as part of a chronic conditions checklist. Poor sleep quality (PSQI >5) and an objectively diagnosed sleep disorder were used to construct the sleep problem severity based on the number of reported problems, which could have three values (0, low; 1, moderate; 2, severe).

Work injury

Work injuries were defined according to Swiss law (Federal Law on Accident Insurance (UVG), 1981), which is consistent with the European methodology as defined by Eurostat (2012), and excludes repetitive strain injuries and commuting accidents. In accordance with Swiss national accident statistics, a trained study nurse collected information on work injuries regarding the following aspects: (1) task in process at time of injury, (2) course of injury, (3) objects involved in the accident, (4) injured body parts and (5) injury diagnosis (Suva, 2009). From this comprehensive information on work injuries (94 items), we defined the following eight, not mutually exclusive, work injury types by factor analysis: caught/hit, handling/carrying, side task, tool/machine, object, cut/open wound, fall/musculoskeletal injury and extremity (Uehli *et al.*, 2013). Information on work injury history was obtained to assess prior work injury frequency, which was defined as the number of positive answers to the following two questions: (1) 'did you have a work injury within the last 12 months (apart from today)'; and (2) 'before the last 12 months, have you ever had a work injury?'.

Covariates

Covariates considered included sociodemographic and work- and health-related factors obtained by validated, self-administered questionnaires in German or specific measuring instruments such as height and weight scales. Questions on sociodemographic factors included gender, age, highest education and occupational status. Socioeconomic status was determined by deriving the average of the educational and the occupational status scores and classifying them as low if the average was below one-third of the maximum score. Questions on work-related aspects included primary job, shift or night work, weekly working hours and perceived work stress. Job risk was determined by a trained study nurse reading the relative work injury risk from the Swiss national accident statistics 2007 based on the respondent's primary job, age and gender (Suva, 2009). Regarding health-related parameters, body mass index (BMI), physical activity [International Physical Activity Questionnaire (IPAQ)], alcohol consumption, caffeine sensitivity, smoking status and comorbid conditions were obtained (for definitions see Data S1).

Statistical analyses

To assess the relationship between PSQI and each individual subject characteristic, univariable logistic regression was performed to estimate the crude odds ratio (OR) and 95% confidence interval (CI). To analyse the relationship between PSQI and work injury types, multivariable logistic regressions were performed, adjusting for the core covariates (for more information see Data S1). When analysing specific types of work injuries, cases without the respective type were excluded. The stability of the regression models was tested in a sensitivity analysis by adding further potentially confounding variables to the core model one by one. Potential additional confounders were selected according to literature and included daytime sleepiness, sleep medication, weekly working hours, marital status, nationality, years in present occupation, safety, general health, waist : hip ratio, depressive syndrome, season of work injury occurrence, working conditions, prior injuries, sick leave absence, general work satisfaction and employment (for definitions see Data S1). To analyse the association of PSQI with prior work injury frequency and the relationship of sleep problem severity with work injury, ordered and multivariable logistic regressions were performed, respectively, adjusting for the core covariates. To assess if the association between sleep problem severity and work injury was non-linear, natural spline models with three to seven knots were compared (Harrell *et al.*, 1984), using the software R (R Development Core Team, Auckland, New Zealand). We evaluated whether the association between sleep quality and work injury was modified by factors that have been discussed in literature, specifically age, gender, job risk, shift or night work, nightly sleep duration and weekly working hours, by means of stratified analyses and using interaction terms. We will use the term 'risk' to denote odds of an adverse outcome. All statistical analyses not specified otherwise were performed using StataIC 12 software (StataCorp, College Station, TX, USA).

RESULTS

Table 1 summarizes the descriptive statistics of the 180 cases and 551 controls. Participants' ages ranged from 18 to 65 years, and the median age was 38 years. The majority of the study population was male (75%), and had a high job risk (58%). Cases did not differ significantly from controls regarding gender and job risk, but were significantly older ($P < 0.01$). For the total sample, the median PSQI was 4 (IQR = 3), and the sleep time median was 7 h per night (IQR = 1.5 h). Extremities were predominantly injured (82%). No accident involved occupational driving.

Table 2 shows the unadjusted associations of the sleep variables and covariates with work injury. Concerning sleep aspects, work injury risk was associated significantly only with increasing sleep problem severity. Too few observations were captured to analyse sleep medication.

Table 1 Characteristics of the study population (n_{cases} = 180, $n_{controls}$ = 551)

	Case		*Control*		*Total*		χ^2
	n	%	n	%	n	%	P
Age (≤30 years)	74	41.1	150	27.4	224	30.8	<0.01
Gender (male)	144	80.0	403	73.4	547	75.0	0.076
Low socioeconomic status	92	51.4	223	41.5	315	44.0	<0.05
Poor sleep quality (PSQI >5)	35	21.1	112	21.2	147	21.2	0.972
Short sleep duration (≤7 h)	78	43.6	261	47.5	339	46.6	0.356
Sleep problem severity							
Low	99	72.8	382	79.1	481	77.7	<0.05
Moderate	24	17.7	82	17.0	106	17.1	
High	13	9.6	19	3.9	32	5.2	
Sleep medication	6	3.3	18	3.3	24	3.3	0.968
Self-report of diagnosed sleep disorder	17	11.7	27	5.4	44	6.8	<0.01
Physical activity (IPAQ)							
Low	35	19.9	78	14.6	113	15.9	<0.05
Moderate	16	9.1	92	17.2	108	15.2	
High	125	71.0	364	68.2	489	68.9	
Regular alcohol consumption (≥1 x/w)	80	44.7	319	58.3	399	55.0	<0.01
Caffeine sensitivity (≥1 symptom)	33	22.4	119	23.9	152	23.6	0.708
Current smoker	90	50	149	27.2	239	32.8	<0.001
Comorbidity (≥1 condition)	46	26.1	144	26.3	190	26.2	0.970
High perceived work stress	55	32.7	159	30.9	214	31.3	0.651
High job risk	112	62.2	308	55.9	420	57.5	0.136
Shift or night work	29	16.1	128	23.2	157	21.5	<0.05
Weekly working hours (≥50 h)	34	18.9	108	19.8	142	19.6	0.786
High-risk worker	21	11.7	70	12.7	91	12.5	0.714
Prior work injury frequency							
None	76	43.2	280	54.3	356	51.5	<0.05
1 point	81	46.0	186	36.1	267	38.6	
2 points	19	10.8	50	9.7	69	10.0	
Work injuries							
Caught/hit	44	24.4					
Handling/carrying	28	15.6					
Side task	52	28.9					
Tool/machine	85	47.2					
Object	87	48.3					
Cut/open wound	90	50.0					
Fall/musculoskeletal injury	62	34.4					
Extremity	149	82.2					
	Median	*IQR*	*Median*	*IQR*	*Median*	*IQR*	*MWW* P
Age (years)	33	17.5	40	19.5	38	19.5	<0.001
PSQI (units)	4	3	4	2	4	3	0.892
Sleep time (h)	7	1.5	7	1.5	7	1.5	0.235
Sleep problem severity (no. symptoms)	0	1	0	0	0	0	0.076
BMI (kg m^2)	25.5	5.9	25.5	4.8	25.5	5.1	0.370
Weekly working hours (h)	43	4.4	43	5.0	43	5.0	0.945
Prior work injury frequency (points)	1	1	0	1	0	1	<0.05

Work injury types were defined based on groups of variables having been identified by factor analysis. They are not mutually exclusive. High-risk workers were defined as being >30 years old, sleeping ≤7 h per night, and working ≥50 h or more per week.
PSQI, Pittsburgh Sleep Quality Index; IPAQ, International Physical Activity Questionnaire; *n*, number of participants; x/w, times per week; h, hours; no., number; χ^2, chi-squared test; MWW, Mann–Whitney–Wilcoxon test; IQR, interquartile range; *P*, *P*-value.

Table 3 shows the adjusted relationships between PSQI and all work injuries combined as well as the different types of work injury. For each 1-unit increase in PSQI, overall work injury risk increased by 14% (95% CI: 2–28%). Workers suffering from poor sleep quality according to PSQI protocol (PSQI >5) had a 1.78-fold (95% CI: 1.01–3.17) higher risk for work injuries compared to their counterparts (PSQI ≤5) (for more information see Table S1). The injury type most susceptible to sleep quality was being caught or hit (OR = 1.25, 95% CI: 1.01–1.55).

Table 3 also shows the associations of sleep problem severity with work injury. For each 1-unit increase in sleep problem severity, work injury risk increased by 64% (95% CI: 11–143%). A logit-linear dose–response relationship between sleep problem severity and the adjusted odds of work injury was suggested by the observation that the simple model with a linear term for PSQI had the lowest Akaike information criterion (AIC) among a set of natural spline models for PSQI with up to seven knots. Self-reports of being diagnosed with a sleep disorder were associated with a doubled work injury risk (OR = 2.21, 95% CI: 1.06–4.60) (for more information see Table S1). Having a diagnosed sleep disorder and suffering from poor sleep quality (PSQI >5) at the same time almost tripled work injury risk (OR = 2.88, 95% CI: 1.21–6.86) (see Table S2).

