Interventions to prevent injuries in construction workers (Review)

van der Molen HF, Lehtola MM, Lappalainen J, Hoonakker PLT, Hsiao H, Haslam R, Hale AR, Frings-Dresen MHW, Verbeek JH

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TABLE OF CONTENTS

[Intervention Review]

Interventions to prevent injuries in construction workers

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ABSTRACT

Background

Construction workers are frequently exposed to various types of injury-inducing hazards. A number of injury prevention interventions have been proposed, yet their effectiveness is uncertain.

Objectives

To assess the effects of interventions to prevent injuries in construction workers.

Search methods

We searched the Cochrane Injuries Group's specialised register, CENTRAL, MEDLINE, EMBASE, PsycINFO, OSH-ROM (including NIOSHTIC and HSELINE), Scopus, Web of Science and EI Compendex to September 2011. The searches were not restricted by language or publication status. The reference lists of relevant papers and reviews were also searched.

Selection criteria

Randomised controlled trials, controlled before-after (CBA) studies and interrupted time series (ITS) of all types of interventions for preventing fatal and non-fatal injuries among workers at construction sites.

Data collection and analysis

Two review authors independently selected studies, extracted data and assessed study quality. For ITS, we re-analysed the studies and used an initial effect, measured as the change in injury-rate in the year after the intervention, as well as a sustained effect, measured as the change in time trend before and after the intervention.

Main results

Thirteen studies, 12 ITS and one CBA study met the inclusion criteria. The ITS evaluated the effects of the introduction or change of regulations (N = 7), a safety campaign (N = 2), a drug-free workplace programme (N = 1), a training programme (N = 1), and safety inspections (N = 1) on fatal and non-fatal occupational injuries. One CBA study evaluated the introduction of occupational health services such as risk assessment and health surveillance.

The overall risk of bias among the included studies was high as it was uncertain for the ITS studies whether the intervention was independent from other changes and thus could be regarded as the main reason of change in the outcome.

The regulatory interventions at national or branch level showed a small but significant initial and sustained increase in fatal (effect sizes of 0.79; 95% confidence interval (CI) 0.00 to 1.58) and non-fatal injuries (effect size 0.23; 95% CI 0.03 to 0.43).

The safety campaign intervention resulted in a decrease in injuries at the company level but an increase at the regional level. Training interventions, inspections or the introduction of occupational health services did not result in a significant reduction of non-fatal injuries in single studies.

A multifaceted drug-free workplace programme at the company level reduced non-fatal injuries in the year following implementation by -7.6 per 100 person-years (95% CI -11.2 to -4.0) and in the years thereafter by -2.0 per 100 person-years per year (95% CI -3.5 to -0.5).

Authors' conclusions

The vast majority of technical, human and organisational interventions that are recommended by standard texts of safety, consultants and safety courses have not been adequately evaluated. There is no evidence that introducing regulations for reducing fatal and non-fatal injuries are effective as such. There is neither evidence that regionally oriented safety campaigns, training, inspections nor the introduction of occupational health services are effective at reducing non-fatal injuries in construction companies. There is low-quality evidence that company-oriented safety interventions such as a multifaceted safety campaign and a multifaceted drug workplace programme can reduce non-fatal injuries among construction workers. Additional strategies are needed to increase the compliance of employers and workers to the safety measures that are prescribed by regulation. Continuing company-oriented interventions among management and construction workers, such as a targeted safety campaign or a drug-free workplace programme, seem to have an effect in reducing injuries in the longer term.

PLAIN LANGUAGE SUMMARY

Interventions to reduce injuries in construction workers

Occupational injury rates among construction workers are the highest among the major industries. While several injury control strategies have been proposed by various organisations, their effectiveness for reducing the rate of injuries in the construction industry remains uncertain.

A systematic search of the literature was conducted on preventing occupational injuries among construction workers. The risk of bias of the studies was assessed and the effectiveness of interventions was evaluated. Thirteen studies were identified.

In these studies, there is no evidence that introducing regulation alone is effective in preventing non-fatal and fatal injuries in construction workers. There is no evidence that regionally oriented interventions such as a safety campaign, training, inspections or the introduction of occupational health services are effective in reducing non-fatal injuries in construction workers. There is low-quality evidence that a multifaceted safety campaign and a multifaceted drug-free workplace programme at the company level are effective in reducing non-fatal injuries.

Introducing regulation alone is not effective in reducing non-fatal and fatal injuries in construction workers. Additional strategies are needed to increase the compliance of employers and workers to the safety measures that are prescribed by regulation. Continuing company-oriented interventions among management and construction workers, such as a targeted safety campaign or a drug-free workplace programme, seem to have an effect in reducing injuries in the longer term.

An evidence base is needed for the vast majority of technical, human factors and organisational interventions that are recommended by standard texts of safety, consultants and safety courses.

BACKGROUND

The construction industry is a vital component of the economies of all countries around the world, employing a considerable workforce. The quality of life of construction workers and the business of excellence in construction are compromised by occupational injuries. The majority of construction fatalities result from falls from heights and being struck by moving vehicles, while the majority of non-fatal injuries result from falls from heights, slips and trips, and from being struck by a moving or falling object (Bentley 2006; Haslam 2005). Injuries are one of the major causal factors for the high proportion of occupational disability with a standardised injury ratio of 2.52 compared with the general workforce (Arndt 2004). The reported risk of a fatal accident is five times more likely than in other industries (Aksorn 2008).

Poor attention to safety during construction and associated fatal and non-fatal occupational injuries have been reported in many studies from around the world, including the USA (Bondy 2005; Hoonakker 2005), the UK (Haslam 2005), Taiwan (Chi 2005), Australia (Larsson 2002) and the Netherlands (Afrian 2011). Fatal injury incidence rates of four (UK) to 11.7 (US) per 100,000 construction workers were reported in 2003 (Dong 2004b; Haslam 2005). In the UK this is five times higher than the average rate across all industries. In addition, reports show a non-fatal major injury (for example, fractures or eye penetration) rate of 375 per 100,000 construction workers in the UK in 2002 to 2003 (Haslam 2005), and an annual injury incidence rate for any injury leading to absenteeism of 7% in the Netherlands in 2010 (Afrian 2011). In one study, over the course of 10 years of follow-up, 16% of German construction workers were granted a disability pension (Arndt 2004).

Construction injuries have significant financial implications (Afrian 2011). During a large construction project in the US, direct workers' compensation costs due to slips, trips and falls ranged from USD0.04 in insulation work to USD20.56 in roofing, with an average of USD4.3 per USD100 payroll cost (Lipscomb 2006). Medical, productivity, supervisory and liability costs further increase the financial losses (Leamon 1995; Loushine 2005). The cost of construction-related traumatic injuries further emphasises the importance of the implementation of effective health and safety interventions. Effective interventions for preventing occupational injuries should be the basis of an effective health and safety policy in the construction industry to protect the health of its workers.

Although the construction work environment and workforce will vary between projects and over time, interventions for reducing injuries are likely to work in similar ways for most construction projects. Haslam 2005 described the following five areas for interventions, which are also used for categorisation in this review, according to the elements of a typical construction project.

1. Worker and work team (the causal factors include worker actions and behaviour, capabilities, communication, health and available supervision).

2. Workplace (the causal factors include site conditions and layout, work environment, work scheduling and housekeeping).

3. Materials (the causal factors include material suitability, usability and condition).

4. Equipment (the causal factors include equipment suitability, usability and condition).

5. Organisation (the causal factors include construction job design, project management, construction processes, safety culture, risk management and productivity control).

Why it is important to do this review

Various interventions to prevent occupational injuries have been proposed and studied (Becker 2001; Darragh 2004; Suruda 2002; Winn 2004). However, the effectiveness of these interventions for preventing injuries remains unclear (Lipscomb 2003). Attempts have been made to summarise the effectiveness of safety interventions in other reviews; however, these are not up-to-date and focus on the prevention of one event, for example, falling (Hsiao 2001; Rivara 2000), focus on one injury type (Lipscomb 2000) or focus on time trends only (Sancini 2012). This review systematically summarises the most current scientific evidence on the effectiveness of interventions to prevent injuries associated with construction work.

OBJECTIVES

To assess the effects of interventions aimed at preventing occupational injuries among workers at construction sites.

METHODS

Criteria for considering studies for this review

Types of studies

Randomised controlled trials (RCT), cluster randomised controlled trials (cRCT), controlled before-after (CBA) studies and interrupted time series (ITS) studies were eligible for inclusion in this review.
Random allocation was not considered feasible for all interventions, for example regulatory studies at national level. It is also

more difficult to carry out randomised studies in the occupational setting because employers and employees are not used to the idea of experimentation with, and evaluation of, interventions to improve health and safety. Thus we decided to include the following non-randomised study designs: ITS and CBA studies.
An ITS study was eligible for inclusion when i) there were at least three time points before and after the intervention, irrespective of the statistical analysis used, and ii) the intervention occurred at a clearly defined point in time (EPOC 2006; Ramsay 2003). CBA studies were eligible for inclusion when the outcome was measured in both the intervention and control group before and after the introduction of the intervention.
In addition, we searched for before and after studies without a control group as well as case reports and retrospective cohort studies. These studies are not included in the review, but are described and compared with the results of the included studies in the discussion section.

Types of participants

The population was limited to construction workers (company workers or self-employed worker). For the purposes of this review, construction workers were defined as people working at a construction site for building/housing/residential or road/highway/civil engineering or offices/commercial or industrial installation (for example, ventilation, pipelines and siding) work.
Construction work is generally managed at a fixed place of business (office), but construction activities are performed at (multiple) project sites. Construction work carried out by the workers includes new work, additions, alterations, or maintenance and repairs. These definitions are based on the North American Industry Classification System (NAICS 2002). Other areas of construction are refurbishment and demolition of building and engineering projects as well as plumbing, heating, ventilation and air conditioning work.

Types of interventions

All interventions aimed at preventing occupational injuries were included. Five categories of interventions were distinguished:

- worker and work team;
- workplace;
- materials;
- equipment;
- organisation.

Types of outcome measures

For a study to be included, work-related injury must have been an outcome.

Primary outcomes

The primary outcome measures were fatal and non-fatal occupational injuries.
We used the following modified definition of injury, which was used in The Injury Chartbook by the World Health Organization (Baker 1984; Peden 2002);

"Non-fatal occupational injury is a body lesion at the organic level, resulting from acute exposure to energy (mechanical, thermal, electrical, chemical or radiant) in a work environment in amounts that exceed the threshold of physiological tolerance. In some cases (for example, drowning, strangulation, freezing), the injury results from an insufficiency of a vital element."
Injuries resulting from traffic crashes were included, if they occurred during the workers' commute to or from their construction work.
All sources of injuries data, including self-report, were considered.

Secondary outcomes

If injuries were reported in an included study as a primary outcome measure, the following secondary outcomes were then considered if also reported:

- the number of lost working days, and
- behaviour changes, such as working habits (Van der Molen 2005).

Search methods for identification of studies

The searches were not restricted by language or publication status.

Electronic searches

We searched the following electronic databases up to 1 September 2011 as described in Appendix 1;

- Cochrane Injuries Group's specialised register;
- the Cochrane Central Register of Controlled Trials (CENTRAL);
- MEDLINE (from 1966);
- EMBASE (from 1988);
- PsycINFO (from 1983);
- OSH-ROM (including NIOSHTIC and HSELINE);
- EI Compendex (from 1990);
- Scopus;
- Web of Science.

We also checked the reference lists of relevant papers identified by the search.
We searched the following websites to June 2006:

- Center for Disease Control, USA (www.cdc.gov/elcosh/index.html);
- Journals of the American Society of Civil Engineers, USA (www.pubs.asce.org/journals/jrns.html);

- Health and Safety Executive, UK (www.hse.gov.uk/research/rrhtm/index.htm);
- Institute for Health Research, France (www.inrs.fr);
- Institute for Working Life, Sweden (www.arbetslivsinstitutet.se/biblioteket/default.asp);
- Hauptverband der gewerblichen Berufsgenossenschaften, Germany (www.hvbg.de/d/bia/pub/ueb/index.html).

Data collection and analysis

The review was conducted according to the methods described in its protocol (van der Molen 2006).

Selection of studies

Titles and abstracts were independently screened by two review authors to identify potentially relevant studies. HM screened all references and all the other review authors independently screened a portion of the references. The full texts of potentially relevant articles were assessed for eligibility against the inclusion criteria.
Disagreement between review authors on the selection of studies for inclusion occurred in about 10% of the references screened and was resolved by discussion. In the two cases where a disagreement persisted, a third review author (JV) made the final decision. Articles in languages other than English were translated by a native speaker.

Data extraction and management

Data were extracted independently by two review authors in the same way as the references were screened. A form was developed to extract data from each article. We extracted data on the following:

- study design (RCT, cRCT, CBA or ITS);
- participants (number, trade, age, gender and exposure);
- intervention (target (worker and work team, workplace, materials, equipment or organisation), form (information, compulsion, education, facilitation or persuasion) and content intervention);
- outcome (primary and secondary outcome, methods used to assess outcome measures and duration of follow-up);
- setting (size of the company, culture, country, industry sub-sector, and trade and job).