Table 2 Relationship between various covariates and work injury: adjusted ORs and 95% CI calculated by multivariable logistic regression (n_{cases} = 180, $n_{controls}$ = 551)

	OR	*95% CI*
Age (years)	0.97	0.96–0.99‡
Male (versus female)	1.47	0.97–2.23
High socioeconomic status (versus low)	0.75	0.53–1.06
Sleep quality (PSQI score)	1.01	0.93–1.09
Sleep duration (h)	1.10	0.91–1.32
Sleep problem severity (score)	1.44	1.04–2.00*
BMI (kg m^2)	1.05	1.00–1.09*
Moderate physical activity (versus low)[a]	0.42	0.22–0.83†
High physical activity (versus low)[a]	0.81	0.52–1.28
Regular alcohol consumption (≥1 versus <1 x/w)	0.58	0.41–0.83†
Caffeine sensitivity (≥1 versus no symptoms)	0.96	0.62–1.51
Current smoker (versus non-smoker)	2.37	1.66–3.40‡
Comorbidity (yes versus no)	1.15	0.77–1.71
High perceived work stress (versus low)	1.04	0.71–1.53
High job risk (versus low)	1.08	0.73–1.58
Shift or night work (versus daytime work)	0.67	0.43–1.05
Long weekly working hours (≥50 versus <50 h)	0.97	0.62–1.51

Adjusted for age and gender. PSQI, Pittsburgh Sleep Quality Index; *n*, number of subjects; x/w, times per week; h, hours; OR, odds ratio; CI, confidence intervals; [a]physical activity assessed by the International Physical Activity Questionnaire (IPAQ); *$P < 0.05$; †$P < 0.01$; ‡$P < 0.001$.

Table 4 gives the association between sleep quality and the frequency of prior work injury. For each 1-unit increase in PSQI, the risk of a higher number of work injuries increased by 12% (95% CI: 2–24%). These analyses were independent of case status because only past work injuries were taken into account.

Table 5 shows the relationships between sleep quality and work injury stratified by factors potentially modifying the effect. For each 1-unit increase in PSQI, work injury risk increased by 20–30% in males, older people, participants with a high job risk, daytime work and short sleep duration. For people working 50 h or more per week, work injury risk increased by 79% per 1-unit increase in PSQI. Combining the characteristics with significant subgroup differences, high-risk workers (>30 years, ≤7 h sleep, ≥50 h work) suffered from a threefold increase in work injury risk for each 1-unit increase in PSQI.

Fig. 2 illustrates how the major effect of sleep quality on work injury was modified by the cofactors with significant subgroup differences. Participants older than 30 years, sleeping 7 h or less, working 50 h or more and participants with all three characteristics present were more affected by sleep quality-related work injuries than their counterparts.

DISCUSSION

Poor sleep quality was a risk factor for work injuries in this study. Sleep quality was related particularly strongly to work

Table 3 Association for sleep quality, as measured by the PSQI, and for sleep problem severity with all work injuries combined as well as the different types of work injuries: adjusted ORs and 95% CI calculated by multivariate logistic regression (n_{cases} = 180, $n_{controls}$ = 551)

	PSQI score		*Sleep problem severity score*	
	aOR	*95% CI*	*aOR*	*95% CI*
All work injuries	1.14	1.02–1.28*	1.64	1.11–2.43*
Caught/hit	1.25	1.01–1.55*	2.20	1.08–4.48*
Handling/carrying	0.97	0.72–1.29	1.22	0.49–3.03
Side task	1.15	0.95–1.40	1.34	0.66–2.68
Tool/machine	1.16	0.98–1.40	1.91	1.15–3.18*
Object	1.15	0.98–1.35	1.48	0.84–2.59
Cut/open wound	1.17	1.00–1.36	1.95	1.18–3.20†
Fall/musculoskeletal injury	1.09	0.91–1.31	1.16	0.60–2.28
Extremity	1.10	0.97–1.25	1.51	1.00–2.28*

Adjusted for sleep hours (linear and squared term), age, gender, job risk, socioeconomic status, shift, physical activity, body mass index (BMI), caffeine sensitivity, alcohol consumption, stress, and smoking. Cases without the respective injury type were excluded from the particular analysis. PSQI, Pittsburgh Sleep Quality Index treated as a semi-quantitative covariable with high values indicating poor sleep quality; OR, odds ratio referring to a 1-unit increase on the PSQI scale (PSQI data ranging from 0 to 16) or a 1-unit increase on the sleep problem severity scale (data ranging from 0 to 3); CI, confidence intervals; *$P < 0.05$; †$P < 0.01$.

Table 4 Relationship between sleep quality, as measured by the PSQI, and the frequency of prior work injury: adjusted ORs and 95% CI calculated by multivariable ordered logistic regression (n = 731)

	All participants		*Cases*		*Controls*	
	OR	*95% CI*	*OR*	*95% CI*	*OR*	*95% CI*
Prior work injury frequency	1.12	1.02–1.24*	1.17	0.96–1.43	1.09	0.97–1.23

Adjusted for sleep hours (linear and squared term), age, gender, job risk, socioeconomic status, shift, physical activity, BMI, caffeine sensitivity, alcohol consumption, stress, and smoking. OR, odds ratio; CI, confidence intervals; *P < 0.05.

Table 5 Relationship between sleep quality, as measured by the PSQI, and work injury, in various subgroups: adjusted ORs and 95% CI calculated by stratified multivariable logistic regression (n_{cases} = 180, $n_{controls}$ = 551)

	OR	*95% CI*
Gender		
Female	1.02	0.80–1.31
Male	1.20	1.04–1.39*
Age		
≤30 years	0.91	0.75–1.11
>30 years	1.30	1.11–1.52†
Job risk		
Low	1.04	0.84–1.28
High	1.20	1.03–1.39*
Shift work		
No	1.18	1.03–1.36*
Yes	0.94	0.73–1.21
Sleep duration		
≤7 h	1.17	1.03–1.33*
>7 h	0.79	0.55–1.13
Weekly working hours		
<50 h	1.10	0.96–1.25
≥50 h	1.79	1.23–2.58†
Comorbidity		
0	1.11	0.96–1.28
≥1	1.27	0.99–1.62
High-risk worker		
No	1.10	0.97–1.25
Yes	3.17	1.38–7.28†

High-risk workers were defined as being >30 years old, sleeping ≤7 h per night, and working ≥50 h or more per week. Adjusted for sleep hours (linear and squared term), age, gender, job risk, socioeconomic status, shift, physical activity, BMI, caffeine sensitivity, alcohol consumption, stress, and smoking. OR, odds ratio referring to a 1-unit increase on the PSQI scale (PSQI data ranging from 0 to 16); CI, confidence intervals; h, hours; *P < 0.05; †P < 0.01.

injuries in participants of older age, sleeping short times and working long hours. The type of injury associated most strongly with sleep quality was being caught or hit. With increasing sleep problem severity, the risk for work injury increased. Having poor sleep quality and a physician's diagnosis almost tripled the work injury risk. A decrease in sleep quality was associated with an increase in prior work injury frequency.

Effect of sleep quality on work injuries

The causal mechanism behind the risk of poor sleep quality for work injuries presumably involves lack of sufficient alertness because of cognitive impairments (Altena *et al.*, 2008) and poor situational reactions in risky situations (Shekleton *et al.*, 2010). This hypothesis is supported by our findings that injuries from being caught, which may be from lack of attention, were associated most strongly with poor sleep quality. The finding that poor sleep quality may be the cause of work injuries was further supported by the dose–response relationship found in our data.

Populations most at risk for sleep quality-related work injuries

Older workers were at high risk for sleep quality-related work injuries, which is plausible because older people generally have more sleep quality problems and more work injuries (Roepke and Ancoli-Israel, 2010; Salminen, 2004). The finding that workers getting little sleep were at a higher risk for sleep quality-related work injuries is likely, because short sleep duration is associated typically with poor sleep quality and with work injury (Keklund and Åkerstedt, 1997; Uehli *et al.*, 2014). Workers with long weekly working hours were at a higher risk for sleep quality-related work injuries, which is plausible because long working hours are associated with reduced sleep quality and with an increased risk of work injury (Dembe *et al.*, 2005; Metlaine *et al.*, 2005). These findings are important, because the number of older people in the workforce is increasing (Auer and Fortuny, 2000), general sleep duration is decreasing (Kronholm *et al.*, 2008) and an increasing number of people work long hours (Jacobs and Gerson, 2004). Therefore, an increasing number of workers are at high risk for sleep quality-related work injuries.

Comparison with related studies

Our major results on the risk of poor sleep quality for work injuries are consistent with our recent systematic review (Uehli *et al.*, 2014). Our injury-type analysis is in line with a study of French construction workers, which reported that