Assessment of risk of bias in included studies

The quality of the included studies was independently assessed by two review authors (HM, JV) in the same way as the data extraction. There was disagreement about items of risk of bias in about 10% of the cases that could all be resolved by discussion. For ITS studies, the quality criteria developed by the EPOC Review Group (EPOC 2006; EPOC 2012) were used. In total, eight categories for risk of bias were assessed: intervention independent of other changes, intervention unlikely to affect data collection, blinded assessment of primary outcome measure, reliable primary outcome measure, completeness of the data set, intervention effect pre-specified, rationale for number and spacing of data points, reliable ITS statistics based on re-analysis. The checklist questions were answered as 'done', 'not clear' or 'not done' as presented in the table 'Characteristics of included studies' in the notes field.
For randomised and non-randomised studies, we used the internal validity scale of Downs and Black (Downs 1998) with 13 categories to assess quality.
Disagreement was resolved by discussion between the two review authors.

Measures of treatment effect

To obtain comparable and reliable effect sizes from included ITS studies, data from original papers were extracted and re-analysed according to recommended methods for analysis of ITS designs for inclusion in systematic reviews (Ramsay 2003). These methods utilise a segmented time series regression analysis to estimate the effect of an intervention while taking into account secular time trends and any autocorrelation between individual observations. If the ITS used a control group, we used the difference in rates between the intervention and the control group as the outcome. For each study, a first-order autoregressive time series model was applied to the data using a modification of the parameterisation of (Ramsay 2003). Details of the mode specification are as follows:
$Y = ß0 + ß1time + ß2\ (time\text{-}p)\ I(time > p) + ß3\ I(time > p) + E$, $E \sim N(0, s2)$
For time = 1,...,T, where p is the time of the start of the intervention, I(time > =p) is a function that takes the value 1 if time is p or later and zero otherwise, and where the errors E are assumed to follow a first order autoregressive process (AR1). The parameters ß have the following interpretation:

- ß1 is the pre-intervention slope;
- ß2 is the difference between post- and pre-intervention slopes;
- ß3 is the change in level at the beginning of the intervention period, meaning that it is the difference between the observed level at the first intervention time point and that predicted by the pre-intervention time trend.

The statistical analysis was performed in Stata 9.2 for Windows (StataCorp LP, College Station, TX USA).
Data on observations over time were derived from tables of results (Aires 2010_Austria; Aires 2010_Belgium; Aires 2010_Germany; Beal 2007; Spangenberg 2002) or graphs (Derr 2001; Miscetti 2008; Wickizer 2004) from the original studies, or directly from the study authors (Bena 2009; Laitinen 2010; Lipscomb 2003; Suruda 2002). All studies with fatal injuries (Beal 2007 (yearly data); Derr 2001 (monthly data); Suruda 2002 (yearly data)) as an outcome were standardised into fatal injuries per 1,000,000 workers per year. The studies with non-fatal injuries (Aires 2010_Austria (yearly data); Aires 2010_Belgium (yearly

data); Aires 2010_Germany (yearly data), Bena 2009 (quarterly data); Lipscomb 2003 (quarterly data); Miscetti 2008 (yearly data); Spangenberg 2002 (yearly data); Wickizer 2004 (quarterly data)) as outcome were standardised into injuries per 100 person-years per year with exception of Laitinen 2010 (yearly data). For Laitinen 2010, the outcome was standardised by the author into million m^3 construction volume. For the study from the US (Lipscomb 2003), the denominator was converted from working hours into person-years by assuming that one person-year equals 2000 working hours. For the Danish study (Spangenberg 2002), the denominator was converted from working hours into person-years by using the calculation provided in the study, that is one person-year equals 1600 working hours.

Re-analysis with autoregressive modelling made it possible to estimate regression coefficients corresponding to two standardised effect sizes for each study: i) change in level and ii) change in slope of the regression lines before and after the intervention (Ramsay 2003). The ß parameters in the above regression model were estimated using the Prais-Winstein first-order autocorrelation version of generalised least squares (GLS) regression, as implemented in the Stata software package (version 9.2). A change in level was defined as the difference between the observed level at the first intervention time point and that predicted by the pre-intervention time trend. A change in slope was defined as the difference between post- and pre-intervention slopes. The change in level stands for an immediate intervention effect and a change in slope for a sustained effect of the intervention. A negative change in level or slope represents an intervention effect in terms of a reduction in injuries.

In the controlled ITS, we used the difference between the intervention and control group as the intervention effect in a similar way. Therefore, a negative change in level or slope represents a larger decrease in injuries in the intervention group compared to the control group.

Data were standardised by dividing the outcome and standard error by the pre-intervention standard deviation as recommended by Ramsay 2001 and entered into RevMan (RevMan 2011) as effect sizes.

Unit of analysis issues

The unit of analysis was the construction worker. There were no unit of analysis issues in this review.

Dealing with missing data

Missing data were sought from study authors, and some data were received.

Assessment of heterogeneity

Heterogeneity of the intervention was assessed in respect to research setting, applied interventions, study design and population. Statistically, heterogeneity was examined with the I^2 statistic (notable heterogeneity when $I^2 > 60\%$).

Data synthesis

Results were pooled for studies that evaluated similar interventions, participants and outcomes with RevMan software (RevMan 2011). Where sufficient quantitative data were available meta-analyses were performed. For ITS the standardised change in level and change in slope were used as effect measures. Meta-analysis was performed using the generic inverse variance method using a random-effects method. The standardised outcomes were put into RevMan as effect sizes and their standard errors. Since we did not find any RCTs, there was no data synthesis conducted for these types of studies.

Subgroup analysis and investigation of heterogeneity

We planned to perform subgroup analyses according to participants, interventions or settings as listed in the 'Data extraction and management' section, because safety policy and culture can vary between work places according to worker and setting characteristics. However, we did not have sufficient data to perform any subgroup analyses.

RESULTS

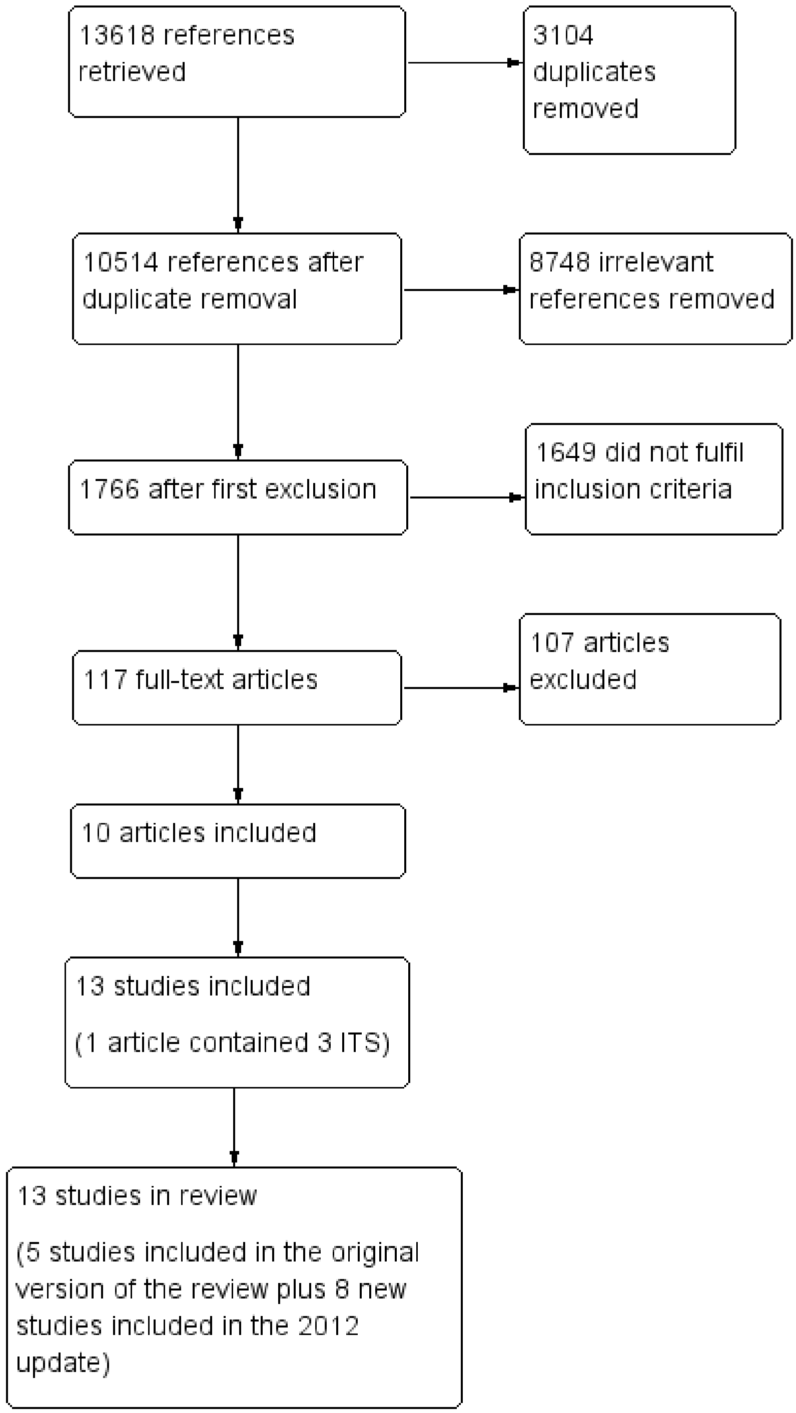
Description of studies

See: Characteristics of included studies; Characteristics of excluded studies; Characteristics of ongoing studies.

Results of the search

Overall, 7522 references were retrieved in the first version of the review: 7484 from electronic databases, 35 from websites and three from checking the reference list of relevant papers and an additional 6096 references were retrieved from the same databases for the update in 2011 making a total of 13,618 references retrieved. After excluding duplicate and irrelevant records, 1766 references remained (Figure 1). Altogether, the full texts of 117 potentially eligible articles were examined, which described studies of interventions for preventing fatal or non-fatal (or both) occupational injuries among workers at construction sites. One article described the introduction of legislation in three different countries in Europe and these were included as three different studies. In total, 13 studies met the inclusion criteria and are included in the review (Aires 2010_Austria; Aires 2010_Belgium; Aires 2010_Germany; Beal 2007; Bena 2009; Derr 2001; Laitinen 2010; Lipscomb 2003; Miscetti 2008; Spangenberg 2002; Suruda 2002; Tyers 2007; Wickizer 2004).

Figure 1. Flow diagram of study selection



Included studies

Of the 13 included studies, four are from the US (Derr 2001; Lipscomb 2003; Suruda 2002; Wickizer 2004), two from the UK (Beal 2007; Tyers 2007), two from Italy (Bena 2009; Miscetti 2008), one from Denmark (Spangenberg 2002), one from Finland (Laitinen 2010), one from Austria (Aires 2010 Austria), one from Belgium (Aires 2010 Belgium) and one from Germany (Aires 2010 Germany). The studies were conducted in 1990, 1991, 1995 (two studies), 1996 (two studies), 1997 (two studies), 1998, 1999 (two studies) and 2004 (two studies).

Seven studies evaluated the effectiveness of regulation (Aires 2010 Austria; Aires 2010 Belgium; Aires 2010 Germany; Beal 2007; Derr 2001; Lipscomb 2003; Suruda 2002), two studies a multifaceted safety campaign (Laitinen 2010; Spangenberg 2002), one study a multifaceted drug-free workplace programme (Wickizer 2004), one study a training programme (Bena 2009), one study the introduction of occupational health services (Tyers 2007) and one study safety inspections (Miscetti 2008).

Regulation

The regulatory interventions were implemented by means of a compulsory implementation strategy and could be characterised as an intervention requiring construction companies to execute safety measures. They targeted (where reported) workers/work team, materials, equipment, workplace and organisation. The contents of these regulations aim at setting in motion a complex set of preventive measures to be taken by employers and employees.

Derr 2001 was an ITS that evaluated the effect of a vertical fall arrest standard on the risk of fatal falls in construction workers. The intervention was implemented in 1995 throughout the US. States could opt for implementing their own plan or taking over the federal one. Twenty-one states implemented the standard based on their own plans. The vertical fall arrest standard requires the use of personal protective equipment and establishment of a fall protection plan that covers actions to reduce the risk of falling, such as appropriate cover for openings and leading edge warnings. Outcome data were obtained from state and national administrative databases. For more information on the specific content of the regulation see: Occupational Safety & Health Administration website.

Lipscomb 2003 was an ITS that evaluated the effect of a vertical fall arrest standard on the risk of non-fatal injuries in carpenters. The intervention was implemented in Washington State, US, in 1991. As in Derr 2001 the vertical fall arrest standard required the use of personal protective equipment and establishment of a fall protection plan that covered actions to reduce the risk of falling, such as appropriate cover for openings and leading edge warnings. Outcome data were obtained from state and national administrative databases. For more information on the specific content of the legislation see: Washington State Legislature website.

Suruda 2002 was an ITS that evaluated the effect of implementation of a trench and excavation standard (a regulatory intervention with a targeted inspection programme) on the risk of fatal injuries in trench and excavation workers. Outcome data were obtained from national administrative databases. For more information on the standard see: Occupational Safety & Health Administration website

Beal 2007 was an ITS that evaluated the effect of a construction design management regulation, issued in 1995, on the risk of fatal injuries in the UK. This regulation focused on organisational design and management procedures. Outcome data were obtained from national administrative databases. For more information on the content of the legislation see: legislation.gov website.