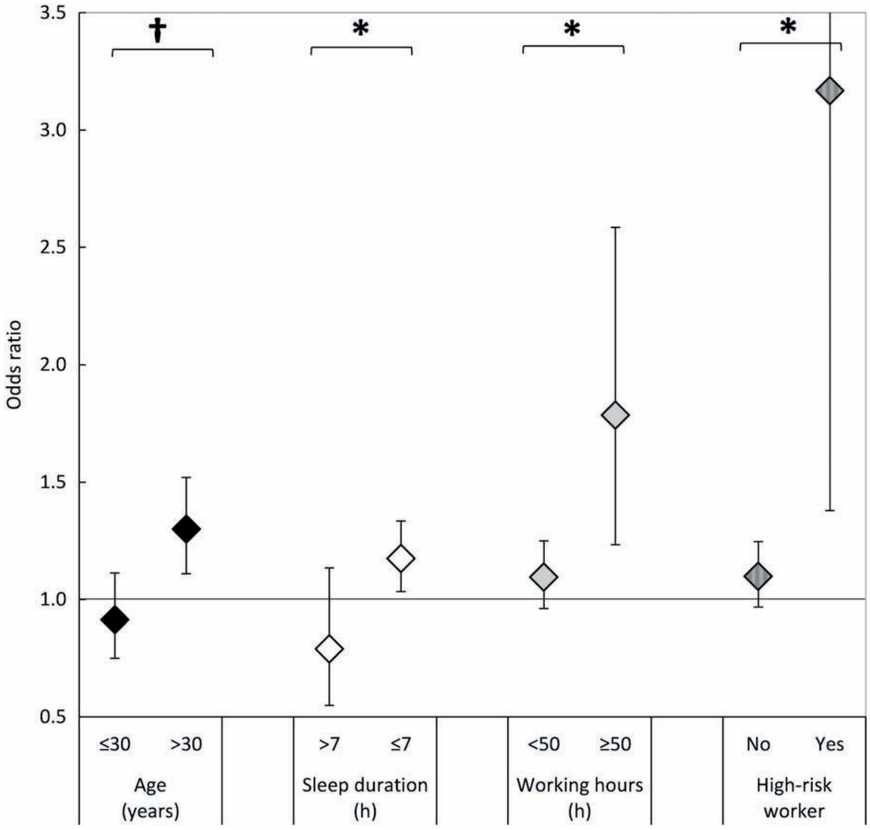

Figure 2. The adjusted associations between sleep quality, as measured by the Pittsburgh Sleep Quality Index (PSQI), and work injury in various subgroups. Sleep quality was measured by the PSQI. High-risk workers were defined as being >30 years old, sleeping ≤7 h per night, and working ≥50 h or more per week. Adjusted for sleep hours, age, gender, job risk, socioeconomic status, shift, physical activity, body mass index (BMI), caffeine sensitivity, alcohol consumption, stress, and smoking. Data on high-risk workers were odds ratio (OR) = 3.17, 95% confidence interval (CI): 1.38–7.28. $^{*}P < 0.05$; $^{\dagger}P < 0.01$.

being caught by a moving object was the type of injury related most strongly to sleep problems (Chau *et al.*, 2002). Concerning subgroup analyses, the finding that older workers were more susceptible to sleep-related work injuries is consistent with our previous meta-analysis (Uehli *et al.*, 2014). We could confirm the results of Kling *et al.* (2010) and Nakata (2011), who found an influence of long working hours on the association between sleep quality and work injuries.

Strength and limitations

The findings of this study are useful, because they address various knowledge gaps that have been identified by recent systematic literature reviews (Kucharczyk *et al.*, 2012; Uehli *et al.*, 2014). To our knowledge, this study is the first to examine the relationship of work injuries and sleep quality with a standardized score facilitating comparisons across studies and to analyse the relationship on a continuous scale without losing information by dichotomizing. The effect of PSQI was adjusted for sleep duration to focus on subjective sleep quality, an adjustment that has been proposed only recently (Dosman *et al.*, 2013). We collected data on work injury characteristics and history and on sleep problem severity, enabling us to investigate the processes involved in the association between sleep quality and work injury. We profited from a large number of covariates that were considered as potential confounders and effect modifiers and complied with recent recommendations to discriminate between motor vehicle crashes and other accidents at work (Kucharczyk *et al.*, 2012). Moreover, the use of three different categories of controls provided additional insight. When comparing cases with controls recruited from workplaces only, the effect estimates for the relationship between sleep problems and work injuries were even stronger (data not shown).

Several limitations should be considered when interpreting the present findings. Our results do not allow us to make firm inferences regarding causality, because they are from a case–control study. The study population was comprised predominantly of males and dayshift workers (75 and 79%, respectively), which may limit the generalizability of the findings. The representativeness of the cases may be restricted due to their limited comparability to the population of interest (Uehli *et al.*, 2013). Only moderate to severe work injuries were included. Serious or life-threatening injuries were excluded, because those patients were not suitable for questioning. Minor injuries were excluded, because the prevalence of minor injuries in the emergency department depends upon many factors other than treatment need, e.g. the patient's concerns or the availability of a general practitioner. However, an association was observed for poor sleep quality with fatal and minor injuries elsewhere (Åkerstedt *et al.*, 2002; Iftikhar *et al.*, 2009). Socially desirable answers may have been a source of differential misclassification and some participants may have been randomly misclassified, although we defined sleep quality based on a standardized questionnaire. However, differential and random exposure misclassifications would have led to an underestimation of the effect of poor sleep quality on work injuries (Rothman, 2002). By using German questionnaires, we may have introduced selection bias. However, considering that reports of insufficient sleep quality were more frequent among excluded cases, one might hypothesize that associations without the exclusion of these persons would have been even stronger.

Further research and implications

Future research investigating susceptibility factors for sleep quality-related work injuries might provide valuable information for identifying vulnerable populations and developing targeted injury prevention strategies. Objective measures may be used to determine sleep quality and to confirm questionnaire-based studies. Other factors influencing sleep quality, such as resting behaviours during the day, should be included in future studies. Prospective methodologies are important in examining the change in risk of work injury after introducing measures aimed at preventing or reducing sleep problems.

Identifying workers with poor sleep quality may be important in preventing work injuries. Focusing upon people older than 30 years and those who sleep for 7 h or less and work for 50 h or more may be a rewarding approach. Providing fatigue risk-management training that includes strategies to improve sleep quality or to enhance daytime alertness could increase safety at work.

CONCLUSION

This study not only confirmed the association between poor sleep quality and work injuries, but also identified populations most at risk. Sleep quality-related work injury prevention measures should benefit everyone, but should focus specifically on workers of older age and those with short sleep duration or long working hours.

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CONFLICTS OF INTEREST

DM and KU are employed at Suva.

AUTHOR CONTRIBUTIONS

KU, DM, EH-T, AJM, RM, CS, NK and JDL were responsible for the study conception and design; KL, DM, RB, SD, SM, SZ and JDL carried out the data acquisition; KU, CS and NK conducted the data analysis; KE, EH-T, CS and NK were responsible for the interpretation; KU drafted the manuscript; KU, DM, RB, SD, EH-T, SM, AJM, RM, CS, SZ and JDL critically revised the manuscript; and JDL was responsible for primary supervision.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Data S1. Definitions of health-related parameters.

Table S1. Association of poor sleep quality (PSQI >5) and self-reported diagnosed sleep disorders, respectively, with each mutually non-exclusive type of work injury: adjusted ORs and 95% CI calculated by multivariate logistic regression (n_{cases} = 180, $n_{controls}$ = 551).

Table S2. Relationship between the severity of sleep problems and work injury, with sleep problem severity as a categorical variable: adjusted ORs and 95% CI calculated by multivariable logistic regression (n_{cases} = 180, $n_{controls}$ = 551).

SUPPLEMENT

DATA S1

The core covariates were sleep hours (linear and squared term), age, gender, socioeconomic status, job risk, shift or night work, work stress, BMI, physical activity, alcohol consumption, caffeine sensitivity, current smoking habits, and comorbidity. Age was considered as a continuous variable. Perceived work stress was based on the job demand and job control scale by Karasek and was indicated as high if the participant had a job demand score above median and a job control score below median (Karasek, 1990). Job risk was classified as high if the relative work injury risk was greater than the Swiss average over the three years prior to study start (2005-2007), which was 68 work accidents per 1000 fulltime employees annually (Suva, 2009). BMI was calculated by dividing weight (kg) by height (m) squared measured by a trained study nurse and treated as a continuous variable. Additional square terms of age and BMI were tested when developing the model but proved to be dispensable. Physical activity was assessed by the long version of the validated international physical activity questionnaire (IPAQ) (IPAQ Group). The three proposed activity levels are based on the current public health guidelines for physical activity (Pate *et al.*, 1995). Alcohol consumption was dichotomised into rarely (<1 x/week) and regularly (≥1 time per week). Caffeine sensitivity was based on nightly symptoms due to caffeine consumption after 4 pm (present or not present). Smoking status distinguished current smoking and non-smoking. In a checklist, information was collected on chronic conditions previously found to have high comorbidity with insomnia (Parish, 2009; Roth, 2009; Sivertsen *et al.*, 2009). Comorbidity was classified as having at least one of the listed chronic conditions diagnosed by a physician over the past three months (cardiovascular disorders, diabetes, rheumatoid diseases, respiratory disorders, digestive disorders, pain conditions, mental disorders, climacteric symptoms common to perimenopausal woman, urinary or bladder problems) (Kessler *et al.*, 2012; Shahly *et al.*, 2012).

Potential additional confounders tested in sensitivity analysis were daytime sleepiness, sleep medication, weekly working hours, marital status, nationality, years in present occupation, safety, general health, waist-hip-ratio, depressive syndrome, season of work injury occurrence, working conditions, prior injuries, sick leave absence, general work satisfaction, and employment. Daytime sleepiness was assessed using the Epworth sleepiness scale (Bloch *et al.*, 1999; Johns, 1991). Sleep medication concerned currently taking sleeping pills including benzodiazepines and hypnotics. Weekly working hours were treated as a continuous variable. Marital status distinguished married and single or divorced. Nationality described being Swiss versus another nationality. Safety was based on the active practices of the safety climate scale by Zohar asking workers if their direct supervisor i) makes sure they receive all the equipment needed to do the job safely, ii) frequently checks to sees if they are all obeying the safety rules, iii) emphasizes safety procedures when they are working under pressure, iv) refuses to ignore safety rules when work falls behind schedule, v) is strict about working safely when they are tired or stressed, vi) makes sure they follow all the safety rules (not just the most important ones), vii) insists that they obey safety rules when fixing equipment or machines, viii) is strict about safety at the end of the shift, when they want to go home, ix) insists they wear their protective equipment even if it is uncomfortable (Zohar and Luria, 2005). General health was obtained with a five-point Likert scale on self-perceived general health status. Waist and hip circumferences were measured by a trained study nurse according to the guidelines of the world health organization to calculate the waist-hip-ratio (WHO, 2008). A depressive syndrome was present if diagnosed by a physician within the past three months (Kessler *et al.*, 2012; Shahly *et al.*, 2012). The seasons when a work injury occurred were separated into spring (March – May), summer (June – August), autumn (September – November), and winter (December – February). Working conditions averaged eight five-point Likert scales on environmental conditions, working environment, and physical work load (Bauer and Schmid, 2008). Prior injuries referred to workers having ever had a work or a leisure time injury apart from today. Sick leave absence corresponded to the number of days of work absence in the previous 12 months due to sickness, leisure time injury or work injury. General work satisfaction was obtained with a five-point Likert scale on self-perceived general work satisfaction. Employment described if the contract was limited or unlimited in time.