Aires 2010 (Aires 2010 Austria; Aires 2010 Belgium; Aires 2010 Germany) evaluated the effects of a European directive on the implementation of minimum safety and health requirements at temporary or mobile construction sites on the risk of non-fatal injuries in European countries. This regulation focused on organisational procedures. For three countries that implemented this directive in their countries in 1998 (Germany) and 1999 (Austria and Belgium) ITS analyses were applicable. Outcome data were obtained from a European administrative database. For more information see: eur-lex.europa.eu website.

Safety campaigns

Spangenberg 2002 was an ITS that evaluated the effect of a safety campaign at company level that used informative (leaflets, newsletters and notice boards), facilitative (feedback about injury rates) and enforcing (safety inspections) implementation strategies on the risk of non-fatal injuries in construction workers. The campaign focused on workers, work teams and organisation. The intervention consisted of attitudinal and behavioural aspects with the following components: campaign mascots at the entrance of all construction sites, leaflets to new workers with the information on purpose of campaign and good practices; quarterly published newsletter with safety activities, accident cases causing injuries and preventive measures; results of the campaign on notice boards; safety inspections of working environment, planning, training and housekeeping; financial incentive awarded to workers at the safest sites; themes on injury risks (for example, crane accidents) during working hours. Outcome data were obtained from the company's records.

Laitinen 2010 was a controlled ITS that evaluated the effect of a safety campaign on non-fatal injuries in Uusimaa region in Finland. The safety campaign (1997 to 2000) consisted of a contest and the involvement of labour inspectorate and targeted workers, workplaces, materials and organisation. Outcome data were obtained from administrative databases. The authors provided us with additional outcome data.

Drug-free programme

Wickizer 2004 was a controlled ITS that evaluated the effect of a drug-free workplace programme targeted at workers, work teams and organisation, on the risk of non-fatal injuries in construction workers. The intervention consisted of the following components: a formal written substance abuse policy, payment for drug testing, a worker assistance programme for referral to treatment, no termination of worker employment when they agreed to receive treatment, an annual educational programme on substance abuse and a minimum of two hours of training for supervisors and managers. The programme used informational, educational, facilitative (for example, financial incentive) and compulsory (drug testing) implementation strategies. Outcome data were obtained from state administrative databases.

Training

Bena 2009 was an ITS that evaluated the effect of a training programme on non-fatal injuries in the area Piemonte in Italy. The training, consisted of two two-hour long sessions focusing on construction workers of a high-speed railway line from Turin to Milan. The training intervention did not occur at the same time for all workers. The programme was considered a useful tool for delivering new notions and for improving skills and abilities, and taught workers how to work safely using methods applicable to the everyday context. Outcome data were obtained from regional administrative databases.

Safety inspection

Miscetti 2008 was an ITS study that evaluated the effect of safety inspections and sanctions for violations of OSH law on non-fatal injuries in the Assisi district in Italy. Intensification of inspections on workplace and organisational procedures followed the intensification of building activities after the earthquake in 1997 in the area. The objective of the study was to show that the intensification of inspections would prevent an increase in injuries related to the increase in building activities. Outcome data were obtained from building site notifications and national administrative databases.

Occupational health and safety services

Tyers 2007 was a CBA study that evaluated the effect of occupational health and safety services (OHS) on non-fatal injuries in two geographical areas in the UK (Leicestershire (intervention group) and Avon (control group)). OHS consisted of site visits, risk assessments, document reviews, training of staff and management, health surveillance by nurses and case management of people on sick leave by OHS professionals. Outcome data were obtained from employers' questionnaires.
See table 'Characteristics of included studies' for further details.

Excluded studies

Among the 18 excluded studies, one study was not about preventive measures (Spangenberg 2005), two studies had no injury outcome but safety features (Kines 2010) or described a protocol of the study (Pedersen 2010); from two studies necessary information of the authors was not retrieved (Halperin 2001; Yassin 2004), two studies did not measure injury rates before and after the intervention (Dong 2004; Kinn 2000), two studies were cross-sectional surveys with no clear intervention time (Lipscomb 2008; Lipscomb 2010), eight studies were before-after studies without a control group (Altayeb 1992; Darragh 2004; Gerber 2002; HSA 2006; Johnson 2002; Marcucci 2010; Salminen 2008; Williams 2010) and one study was a retrospective cohort study (Nelson 1997). See 'Characteristics of excluded studies' and Table 1 for further information.

Risk of bias in included studies

For the ITS studies the most important risk of bias was due to uncertainty about the independence of other changes than the intervention itself, and the lack of rationale about the number and spacing of data points. We presented the methodological features of each study in the notes section of the 'Characteristics of included studies' section.
Overall, the methodological quality of the seven regulation studies was less than 88% of the total quality score for ITS studies (EPOC 2006). The quality scores were 63% with five out of the eight quality criteria being met for five studies (Aires 2010 Austria; Aires 2010 Belgium; Aires 2010 Germany; Derr 2001; Suruda 2002), 75% with six out of the eight quality criteria being met for one study (Beal 2007) and 88% with seven out of the eight quality criteria being met for one study (Lipscomb 2003).
The ITS study that evaluated the multifaceted safety campaign at the company level (Spangenberg 2002) had a methodological quality score of 50% with four of the eight quality criteria being met (EPOC 2006). In addition, the risk of injuries probably changed over time, because the population changed over time as the building process changed. However, this aspect was not covered by the quality checklist. The controlled ITS study that evaluated a regionally oriented safety campaign (Laitinen 2010) had a methodological quality score of 54% according to the internal validity scale of Downs and Black's quality checklist of controlled cohort studies (Downs 1998) and 75% according ITS quality checklist with six out of the eight quality criteria being met (EPOC 2006).
One controlled ITS study that evaluated a drug-free workplace programme (Wickizer 2004) used a non-equivalent concurrent comparison group. Therefore it was possible to classify this study also as a CBA study. According to the internal validity scale of Downs and Black's quality checklist of controlled cohort studies (Downs 1998) and the ITS quality checklist (EPOC 2006) the methodological quality score was 46% and 75% respectively.
The ITS studies that evaluated a training programme (Bena 2009)

and an inspection programme (Miscetti 2008) had methodological scores of 63% and 75%, respectively.

One CBA study that evaluated the introduction of occupational health services (Tyers 2007) had a methodological score of 23% (Downs 1998).

None of the ITS studies sufficiently clarified that the intervention was independent from other changes. We re-analysed all ITS with the methods described in the methods section. However, we judged the risk of bias based on the original analyses by the authors of the studies. The risk of bias of the data presented in the review is thus less than in the formal assessment of the studies (EPOC 2006).

Effects of interventions

Primary outcomes

1. Effect of national regulation on fatal and non-fatal injuries

Seven studies evaluated regulation (Aires 2010 Austria; Aires 2010 Belgium; Aires 2010 Germany; Beal 2007; Derr 2001; Lipscomb 2003; Suruda 2002). There was a downwards trend in injuries over time before the regulation was introduced as indicated by the negative values for the pre-intervention slopes (Table 2). However, none showed a significant initial or sustained intervention effect in terms of a significant downwards change in level or slope. On the contrary, three studies showed a significant increase in level and three studies showed a significant increase in slope after the intervention. This effect was similar for both fatal and non-fatal injuries (Analysis 1.1; Analysis 1.2). The seven studies were judged to be sufficiently homogeneous to be combined in a meta-analysis because the mechanism of the intervention (regulation) was assumed to have a similar effect for both fatal and non-fatal injuries. However, the changes in both level and slope were statistically heterogeneous (I^2 = 71% and 56%, respectively). Most heterogeneity was caused by two studies (Aires 2010 Austria; Derr 2001;) that had different results but we could not explain why they were different. Most of the included studies had rather short time series and thus these were fairly small studies, which could explain the variation in the results. The meta-analyses of the change in level and in slope showed a small but significant effect, indicating an increase in injuries immediately after the intervention (effect size 0.79; 95% CI 0.00 to 1.58) and in increase in injuries over time after the intervention (effect size 0.23; 95% CI 0.03 to 0.43).

One study (Lipscomb 2003) reported a decline in the number of paid lost working days per injury as a secondary outcome measure, but re-analysis of the main outcome measure revealed an underlying downwards trend of injuries and no intervention effect.

In conclusion, data from the seven studies with considerable risk of bias indicated that there is no evidence that regulation had an initial or sustained effect of reducing fatal and non-fatal injuries.

2. Effect of a safety campaign on non-fatal injuries

Two studies (Laitinen 2010; Spangenberg 2002) evaluated the effect of a safety campaign aimed at promoting positive attitudes towards safety and at behavioural safety aspects at work. One study (Spangenberg 2002) evaluated the effect of a campaign within one company and the study showed an initial intervention effect of a reduction in non-fatal injuries of 3.75 per 100 person-years (Table 2). A sustained effect of the intervention was observed with a reduction in non-fatal injuries of 2.67 per 100 person-years per year. This yielded effect sizes of -1.82 (95% CI -2.90 to -0.74) and -1.30 (95% CI -1.79 to -0.80) for initial effect and sustained effect respectively (Analysis 2.1; Analysis 2.2).

Another study evaluated the effect of a programme that focused on all construction firms in one geographical region (Laitinen 2010). The study did not show an initial or sustained reduction in injuries from a safety campaign consisting of a contest and inspections with effect sizes of 0.47 (95% CI -0.04 to 0.98) and 0.46 (95% CI 0.36 to 0.56), respectively (Analysis 2.1; Analysis 2.2).

In conclusion, low-quality evidence exists for the effectiveness of a company-oriented multifaceted safety campaign to prevent non-fatal injuries. The evaluation of a regional safety campaign to prevent non-fatal injuries did not provide evidence of a reduction in injuries based on one low-quality study.

3. Effect of a drug-free workplace programme on non-fatal injuries

One study (Wickizer 2004) showed a significant initial intervention effect of a drug-free workplace programme with a non-fatal injury rate difference of -7.59 per 100 person-years between the intervention and control group; the study had an downwards trend of injuries over time (Table 2). A sustained effect of the intervention was observed with an injury rate difference of -1.97 per 100 person-years per year between the intervention and control group. This yielded effect sizes of -6.78 (95% CI -10.01 to -3.55) and -1.76 (95% CI -3.11 to -0.41) for initial effect and sustained effect, respectively (Analysis 3.1; Analysis 3.2).

For the intervention group alone, an initial effect of a drug-free workplace programme was found with a reduction in non-fatal injuries of -4.62 per 100 person-years; no sustained intervention effect was found.

In conclusion, low-quality evidence exists for the effectiveness of a drug-free workplace programme to prevent non-fatal injuries based on one study.

4. Effect of training on non-fatal injuries

One study (Bena 2009) showed no significant initial or sustained intervention effect of a training programme on non-fatal injuries with effect sizes of 0.10 (95% CI -1.74 to 1.94) and -0.43 (95% CI -0.96 to 0.10), respectively (Analysis 4.1; Analysis 4.2).

5. Effect of inspections on non-fatal injuries

One study (Miscetti 2008) showed no significant initial or sustained intervention effect of safety inspections combined with sanctions for violations on non-fatal injuries with effect sizes of 0.07 (95% CI -2.83 to 2.97) and 0.63 (95% CI -0.35 to 1.61), respectively (Analysis 5.1; Analysis 5.2). The intention of the study was to show that in spite of increased construction volume there would not be an increase in injury rate, actually a so-called non-inferiority or equivalence study. Even though there were no significant changes in level and in slope, the CI values were very wide. Therefore the study does not provide evidence that rates before and after the increase of inspections were equivalent.

6. Effect of occupational health services on non-fatal injuries

One CBA study (Tyers 2007) evaluated the introduction to, and raising awareness of, occupational health issues in the construction industry but did not find a significant difference between the injury rates in the intervention and the control group. The injuries were measured with seven different questions in a questionnaire and the results were analysed using multivariate analysis. No data could be extracted from the article. Response to three of the questions favoured the control group and the other four provided statistically non-significant results.

Secondary outcomes

None of the studies reported separately on the number of lost work days or on the effect on working habits.

DISCUSSION

Summary of main results

We found no evidence that introduction of regulation is effective in preventing non-fatal and fatal injuries in the construction industry or that a regional safety campaign or training or inspections or the introduction of occupational health services are effective to reduce non-fatal injuries in construction work. For a multifaceted safety campaign at company level and a multifaceted drug-free workplace programme, we found low-quality evidence that these interventions can reduce non-fatal injuries in the construction industry.

Overall completeness and applicability of evidence

Systematic searching in multiple databases makes it very likely that most of the published studies have been located.

Implementation level and strategy

Due to the scarce description of most of the interventions, it was not possible to characterise all interventions precisely. Another concern is the lack of information about the implementation of the proposed intervention, since inadequately implemented interventions make it impossible to draw firm conclusions about the potential effectiveness.