TABLE S1

Table S1 Association of poor sleep quality (PSQI >5) and self-reported diagnosed sleep disorders, respectively, with each mutually non-exclusive type of work injury: adjusted ORs and 95% CI calculated by multivariate logistic regression (n_{cases} = 180, $n_{controls}$ = 551)

	PSQI >5			Self-report of diagnosed sleep disorder		
	aOR	**95% CI**		**aOR**	**95% CI**	
All work injuries	1.78	1.01 – 3.17	*	2.21	1.06 – 4.60	*
Caught/hit	2.63	0.92 – 7.51		3.16	0.89 – 11.2	
Handling/carrying	0.73	0.16 – 3.26		2.69	0.59 – 12.3	
Side task	1.85	0.72 – 4.80		0.78	0.16 – 3.76	
Tool/machine	2.06	0.94 – 4.49		3.01	1.20 – 7.54	*
Object	1.71	0.76 – 3.85		1.69	0.57 – 5.05	
Cut/open wound	2.26	1.08 – 4.74	*	2.91	1.16 – 7.30	*
Fall/musculoskeletal injury	1.53	0.62 – 3.79		0.65	0.14 – 3.10	
Extremity	1.73	0.95 – 3.15		1.71	0.76 – 3.83	

Adjusted for sleep hours (linear and squared term), age, gender, job risk, socioeconomic status, shift, physical activity, BMI, caffeine sensitivity, alcohol consumption, stress, and smoking. Cases without the respective injury type were excluded from the particular analysis.
Abbreviations: PSQI, Pittsburgh Sleep Quality Index; OR, odds ratio; CI, confidence intervals; *, P<0.05.

TABLE S2

Table S2 Relationship between the severity of sleep problems and work injury, with sleep problem severity as a categorical variable: adjusted ORs and 95% CI calculated by multivariable logistic regression (n_{cases} = 180, $n_{controls}$ = 551)

	OR	95% CI
Sleep problem severity (categories)		
Low	Ref.	
Moderate	1.52	0.82 – 2.80
Severe	2.88	1.21 – 6.86 *

Adjusted for sleep hours (linear and squared term), age, gender, job risk, socioeconomic status, shift, physical activity, BMI, caffeine sensitivity, alcohol consumption, stress, and smoking.
Abbreviations: OR, odds ratio; CI, confidence intervals; Ref., reference group; *, $P<0.05$.

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6 SUMMARY OF THE MAIN FINDINGS

The findings presented in *Chapters 3* to *5* will be summarised in this chapter. The objectives of this thesis are defined by the research questions in *Chapter 2*, which are answered here in brief. More detailed results and discussions are given in the chapters covering the respective topic, which are referenced. More general aspects of this thesis will be discussed in *Chapter 7*.

UNDERSTANDING THE RISK OF SLEEP PROBLEMS FOR WORK INJURIES

1) Are sleep problems consistently associated with work injuries?

The present systematic review identified 27 observational studies published between 1982 and 2011, comprising a total of 268,332 participants who were eligible for inclusion (for more details, see *Chapter 3: Paper 1: Sleep problems and work injuries: a systematic review and meta-analysis).* Of the 54 estimates provided, 53 results suggested a positive relationship between sleep problems and work injury, of which 34 associations were statistically significant. One case-control study on Australian male farmers investigating the association between excessive daytime sleepiness with serious or fatal work injuries found an apparent protective effect for sleepiness that the authors could not explain.[88] However, a possible reason might be the use of an inadequate exposure measure (the Epworth sleepiness scale)[72] that is resumed in other parts of this thesis *(Chapter 7.3: How to identify the risk in an occupational setting: Work-up of sleep problems* and *Chapter 7.4: Study design and methodological aspects: Recommendations for future studies).*

2) What is the pooled risk estimate of sleep problems for work injuries?

The present meta-analysis pooled 31 of the 53 estimates, which were selected in a systematic way to ensure that populations were mutually not overlapping (for more details, see *Chapter 3*). The pooled estimate suggested that workers with sleep problems had a 1.62 times higher risk of being injured at work compared to workers without sleep problems. Individual estimates ranged from 1.07[89] to 4.3,[53] with one low outlier at 0.51[88] and two high outliers at 7.88[90] and 8.32[91]. The low outlier showing a protective effect was described in the paragraph above. The high outliers were both cross-sectional studies assessing more severe sleep problems that generally tend to show higher risks (see *Chapter 3)*. For a general discussion, see the respective chapter *(Chapter 7.1: Sleep problems are a considerable risk for work injuries: Worldwide and in Switzerland).*

3) What percentage of work injuries can be attributed to sleep problems?

The results from the systematic review and the meta-analysis allowed us to calculate the population attributable risk per cent (PAR %) (for more details, see *Chapter 3*). The estimated PAR % indicated that sleep problems were involved in approximately 13 % of the work injuries. For PAR % calculations for Switzerland and the corresponding interpretation, see the respective chapters *(Chapter 7.1: Sleep problems are a considerable risk for work injuries: Percentage of work injuries potentially preventable* and *Chapter 7.2: Highly relevant socioeconomic costs).*

4) What types of sleep problems have the highest risks for work injury?
A first subgroup meta-analysis of all 54 identified estimates revealed that each type of sleep problem was significantly associated with an increased risk for work injury (for more details, see *Chapter 3*). The largest pooled effects were calculated for the use of sleep medication and for breathing-related sleep problems; the smallest effect was observed for daytime sleepiness. Intermediate effects were reported for sleep quality and sufficiency, sleep quantity and multiple symptoms. These results are further discussed later in this thesis *(see Chapter 7.3: How to identify the risk in an occupational setting: Work-up of sleep problems).*

5) What factors may be underlying the overall effect of sleep problems on work injuries?
A second subgroup analysis and a meta-regression analysis did not reveal significant underlying effects for the considered factors and confirmed the stability of our results (for detailed findings, see *Chapter 3*). However, a tendency was observed that sleep problems may lead to more severe work injuries, and that workers with more severe sleep problems may be at higher risk for work injuries. Furthermore, studies with a higher proportion of females and a higher mean age tended to result in higher risks of work injury. These findings are further discussed in the general considerations *(Chapters 7.1: Sleep problems are a considerable risk for work injuries: Worldwide and in Switzerland).*

IDENTIFYING SUSCEPTIBLE TYPES OF WORK INJURIES AND POPULATIONS MOST AT RISK

6) Which injury types are most susceptible to sleep problems?
7) What dimensions of sleep problems (sleep quality, sleep duration or daytime sleepiness) are relevant for the risk of different work injury types?
At the emergency department of the UHB, Switzerland, 180 male (80%) and female (20%) work injury patients with a mean age of 35.5 years were recruited (for detailed findings, see *Chapter 4: Paper 2: Sleep problems and work injury types: a study of 180 patients in a Swiss emergency department*). In our cross-sectional analysis, the injury types significantly associated with sleep problems were falls and musculoskeletal injuries, injuries while working with or being injured by a tool or machine, and injuries while performing a side task. We observed that each sleep problem dimension was a significant risk factor for at least one of the work injury types. Poor sleep quality and abnormal sleep duration significantly increased the risk for the incidence of work injuries during side tasks or due to falls two- to five-fold. Daytime sleepiness was significantly related to injuries involving a tool or a machine, increasing the risk approximately four-fold. The ways that these findings may help in identifying the risk of sleep problems in an occupational setting are discussed in *Chapter 7.3: How to identify the risk in an occupational setting: Investigating work injuries* and *Work-up of sleep problems.*

8) What are the most vulnerable populations at risk for poor sleep quality increasing work injuries?

In addition to the 180 cases, 551 male (73 %) and female (27 %) controls with a mean age of 38.3 years were recruited in the catchment area of the UHB, Switzerland (for detailed findings, see *Chapter 5: Paper 3: Sleep quality and the risk of work injury: a Swiss case-control study*). In our case-control analysis, poor sleep quality was an overall risk factor for work injuries. In particular, workers older than 30 years, who slept 7 hours or less and who worked 50 hours or more were at higher risk for sleep quality related work injuries than their counterparts. For a broader discussion of these findings in light of the current trends in the workforce, see *Chapter 7.3: How to identify the risk in an occupational setting: Prevention in populations at risk*.

VERIFYING OUR INTERNATIONAL FINDINGS FOR SWITZERLAND

9) Are the findings from Switzerland in line with the findings from the meta-analysis?

In our meta-analyses and meta-regression analyses, we processed data form 15 countries other than Switzerland *(Chapter 3)*. Swiss data were gathered in our case-control study at the UHB *(Chapter 5)*. Comparing the findings, we confirmed the results from the meta-analysis in our Swiss case-control study. Similar risks for work injury associated with poor sleep quality were observed ($OR_{\text{meta-analysis}} = 1.46$ vs. $OR_{\text{case-control study}} = 1.78$, $p = 0.75$), and in both settings, workers with more severe sleep problems were at higher risk for work injury. Sleep problems were associated with more severe work injuries in the meta-analysis and led to a greater history of work injuries in the case-control analysis. Country comparisons, also including the developing world, are further discussed in *Chapter 7.1: Sleep problems are a considerable risk for work injuries: Worldwide and in Switzerland.*

7 GENERAL DISCUSSION AND CONCLUSIONS

The findings published in the framework of this thesis provide new insights into the association of sleep problems with work injuries and, for the first time, quantitatively pool the magnitude of this risk. Our findings further elucidate the underlying mechanisms of this association by identifying high-risk sleep problems, susceptible types of work injuries and the populations most at risk.