No information was available on how, and to what extent, the regulatory interventions were implemented at work sites. No information was given about the extent employers and workers were motivated to comply with the regulation. It could be argued that obligatory regulatory interventions are just organisational interventions to commit or compel employers and workers to reduce the risks for injuries. Lipscomb 2003, for example, stated in the discussion section that informational and educational programmes could accompany regulation. Also in health and work ability studies, it is argued that legislation or regulation alone is not powerful enough to change attitudes and behaviour in the desired direction in today's society (Ilmarinen 2006). Our analyses revealed that after the introduction of regulation there was an actual increase in both of fatal and non-fatal injuries. This can also be explained by variation in implementation of preventive measures. It has been argued and shown that stakeholders already start preparing for compliance before the new regulation is effective (LaMontagne 2004). This would mean that the actual interruption of the time-series does not take place on the moment the regulation is introduced. However, since we have no data about the compliance with regulation in the construction industry this must remain speculative. For the increase of non-fatal injuries we could imagine that more attention to safety during the introduction of new regulations would increase the reporting of non-fatal injuries but this is hardly conceivable for the fatal injuries.

The studies of the multifaceted safety campaign on company level (Spangenberg 2002) and the drug-free workplace programme (Wickizer 2004), described the content of their interventions and the corresponding implementation strategies in detail. Spangenberg 2002 also provided information about the familiarity and appreciation of the safety campaign, but no information was provided with respect to implemented activities or performance indicators of the proposed behaviour (for example, good housekeeping). However, the use of drug testing in the workplace has several ethical and legal controversies.

Both multifaceted intervention studies (Spangenberg 2002; Wickizer 2004) have used multiple and continuing interventions targeted on the whole work organisation (that is, workers, staff and employers), implemented by various strategies. Informational and facilitative strategies that influence the safety culture at work sites combined with enforcement such as work site inspection or mandatory drug testing, were important activities in these multifaceted interventions. Other studies (for example, Neal 2000) confirmed an association between safety climate and individual safety behaviour.

In summary, for the two multifaceted intervention studies (Spangenberg 2002; Wickizer 2004) we can assume that there was some degree of implementation of the interventions; however, it would have been preferable if the studies had documented this quantitatively as an intermediate measure. For the regulatory studies we do not know what the implementation level was. It is possible that nobody did anything, or only the 'good' companies took action, where compliance was already high in anticipation. It should also be considered that the introduction of regulation could have encouraged companies to pay further attention to injuries, resulting in an apparent increase in incidents due to improved reporting.

Secondary effects and ethical considerations

Although the authors of two regulation studies from the US (Derr 2001; Lipscomb 2003) reported significant reductions in injury rates in their original articles, the overall injury rate in the US construction industry also dropped considerably in that time period (BLS 2007; Hoonakker 2005). Re-analysis with autoregressive time series revealed no short-term (level) and no long-term (slope) regulatory intervention effects on the reduction of injuries in the studies. The four more recently published regulation studies from Europe (Aires 2010 Austria; Aires 2010 Belgium; Aires 2010 Germany; Beal 2007) found no evidence of an effect on the reduction of injuries when taking time trends into account.

None of the included studies reported changed behaviour as a secondary outcome measure.

Finally, in case of any drug-testing interventions, there is still the discrepancy between an employer's right to test its organisation's (new) workers versus existing workers' right for privacy and protection against unreasonable drug testing (Altayeb 1992).

Quality of the evidence

We did not identify any RCTs that assessed interventions for preventing injuries in the construction industry. The methodological quality of all 13 included studies, 12 ITS studies and one CBA study, was low. Safety research in the construction industry is not easy to perform; however, the more recently published studies showed higher quality scores. One study (Bena 2009) followed the recommended ITS analysis referred to in this review and one protocol of an RCT (Pedersen 2010) has been published.

Although the quality scores of the re-analysed ITS studies showed moderate scores, all suffered from bias due to uncertainty about the independence of other changes than the intervention. Therefore, these ITS studies were rated as low-quality evidence. However, the magnitude of the problem with a considerably high risk of fatal and non-fatal injuries in the construction industry warrants more efforts of both industry and researchers to perform higher quality research.

Only 13 studies were relevant for inclusion out of over 10,000 references identified through database searching. It was encouraging that more recent studies were published that evaluated interventions that are recommended by standard texts of safety, safety consultants and safety courses. Examples of such interventions are training courses (Bena 2009) and inspections (Miscetti 2008). However, the vast majority of recommended safety interventions such as risk analysis, incident and accident analysis, reporting and resolution of dangerous situations, confrontation and discussion of hazardous behaviour, improvements to work methods, tools and equipment, toolbox meetings, audits, workplace logistics, preplanning and subcontractor management (coordination and information activities), safer design of buildings and construction remains to be evaluated. This does not mean that these interventions are not effective, only that there is no proof as to whether they are or are not effective.

This review shows that the ITS design offers a good opportunity for the evaluation of rare or stochastic events such as fatal and nonfatal injuries when (randomised) controlled trials are not possible. However, the ITS studies should be analysed in a correct manner (Ramsay 2003). The included ITS studies, with the exception of Bena 2009, did not meet the Effective Practice and Organisation of Care (EPOC) criteria for statistical analysis (EPOC 2006). To minimise bias due to the influence of time trends and due to autocorrelation among repeated measurements over time, all ITS studies in this review were re-analysed according to the EPOC criteria (EPOC 2006; Ramsay 2003). Because the construction process involves many different tasks, activities, contractors, employers and environmental conditions with different levels of injury risk exposure, future ITS designs in the construction industry should also take the variability of the construction process into account in order to increase the internal validity as noted by Spangenberg 2002.

Ideally, the development of an intervention is based on theory and models that illuminate the pathway of how work-related injuries can be prevented. The definition and measurement of process indicators, designed for evaluating the implementation of the intervention, are necessary to determine to what extent the proposed intervention has actually been applied. Testing the association of determinants from underlying theories or models with intervention outcomes increases the insight into potentially effective elements of the intervention. Measuring the behavioural change of workers as a direct effect of the intervention along with injuries, provides a better insight into how the intervention works and also strengthens the evidence for an effect on the injury outcome (Robson 2001). Aksorn 2008, for example, identified four critical factors that effects the implementation of safety programmes in Thai construction projects: worker involvement (for example, creating favourable safety attitudes and motivation), safety prevention and control system (for example, effective enforcement), safety arrangement (for example, information dissemination and adequate resources) and management commitment.

Future research in this area should focus on:

1. defining indicators for evaluating the implementation of the intervention;
2. implementing the interventions in the best possible way;
3. measuring the behavioural change of workers as a direct result of the intervention process;
4. measuring fatal and non-fatal injuries as main outcome variable for evaluating the effectiveness of the intervention;
5. testing the association of behavioural changes with the main outcome measures.

Potential biases in the review process

Publication bias due to lack of identification of non-published negative studies is possible. However, inspection of the excluded lower quality studies revealed that there were also relatively small studies with a reported statistically negative outcome. Therefore, it has been assumed that the risk of publication bias for the conclusions of this review is low.

We did not exclude any studies based on language or publication status.