In the following section, our international and national findings are compared, the percentage of potentially preventable work injuries is assessed, and comparisons are drawn between the risk of sleep problems for work injuries and for other types of injuries. Furthermore, the socioeconomic cost of work injuries related to sleep problems is estimated, and guidance on how to identify sleep-related work injury risk in an occupational setting is given. Finally, the strengths and limitations of this work, considerations for further investigations in this field of research and the consequences of the present findings for practice are discussed.

7.1 SLEEP PROBLEMS ARE A CONSIDERABLE RISK FACTOR FOR WORK INJURIES

Sleep problems were considered a risk factor for work place safety in expert panels and narrative reviews.[38,48,49] Never before has this relationship been investigated systematically and quantitatively pooled. This thesis is an important step towards a better recognition of sleep problems as a risk factor in workplace injuries because quantitative risk assessments play a role in the decision-making process of health and safety executives.[92]

WORLDWIDE AND IN SWITZERLAND

In our meta-analysis, we pooled studies from five different continents and observed that workers with sleep problems had a significantly higher chance of injury at work than workers without sleep problems *(Chapter 3)*. This result quantitatively confirmed the belief of the experts in this field. We observed a tendency of workers with sleep problems to be at higher risk for more severe work injuries than workers without sleep problems, confirming the theory introduced in the overall framework of this thesis that sleepy workers may not adequately react in dangerous situations *(Chapter 1)*. Three of the 27 included studies had a prospective design *(Chapter 3)* and suggested that sleep problems may be a cause rather than a consequence of work injury. This causal interpretation of the findings was supported by a dose-response relationship wherein workers with more severe sleep problems tended to be at higher risk for work injuries *(Chapter 3)*.[93] Overall, these results suggest that sleep problems are a considerable risk factor for work injuries.

For Swiss decision-makers, it is important to know whether the international findings also apply to Switzerland. The Swiss findings were similar as those reported in international studies supporting the generalisation of the physiological pathways described in the introduction *(Chapter 1)*. There may be several methodological reasons for the slightly higher Swiss result. Studies in the general working population, with relatively small sample sizes, of non-prospective design and that investigate more severe accidents tend to report higher risk estimates than their counterparts.[94] Our result was in line with a geographically close case-control study on French construction workers reporting similar risks for sleep problem related work injuries.[12]

Developing countries were underrepresented in our meta-analysis, with four out of 27 studies (Ethiopia, Malaysia, Pakistan and India; *Chapter 3*).[95] However, injuries and deaths on the job take a particularly heavy toll in developing countries, where a large part of the population is engaged in hazardous, mainly agriculture-based, activities.[96] From the 2004 global occupational fatalities, 96 % occurred in low and middle income countries; Africa contributed 12 % and south-east Asia 34 % of the total global estimated deaths on the job.[97] In the years ahead, the numbers may increase as the process of industrialisation advances.[98] At the same time, the prevalence of sleep problems in the developing world is approaching that seen in developed nations.[99] Furthermore, studies from the developing countries observed similar sleep problem related work injury risks as the studies from Western countries *(Chapter 3)*,[57,90,100–103] supporting the hypothesis of the same underlying mechanisms regulating sleep and wakefulness in all human beings *(Chapter 1)*. Nonetheless, many companies in developing countries are not familiar with workplace safety,[1] although universally applicable safety control systems exist.[104] In conclusion, the numbers from developed as well as developing countries indicate that prevention of sleep problems in occupational health and safety programs are recommended across the world.

SLEEP PROBLEMS AND OTHER INJURY TYPES

In the background of the physical pathway described in the introduction *(Chapter 1)*, we could assume that sleep problems affect not only work injuries but also various other injury types, such as motor vehicle crash (MVC), sports and leisure-time injuries. Concerning MVCs, we may expect higher risk estimates than observed in this thesis for work injuries because driving a vehicle is more sensitive to reduced alertness than other working tasks.[38] This assumption was confirmed by strong empirical evidence that sleep problems are a significant cause of MVCs, resulting in a two- to sevenfold increased risk.[37,38,105,106] Because the elevated injury risk is also evident in commercial driving,[33,38,107,108] discrimination between professional MVC and other injuries at work is recommended;[46] we followed this recommendation in this thesis. Regarding sports injuries, higher risk estimates for sleep problem related sports injuries might be expected compared to work injuries because sports activities highly depend on psychomotor performance, which is decrashed with sleep deprivation.[109] However, there are too few studies to evaluate this comparison conclusively. Short sleep duration resulted in an increased risk of sports injuries in youth athletes,[110] whereas in a recent French public health report, no significant effect was observed for poor sleep quality on sports injuries.[111] Concerning leisure-time injuries, we may expect similar injury risks for leisure-time and work injuries because activities are very diverse in both settings. However, evidence for sleep problem related leisure-time injuries is sparse. To our knowledge, only one study reports leisure-time injuries separately from MVC or work injuries. The aforementioned French public health report found similar risks for moderate and slightly higher risks for severe sleep problems in leisure-time injuries compared to work injuries.[111] In conclusion, sleep problems are an even higher risk factor for MVC than for work injuries and may potentially influence sports and leisure-time injuries, which requires further investigation.

PERCENTAGE OF WORK INJURIES THAT ARE POTENTIALLY PREVENTABLE

The percentage of work injuries that would be prevented if sleep problems were eliminated is expressed by the PAR% *(Chapter 3)*.[112] The results of this thesis enabled the estimation of the PAR% in a Swiss and international context (data for calculations are below). In the Swiss and international situations, 20% and 13%, respectively, of the work injuries were attributed to sleep problems and could therefore be prevented by eliminating sleep problems *(Chapter 3)*. It is unclear whether these estimates are significantly different. However, several explanations for a higher PAR% in the Swiss context are possible. The PAR% is proportionally related to the prevalence of sleep problems and the relative risk of the association between sleep problems and work injuries *(Chapter 3)*.[112] Thus, one aspect may be the high prevalence of sleep problems in Switzerland (31.4%)[29] compared to the international average (24.8%; *Chapter 3* and *Figure 3*). Thereby, development status may play a role because developed countries generally have a higher sleep problem prevalence than developing countries.[99] Cultural differences may also influence sleep habits; middle and northern Europeans awaken earlier and sleep for shorter time periods compared to southern Europeans.[113] Furthermore, climate may play a role, with people from milder countries reporting fewer sleep problems.[28] Another aspect may be the higher sleep problem related work injury risk observed in Switzerland (OR = 1.78; *Chapter 5*) compared to the internationally pooled estimates (OR = 1.62; *Chapter 3*), which was discussed afore. However, the difference between these relative risks is not statistically significant and may be due to chance.[112] In other words, our data, which are more reliable for the Swiss context than for the international setting using a pool of mixed-quality data sources and concepts, indicate that the internationally derived PAR% may be conservative. Indeed, every fifth work injury may be preventable. This presents a preventable burden of similar magnitude as for severe MVCs (PAR% = 10 – 15%)[114] and underscores the public health relevance of sleep problems.

7.2 HIGHLY RELEVANT SOCIOECONOMIC COSTS

Several strategies exist to examine the socioeconomic cost.[115] As often used in other context, one methodology used for cost estimation of sleep problem related work injuries is based on first estimating the PAR%.[56,116] The total annual work injury costs (CHF 1,460 million in

2010)[117] are multiplied by the PAR% of the same year (19.7%; *Chapter 5*) and, in the Swiss case, yielded approximately CHF 290 million spent on the consequences of sleep problem related work injuries every year. Compared to other countries, the Swiss absolute cost for sleep problem related work injuries is minor because the working population is small and the total work injury expenses are low. For the United States (US) in 2009, annualised estimates from the American Insomnia Survey estimated the insomnia related work injury cost at US$ 442.4 million for costly workplace injuries.[56] Earlier analyses for the US by the National Commission on Sleep Disorders Research estimated the sleepiness attributed work injury cost at between US$ 10.27 and 13.34 billion for the year 1988.[118] Australian calculations based on 2004 data yielded US$ 1,956 million work injury related net health costs for sleep disorders combined (e.g., insomnia, sleep apnoea and periodic limb movement).[116]

Relating this cost to the number of people at risk of a work injury, estimated sleep-related work injury cost yielded US$ 3 for insomnia and US$ 89 to 116 for sleepiness per US worker, US$ 70 (CHF 63) for sleep problems per Swiss worker and US$ 202 for sleep disorders combined per Australian worker using a US labour force of 115 million in 1988 and 140 million in 2009, a Swiss labour force of 4.6 million in 2010 and an Australian labour force of 9 million in 2004.[119–121] The per capita estimates might be considered to be of similar magnitude in all these countries as the apparent variations may be largely explained by the very different methods used. In the American Insomnia Survey, 56 citizens retrospectively estimated the costs of their costly work injury (US$ ≥ 500) and projections were made to the US population potentially increasing possible errors.[56] The report of the National Commission on Sleep Disorders Research was harshly critiqued for its assumption that sleepiness related work injuries may be identified by the task or the time of the day of occurrence.[122] The Australian cost estimates were calculated using an incidence PAR% that was based on Swedish data from 1984–1994.[116] Our own cost estimate was also based on a PAR% directly derived for incidence not on a PAR% for cost. The PAR% for cost might be higher than the PAR% for incidence because sleep problem related work injuries are more severe and may result in higher than average cost.[12] Therefore, we may have potentially underestimated the expenses. Despite the few cost calculations and their limitations,[123] the numbers indicate that the role of sleep problems appears to be underestimated compared to classic causes of injuries, such as alcohol,[118] and that there should be more attention on sleep problem prevention in the workplace.

7.3 HOW TO IDENTIFY THE RISK IN AN OCCUPATIONAL SETTING

Sleep problem related injury prevention in the workplace might be approached from various perspectives. This thesis adds valuable information on where to look and what to look for. In this chapter, the gained knowledge is discussed in the context of a work injury (see *Investigating work injuries*), a worker affected by a sleep problem related work injury (see *Work-up of sleep problems*) and a working population (see *Prevention in populations at risk*).

INVESTIGATING WORK INJURIES

Incident investigation is an important component of occupational health and safety programs and a method for finding out the primary cause of injuries.[124] When the cause is determined, it is usually found that many injuries are predictable and could be prevented if the right actions had been taken.[124] In our cross-sectional analysis, we investigated work injuries in light of sleep problems and identified various injury types occurring more often in workers with sleep problems than in workers without sleep problems (for more details, see *Chapter 4*). Based on these findings, special attention should be paid to the influence of the worker's sleep habits or sleepiness when investigating injuries including falls and musculoskeletal injuries, injuries while working with or being injured by a tool or machine, and injuries while performing a side task *(Chapter 4)*. Using multivariate logistic regressions, we identified specific questions that were highly related to at least one of the various work injury types *(Chapter 4)*. Therefore, when investigating one of the named injury types, an occupational health and safety officer could ask the following questions identified by our analysis: i) How often did you have problems staying awake, i.e., while driving a car, eating or at social events, over the last four weeks? ii) How many hours did you sleep per night over the last four weeks? iii) When did you typically go to bed and get up over the last four weeks (to calculate the time in bed and sleep efficiency)?[69,70] This approach may detect processes, procedures and environmental factors at work causing fatigue or sleepiness and identify persons suspected of sleep problems. Our findings may therefore contribute to a better understanding of injury causation and may lead to a more comprehensive identification of injury causes, potentially resulting in improved work injury prevention.

WORK-UP OF SLEEP PROBLEMS

Individual workers being treated by an occupational physician for a work injury that might have been caused by sleepiness or fatigue may be tested for sleep problems. In this thesis, we identified breathing related sleep problems, sleep quality, sleep quantity, daytime sleepiness and use of sleep medication as potential risk factors for work injuries (for detailed findings, see *Chapter 3*). Therefore, checking the medical status of a person with what could be a sleepiness related work injury for these symptoms may be advisable. Literature suggests a two-step procedure, consisting first of simple screening tests and then of clinical diagnostics for a work-up of sleep problems in the workforce under daily conditions of occupational medicine.[125]

Breathing related sleep problems

Breathing related sleep problems were highly correlated with work injuries in our subgroup meta-analysis *(Chapter 3)*. Our findings are in line with findings for motor vehicle crashes[44] and indicate that breathing related sleep problems seriously disturb the sleep architecture. However, this relative risk pooled several crude estimates and estimates from low quality studies; the level of adjustment and the grade of study quality were inversely related to the estimated magnitude and possibly contributed to the higher risk *(Chapter 3)*. According to a meta-analysis of screening tests for OSAS, the Berlin questionnaire[126] and the Sleep Disorders Questionnaire[127] were the two most accurate screening tools.[128] For clinical diagnosis of OSAS, polysomnography is the gold standard, but significant issues with resource availability reduce its value in OSAS management.[129] Treatment of OSAS with continuous positive airway pressure (CPAP) is effective, and its protective effect on motor vehicle crashes could be demonstrated in the virtual environment and in real life.[130] In commercial drivers, screening for OSAS is more cost-effective than not screening.[131]

Sleep quality and quantity related sleep problems

Sleep quality, sleep quantity and multiple symptoms were moderately associated with work injuries in our meta-analysis *(Chapter 3)* and can be subsumed under insomnia. Several questionnaires are recommended for screening insomnia, such as the Pittsburgh Sleep Quality Index (PSQI) or the Insomnia Severity Index (ISI).[132] Clinical diagnosis includes a thorough assessment of the sleep history and a detailed evaluation of the medical, substance and psychiatric history.[132] Insomnia treatment has proven empirically effective[133,134] but has not yet been investigated in relation to injury risk reduction.

Daytime sleepiness

Interestingly, for sleepiness, we observed the lowest pooled risk estimate in our meta-analysis compared to the other sleep problems *(Chapter 3)*, although sleepiness may be seen as a link between poor sleep and injury.[33] Sleepy people may be aware of their limitations at the time of the risk and therefore adopt coping strategies *(Chapter 3)*, or sleepiness may not be measured adequately with the questionnaires used in the epidemiological studies included in our meta-analysis. Mostly, the ESS was used *(Chapter 3)*,[71,72] which is a simple scale on which there is an on-going debate as to whether it reflects objective levels of sleepiness.[105,106,135] A stumbling block is to capture acute sleepiness, which may be a more appropriate measure in relation to injury risk than the ESS, that assesses sleepiness in the previous weeks.[71,72] Sleepiness detection technologies and their limitations will be discussed in the outlook (see *Chapter 7.5: Implications for research and practice*).

Sleep medication

Independent of the type of sleep problem, using sleep medication was highly associated with work injuries in our meta-analysis *(Chapter 3)*, which may be explained in two ways. First, people with severe sleep problems may be more likely to take sleeping pills and cause more injuries due to their more severe sleep problem, or they may not recover fully from the narcotic effect, causing more accidents due to their medication. However, the pooled relative risk included only four estimates, of which two were unadjusted and two were from low quality studies, which methodically are more likely to result in higher risk estimates *(Chapter 3)*. To our knowledge, there is no previous study investigating these underlying mechanismus so far.

PREVENTION IN POPULATIONS AT RISK

In a population-based approach, prevention measures may not be targeted at certain incidents or individuals but instead are targeted at vulnerable populations. In this thesis, we identified workers of older age, with short sleep duration or with long working hours as the population most susceptible to the risk of poor sleep quality related work injuries, which is in line with recent studies (for details, see *Chapter 5*).[52,58,60,61,94] This is an important finding in light of the on-going changes in the workforce, indicating that the number of people in the vulnerable populations is increasing. The number of older people in the workforce will increase because the large proportion of workers from the "baby-boom" years are aging and because the older workforce will have to remain in the labour market for additional years as a consequence of a shrinking supply of young entrants.[136] Furthermore, there is a general decrease of sleep duration in the middle-aged population, which was quantified in a comparative Finnish review of 251,083 individuals at approximately 18 min over a time span of 33 years up to 2005.[137] Additionally, the proportion of workers reporting long workweeks rose sharply in the post-industrial economy while the mean work week stayed the same due to a division into workers that are either overworked or underemployed.[138] As a consequence, there is a need to take sleep quality, sleep duration, age and working hours into account when developing sleep problem related work injury prevention.

Approaching work injury prevention, including as described in this chapter, will raise questions, many of which are currently unanswered and will therefore be addressed in the outlook (see *Chapter 7.5: Implications for research and practice*).

7.4 STUDY DESIGN AND METHODOLOGICAL ASPECTS

This chapter covers more general strengths and limitations of this thesis, while several specific benefits and restrictions have already been mentioned in the respective chapters (see *Chapters 3* to *5*). This thesis consists of two methodological phases. First, a systematic review and meta-analysis were conducted to identify, appraise and synthesise all research-based evidence that addresses the relationship between sleep problems and work injuries. Second, a case-control study was conducted to confirm the international findings in Switzerland and to furthermore close the knowledge gaps identified by our preceding systematic review. The results presented in this thesis are plausible and in line with findings from previous studies.

WHAT IS NEW ABOUT THIS THESIS?

This thesis is novel in several ways. This thesis offers the most comprehensive systematic literature review on the relationship between sleep problems and work injuries, including 27 studies and 59 estimates *(Chapter 3)*. Furthermore, we not only confirmed the association between sleep problems and work injuries, we also quantified this relationship for the first time *(Chapter 3)*. Our cross-sectional study is the first to use a factor analysis to describe work injury types, and ours is the only study associating different work injury types with sleep problems in Switzerland *(Chapter 4)*. Current research is concentrating on investigating the mechanisms influencing the impact of sleep problems on work injuries.[54,58] In our case-control analysis, we went beyond actual studies and analysed a large number of effect modifiers to identify the most vulnerable populations *(Chapter 5)*. Additionally, the case-control study is the first study on work injuries to examine sleep quality with a standardised score, facilitating comparisons across studies, and with analyses on a continuous scale without losing information by dichotomising *(Chapter 5)*.

STRENGTHS AND LIMITATIONS

Systematic review and meta-analysis

By reviewing the literature, we provided an important source of summarised evidence for the risk of sleep problem related work injuries.[139] We used explicit, systematic methods to minimise bias and to provide reliable findings from which conclusions can be drawn and decisions made.[140,141] A meta-analysis was then used to combine the information from all the relevant studies and to calculate more precise estimates of the effect than those derived from the individual studies included within the systematic review.[62] Systematic reviews and meta-analyses are rated with the highest strength of the principal research types.[65] However, these study types also have potential limitations. First, the pooled estimates provided in our meta-analysis of the literature are only as reliable as the methods used to estimate the effect in each of the included studies.[142] We conducted a sensitivity analysis to illustrate the impact of study quality and study design on our pooled effect estimates and did not detect a significant influence (see *Chapter 3*). Second, bias may also occur from the way that studies are selected for inclusion.[142] We followed the recommendations in the Cochrane handbook whenever possible to minimise selection bias;[62] however, only peer-reviewed articles were searched, and only English, French, German and Italian articles were considered during the full-text review. Third, the selective publication of studies based on the magnitude and direction of their findings may have reduced the validity of the results in our meta-analysis.[143–145] We assessed publication bias by the Egger's regression coefficient and visual inspection of the funnel plot, which indicated a moderate under-representation of weaker effects in smaller studies (*Chapter 3*).[62] Finally, only similar individual studies should be pooled. To assess their similarity, the direction of the estimated effects may be inspected in the forest plot and statistical tests for heterogeneity may be performed.[146] We found moderate heterogeneity, which we assumed to have its source not between the different aspects of sleep problems but within each aspect, allowing for pooling *(Chapter 3)*.

Case-control study
By conducting a case-control study, we identified important findings in a relatively short time period and with relatively little money and effort compared to other study designs.[66] However, case-control studies are rated comparatively low in the hierarchy of evidence-based studies because they tend to be more susceptible to biases than other comparative studies.[65,66] Factors that may greatly affect a study's vulnerability to bias include choosing the cases, choosing the controls and obtaining exposure history.[66]

The cases were selected using a clear definition of the outcome and detailed eligibility criteria (see *Chapters 4* and *5*). In practice, however, we had to allocate our resources wisely and thus restricted our sampling to times with the highest work injury incidence rates at the hospital, potentially introducing selection bias. Furthermore, we only included cases from the area of Basel and ended up with a study sample that was not representative of the work injuries in Switzerland. We concluded that caution is needed when generalising the findings in this regard (for more details, see *Chapter 4*).

The controls were selected from departments other than the Emergency Department within the UHB, from nearby companies and among blood donors from the blood donor centre of both cantons Basel-Stadt and Basel-Land. In principal, controls should come from the same population as the cases, and potential biases that could arise need to be anticipated.[66] For practical reasons, not all of the potential biases could be handled in the design phase and were thus controlled for in the analyses.[112,147,148] For example, the mean age of the control group was higher than the mean age of the case group *(Chapter 5)*. Older people generally have more sleep problems, which may have led to an underestimation of the association between sleep problems and work injuries in the cases. As a consequence, we controlled our analysis for age and reported the estimates for older and younger workers separately (for more details, see *Chapter 5*). A strength of this thesis is the large number of potential confounding factors for which we controlled. However, underlying influences that are not accounted for must be kept in mind when interpreting the findings.

Information on the sleep problem history was obtained using two standardised and validated self-administered questionnaires, the PSQI[69,70] and the ESS.[71,72] Participants, both cases and controls, might inaccurately remember past exposures and introduce random bias (information bias).[66] Furthermore, cases often remember exposures to putative risk factors differently than controls, which might lead to a differential bias (recall bias).[66] However, differential and random exposure misclassifications would have led to an underestimation of the effect of poor sleep quality on work injuries rather than an overestimation.[112]

RECOMMENDATIONS FOR FUTURE STUDIES

Limitations in the presented studies are specifically discussed in the respective chapters (*Chapters 3* to *5*) and more generally in the above overall chapter *(Chapter 7.4: Study design and methodological aspects: Strength and limitations)*. This chapter discusses possibilities and gives recommendations for improving future case-control studies on sleep problem related work injuries and is structured according to the three limitating factors mentioned afore: choosing the cases, choosing the controls and obtaining exposure history.

Case recruitment may be improved in the following three ways: i) a higher sampling rate, ii) a lower potential selecting bias and iii) improved representativeness. From the 1,748 patients with moderate or severe work injury admitted to the UHB, only 46 % were seen by our study nurses (see *Chapter 4* and *5*). This may have been due to one of several reasons. Providing sufficient staff at the time dedicated to case recruitment may increase the sampling rate. Furthermore, extending the sampling time from business hours to 24/7 may not only have increased sampling rate but also reduced the potential selection bias. Additionally, representativeness for Switzerland may have been improved by conducting a multi-centre study.

The quality of controls may be improved in the following three ways: i) stringent matching, ii) the use of work colleagues and iii) paying attention to shift schedules in the planning phase. It is challenging to select controls in such a way that they represent the population at risk of becoming cases and that anticipates all of the potential biases that could arise.[66] We aimed for a frequency matching by age, gender and job risk but did not reach the target percentage of young controls *(Chapter 5)*. Stringent paired or triplet matching may have improved the quality of the control group. Furthermore, asking included cases for colleagues with the required characteristics and randomly picking from the list of names is a matching method that controls for a number of work characteristics.[149] This matching would also correct for shift work, which we found to be more frequent in our control subjects who were from nearby businesses. However, feasibility needs to be tested in a pilot study considering the many small businesses in Basel with few workers having the same personal and occupational characteristics in a company.[150]

Exposure measurements may be improved. We used the currently recommended questionnaires to measure sleep problems and daytime impairment and yielded good results with the PSQI *(Chapter 5)*.[135] The ESS was neither associated with any work injury type nor with work injury in general (*Chapters 4* and *5*). Therefore, the ESS may not be able to capture injury relevant sleepiness and may not be useful in this context. This is in line with a systematic review finding no consistent relationship between the ESS and MVC.[105] Similar conclusions can be drawn for bioelectrical impedance analysis (BIA), which we performed but did not use for analyses in the end. BIA may be a useful tool to capture the body composition in relation to health;[151] however, sensitivity analysis indicated that either BMI or BIA may be useful for controlling the association of sleep problems with work injuries. Thus, using BMI over BIA was in line with reports in the literature and required fewer resources.

7.5 IMPLICATIONS FOR RESEARCH AND PRACTICE

The current knowledge has been systematically analysed and research needs have been defined in *Chapter 3*. Based on these knowledge gaps, we have answered some of the research questions in *Chapters 4* and *5*. In this chapter, open questions in basic research, applied science and practice are noted that should be addressed in the future.

Basic research in the field of sleep problem related work injuries needs to provide a better understanding of the mechanisms involved in the ways that sleep problems affect work injuries. For this purpose, laboratory simulations utilising controlled conditions may help untangle the relative contributions of sleep time, sleep depth and the circadian system to mediating the changes in performance of simple cognitive tasks.[152] However, it remains unclear how performance in laboratory settings and performance of complex tasks required to operate safely in the workplace are related.[152] Epidemiological studies are essential for investigations under real conditions and to identify the populations that are most at risk for sleep problem related work injuries. Further research is needed to extend the findings of this meta-analysis, especially on the strong impact of sleep medication and the surprisingly weak indicator “daytime sleepiness”, which have wide consequences for preventive measures. Our results that workers of older age, with short sleep duration or with long working hours are the most vulnerable to sleep quality related work injuries need to be confirmed in future studies. As a new method in this field, structural equation modelling was suggested for analysing the interplay of various influencing factors,[58] but the technique was also critiqued for the many assumptions that are employed and that it should be used principally for the purposes of exploratory analysis and hypothesis generation rather than for testing the effect of a single fixed exposure.[153] In addition to analysis methods, instruments to capture the injury relevant aspects of sleep in the workplace setting need further development. Additional developments may increase the standardisation in research measures, facilitate comparisons across studies, improve interpretability of findings and help to design target interventions.

Applied science in the field of sleep problem related work injuries is challenged with providing practical knowhow on how to protect workforces from sleep problem related work injuries. Peer-reviewed research should provide evidence-based information, which is a key feature for implementing fatigue management measures in practice.[154] Important information is needed all along the causal chain of events that potentially contribute to an incident.[155]

In the first place, employees need to be allowed an adequate opportunity for sleep, and the employee needs to use that time for adequate sleep. Thus, there is a need for tools predicting alertness and sleep tendency for a given shift system. A number of such models exist, but they are not capable of predicting data for all scenarios, such as those involving chronic sleep restriction.[156] A novel behaviourally based methodology for predicting the average levels of fatigue at the organisational level, as well as control mechanisms for the individual risk of fatigue, has been proposed.[155] While this model is a step toward monitoring sleep on an institutional and individual level, it is "developmental" at best. This methodology lacks organisation-, individual- and task-specific data to appropriately determine the threshold values for sufficient/insufficient sleep. Therefore, post-implementation research is needed to refine the thresholds.

Educating people is a possibility to raise awareness and enable workers to take responsibility for themselves and their colleagues. For example, Melamed and Oksenberg, 2002, observed a decrease in the work injury rate by one-third in the workers with excessive daytime sleepiness, but there was no change in the workers without excessive daytime sleepiness in the year after a 90 minute sleep education with subsequent notification of the test results of the ESS and the Mini Sleep Questionnaire.[157] However, this was the only intervention study identified by our systematic review, and more applied studies are needed.

It may be necessary to ensure that employees who obtain adequate sleep are not experiencing fatigue-related behaviours because of, for instance, sleep disorders. Therefore, screening the workforce for sleep problems may be helpful. However, no evidence has been published so far that a sleep problem screening program will do more good than harm at an affordable cost.[158] Therefore, if sleep problems are appropriate for screening, it should be investigated whether valid and reliable screening tests are available, feasible and effective.[159]

The use of fatigue detection technologies may be a way to track fatigue and mitigate fatigue risk. Several recently developed technologies exist that can be implemented within a fatigue risk management system, mainly for the road transport or mining industries and not for less sedentary tasks.[160] However, there are many challenges to address before the promise of these technologies can be realised. Fitness-for-duty tests are typically performed before an employee starts working to determine whether his or her current alertness level is sufficiently safe for working the duration of the shift.[160] However, these tests only assess fatigue at the time of testing and not during shifts. Evidence is needed as to whether these tests can predict subsequent fatigue over the course of a shift. Continuous operator monitoring devices directly measuring physiological correlates of fatigue during work may therefore be more suitable.[160] However, these devices measure worker safety indirectly through proxy measures, such as eye movements or brain waves, which have been linked to fatigue. Warning levels may not apply to all users, and interpersonal cut-off scores that predict impaired performance need to be established. Performance-based monitoring devices directly track the indicators of work performance that are associated with fatigue-related work incidents, such as lane variability in

driving.[160] Instead of monitoring the operator, controlling the worker's safe performance may be more reliable and more acceptable for the users.[160] However, independent reliability and validity investigations on large and demographic diverse populations are needed to provide a comprehensive solution to managing fatigue-related risk at the individual level in real time.
Strategies are needed to decrease the likelihood that a fatigue-related error will lead to an incident.[155] Informal fatigue proofing strategies are relatively common within organisations and have evolved as part of traditional work practices.[161] However, due to unidentified dysfunctional measures, these strategies may carry considerable risk.[161] It is a novel idea to formally develop, evaluate and implement fatigue proofing strategies as one component of a broad safety management system.[161]
Finally, in the case of a fatigue-related event, error and incident analysis require comprehensive knowhow of the work procedures[124] as well as of the sleep-wake-processes. This knowhow may be lacking in occupational health and safety officers, and these officers may need to be trained and educated by sleep medicine specialists for their new challenging task of investigating whether an error or incident may have been fatigue-related.

In practice, the knowledge about the impact of sleep problems on work safety obliges employers to have an active strategy for anticipating and preventing such events. In injury prevention, passive (structural) and active (behavioural) strategies need to be integrated,[162] and ideas for this are not lacking. Concerning structural strategies, we could optimise shift and duty scheduling to minimise worker's fatigue; balance the workload and staffing to average work hours; design a workplace environment with appropriate light, temperature, noise and ergonomics or specific rest rooms for napping to improve alertness; or monitor fatigue at work to prevent fatigue-related injuries. Regarding behavioural strategies, we could educate employees on the principles of alertness management, train them with fatigue assessment tools, teach them sleep hygiene and encourage them to obtain medical care for sleep disorders. We could set up workplace programs from the screening to the assessment of treatment adherence to manage sleep disorders.
A few ideas have been realised by the Suva in the pilot phase, and progress is being made in screening professional truck drivers for obstructive sleep apnoea and in educating shift workers on how to better cope with their irregular work schedule. However, many issues are not yet resolved and require clarification, sometimes even on a case-to-case basis.
It is beyond the scope of this thesis to discuss all open issues. However, the following questions emerge as relevant topics to be addressed comprehensively in the planning of preventive strategies: If we surveyed the workforce for sleep problems, would participation be mandatory or voluntary? Who would be screened, workers solely involved in high-risk jobs or the whole workforce? What screening tool would be used, one for insomnia, obstructive sleep disorders or daytime sleepiness? Could we expect truthful answers on questionnaires? Who would obtain the test results? How would we address false positives? What action would be taken based

on the results of the test? What would be the consequences for the person's ability to work? Would effective treatments be available for the screened disorder? Would treatments be accessible and affordable, and who would pay the cost? What would happen if a patient did not comply? If we implemented fatigue detection devices, what would happen if and when the devices detect fatigue? Could reasonable options for on-the-job fatigue management be provided? Who would carry the loss of working hours? What if a worker kept on working despite the alarm and nothing/something happened? What if drowsy workers were to injure themselves while being monitored by a fatigue detection device? Who would be legally responsible once the company has implemented a device? Would it be legally sound to gather data on an individual basis or aggregated across individuals? Who would take responsibility for the information? Would there be consequences for workers with frequent alarms?

In conclusion, many issues need to be resolved before fatigue management systems may realise their full potential of contributing to injury prevention. Whatever actions may be taken, they should be based on a healthy safety climate with the joint goal of managing fatigue in the workplace and reducing sleep problem related work injuries.

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9 APPENDIX

EXCERPT FROM THE QUESTIONNAIRES

Schlafbezogene Fragen

Die folgenden Fragen beziehen sich auf Ihre üblichen Schlafgewohnheiten und zwar nur während der letzten vier Wochen. Ihre Antworten sollten möglichst genau sein und sich auf die Mehrzahl der Tage und Nächte während der letzten vier Wochen beziehen. Beantworten Sie bitte alle Fragen.

PSQ01 - Wann sind Sie während der letzten vier Wochen gewöhnlich abends zu Bett gegangen?

übliche Uhrzeit:

ca. ☐☐ : ☐☐ Uhr

PSQ02 - Wie viele Minuten hat es während der letzten vier Wochen gewöhnlich gedauert, bis Sie nachts eingeschlafen sind?

Minuten

PSQ03 - Wann sind Sie während der letzten vier Wochen gewöhnlich morgens aufgestanden?

übliche Uhrzeit:

ca. ☐☐ : ☐☐ Uhr

PSQ04 - Wie viele Stunden haben Sie während der letzten vier Wochen pro Nacht tatsächlich geschlafen?
(Muss nicht mit der Anzahl der Stunden, die Sie im Bett verbracht haben, übereinstimmen)

Stunden

RLL01 - Wenn Sie sich abends entspannen oder nachts schlafen wollen, haben Sie dann jemals unangenehme, unruhige Gefühle in den Beinen, die durch Bewegung oder Herumgehen gebessert werden können?

☐ nein ☐ ja

PSQ05/15 - Wie oft haben Sie während der letzten vier Wochen schlecht geschlafen, ...

	Während der letzten vier Wochen gar nicht	Weniger als einmal pro Woche	Einmal oder zweimal pro Woche	Dreimal oder häufiger pro Woche
... weil Sie nicht innerhalb von 30 Minuten einschlafen konnten?	☐	☐	☐	☐
... weil Sie mitten in der Nacht oder früh morgens aufgewacht sind?	☐	☐	☐	☐
... weil Sie aufstehen mussten, um zur Toilette zu gehen?	☐	☐	☐	☐
... weil Sie Beschwerden beim Atmen hatten?	☐	☐	☐	☐
... weil Sie husten mussten oder laut geschnarcht haben?	☐	☐	☐	☐
... weil Ihnen zu kalt war?	☐	☐	☐	☐
... weil Ihnen zu warm war?	☐	☐	☐	☐
... weil Sie schlecht geträumt hatten?	☐	☐	☐	☐
... weil Sie Schmerzen hatten?	☐	☐	☐	☐
...weil es Ihnen zu lärmig war?	☐	☐	☐	☐
...aus anderen Gründen?	☐	☐	☐	☐

Falls Sie aus einem anderen Grund schlecht geschlafen haben: **PSQ16 - Bitte beschreiben Sie diesen anderen Grund**

PSQ17 - Wie würden Sie insgesamt die Qualität Ihres Schlafs während der letzten vier Wochen beurteilen?

- ☐ Sehr gut
- ☐ Ziemlich gut
- ☐ Ziemlich schlecht
- ☐ Sehr schlecht

PSQ18 - Wie oft haben Sie während der letzten vier Wochen Schlafmittel eingenommen? (vom Arzt verschriebene oder frei verkäufliche)

- ☐ Während der letzten vier Wochen gar nicht
- ☐ Weniger als einmal pro Woche
- ☐ Einmal oder zweimal pro Woche
- ☐ Dreimal oder häufiger pro Woche

Falls Sie Schlafmittel eingenommen haben:

PSQ19 - Welche Schlafmittel haben Sie eingenommen?

PSQ20 - Hatten Sie während der letzten vier Wochen Probleme, mit genügend Schwung die üblichen Alltagsaufgaben zu erledigen?

- ☐ Keine Probleme
- ☐ Kaum Probleme
- ☐ Etwas Probleme
- ☐ Grosse Probleme

PSQ21 - Wie oft hatten Sie während der letzten vier Wochen Schwierigkeiten wachzubleiben, etwa beim Autofahren, beim Essen oder bei gesellschaftlichen Anlässen?

- ☐ Während der letzten vier Wochen gar nicht
- ☐ Weniger als einmal pro Woche
- ☐ Einmal oder zweimal pro Woche
- ☐ Dreimal oder häufiger pro Woche

ESS01/08 - Wie leicht fällt es Ihnen, in folgenden Situationen einzuschlafen?

Gemeint ist nicht nur das Gefühl müde zu sein, sondern auch wirklich einzuschlafen. Die Frage bezieht sich auf das übliche tägliche Leben der vergangenen Wochen. Auch wenn Sie einige der beschriebenen Tätigkeiten in letzter Zeit nicht ausgeführt haben, versuchen Sie sich vorzustellen, welche Wirkung diese auf Sie gehabt hätten. Wählen Sie aus der folgenden Skala die für die entsprechende Frage am besten zutreffende Antwort:

	Würde nie einschlafen	Würde kaum einschlafen	Würde möglicherweise einschlafen	Würde mit grosser Wahrscheinlichkeit einschlafen
Sitzen und Lesen	☐	☐	☐	☐
Fernsehen	☐	☐	☐	☐
Sitzen an einem öffentlichen Ort (z.B. Theater, Sitzung, Vortrag)	☐	☐	☐	☐
Als Mitfahrer im Auto während einer Stunde ohne Halt	☐	☐	☐	☐
Abliegen, um auszuruhen am Nachmittag, wenn es die Umstände erlauben	☐	☐	☐	☐
Sitzen und mit jemandem sprechen	☐	☐	☐	☐
Ruhig sitzen nach Mittagessen ohne Alkohol	☐	☐	☐	☐
Im Auto beim Stop an einer Verkehrsampel während einigen Minuten	☐	☐	☐	☐