We re-calculated all outcomes so that they were comparable. Only for the study of Laitinen 2010 were we not able to re-calculate the number of injuries per m^3 of construction volume to a denominator of workers involved. We assumed that these numbers would be comparable. We do not believe that this has influenced the outcome to a great extent because it equally influences the outcomes before and after the introduction of the intervention and similar trends over time would have resulted.

Agreements and disagreements with other studies or reviews

We do not know of any other systematic reviews of effectiveness of interventions in the construction industry. In general, there are only a few systematic reviews of safety interventions. To our knowledge only training and education (Robson 2012) to prevent injuries has been covered with a systematic review but reviews of the effects of interventions for other major causes of injuries such as falls from heights or trips and slips are lacking.

After the first version of our review was published, Lipscomb 2008b criticised the methods used in the review both for misinterpreting the outcome of their included regulatory study and for not making better use of qualitative studies. The interpretation of ITS is not straightforward and can be easily subject to bias. In many studies, authors judge time trends purely based on looking at the data. Therefore we think that a statistical analysis in a standardised way will decrease the risk of bias. In their study (Lipscomb 2003), the authors specified an effect of introduction of regulation three years after the introduction of the intervention. In our view, this is a data-driven interpretation of the results. Since we do not have arguments to specify the occurrence of the intervention effect, we have chosen not to use other time points for the occurrence of the intervention than either immediately following the intervention or as an increased downwards trend. Given the existing downwards trends of injury rates, we believe that we should be careful with attributing the effects of interventions to changes in trends over time. We do not consider that the approach is too conservative, because the regulatory studies that are included in this updated review show the same results as those that were included in the review already. In our opinion, this reveals that introducing new or changed regulation does not impact on injury rates without sufficient implementation. This has also been shown to be the case for regulation for preventing occupational noise-induced hearing loss (Verbeek 2009).

AUTHORS' CONCLUSIONS

Implications for practice

Based on the seven included regulatory studies, there is insufficient evidence for or against the effectiveness of regulations to reduce fatal and non-fatal injuries among construction workers. Neither is there sufficient evidence in the included studies that regionally oriented safety interventions such as campaigning, training, inspections or the introduction of occupational health services are effective at reducing non-fatal injuries in construction workers. There is a need for additional strategies to maximise the compliance of employers and workers to the safety measures as prescribed by regulation or advocated through regionally oriented interventions. Multifaceted and continuing interventions, such as a targeted safety campaign at company level or a drug-free workplace programme, may be effective for reducing injuries in the longer term. Trying to influence the safety culture and the enforcement of the implementation of safety measures at work sites among management and construction workers is important. However, lack of evidence for safety interventions does not mean that these interventions do not work, but that better evaluation is necessary.

Implications for research

In the construction industry, more, preferably RCTs are needed to establish the effect of various safety interventions on both the implementation of safety measures as well as on fatal and non-fatal injuries. Studies with ITS over several years a high internal validity and a correct statistical analysis are feasible when controlled studies are not possible. In the regulatory ITS studies, more attention should be given to the compliance with regulation and enforcement aspects, both during the intervention as well as in the evaluation phase.

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* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Aires 2010 Austria

Methods	ITS based upon 4 years before and 7 years after intervention; yearly data
Participants	Construction workers in Austria (N = not clearly reported)
Interventions	Council Directive 92/57/EEC on the implementation of minimum safety and health requirements at temporary or mobile construction sites. Implemented in 1999 Target: organisational procedures Form: compulsion by regulation
Outcomes	Non-fatal injuries per 100 workers with more than 3 lost work days (per year): 11.1 (1995), 7.9 (1996), 7.0 (1997), 6.4 (1998), 6.3 (1999), 5.5 (2000), 4.8 (2001), 5.0 (2002), 4.5 (2003), 5.0 (2004), 4.7 (2005)
Notes	Intervention independent of other changes: NOT DONE Intervention unlikely to affect data collection: DONE Blinded assessment of primary outcome measure: DONE Reliable primary outcome measure: DONE Completeness of data set: NOT CLEAR Intervention effect pre-specified: DONE Rationale for number and spacing data points: NOT DONE Reliable ITS statistical analysis based on re-analysis: DONE

Aires 2010 Belgium

Methods	ITS based upon 4 years before and 7 years after intervention; yearly data
Participants	Construction workers in Belgium (N = not clearly reported)
Interventions	Council Directive 92/57/EEC on the implementation of minimum safety and health requirements at temporary or mobile construction sites. Implemented in 1999 Target: organisational procedures Form: compulsion by regulation
Outcomes	Non-fatal injuries per 100 workers with more than 3 lost work days (per year): 10.5 (1995), 9.0 (1996), 8.7 (1997), 8.7 (1998), 9.5 (1999), 7.9 (2000), 8.1 (2001), 6.8 (2002), 6.4 (2003), 6.2 (2004), 5.5 (2005)
Notes	Intervention independent of other changes: NOT DONE Intervention unlikely to affect data collection: DONE Blinded assessment of primary outcome measure: DONE Reliable primary outcome measure: DONE Completeness of data set: NOT CLEAR Intervention effect pre-specified: DONE

	Rationale for number and spacing data points: NOT DONE Reliable ITS statistical analysis based on re-analysis: DONE

Aires 2010˙Germany

Methods	ITS based upon 3 years before and 8 years after intervention; yearly data
Participants	Construction workers in Germany (N = not clearly reported)
Interventions	Council Directive 92/57/EEC on the implementation of minimum safety and health requirements at temporary or mobile construction sites. Implemented in 1998 Target: organisational procedures Form: compulsion by regulation
Outcomes	Non-fatal injuries per 100 workers with more than 3 lost work days (per year): 11.1 (1995), 9.7 (1996), 10.0 (1997), 9.8 (1998), 9.7 (1999), 8.9 (2000), 8.0 (2001), 7.6 (2002), 7.0 (2003), 6.7 (2004), 6.1 (2005)
Notes	Intervention independent of other changes: NOT DONE Intervention unlikely to affect data collection: DONE Blinded assessment of primary outcome measure: DONE Reliable primary outcome measure: DONE Completeness of data set: NOT CLEAR Intervention effect pre-specified: DONE Rationale for number and spacing data points: NOT DONE Reliable ITS statistical analysis based on re-analysis: DONE

Beal 2007

Methods	ITS based upon 10 years before and 10 years after intervention; yearly data
Participants	Construction workers in UK (N = not clearly reported)
Interventions	Construction design management (CDM) regulation Issued in 1995 Target: organisation (design and management procedures) Form: compulsion by legislation
Outcomes	Fatal injuries per 1,000,000 workers (per year) 86 (1985), 86 (1986/7), 93 (1987/8), 85 (1988/9), 86 (1989/90), 71 (1990/1), 62 (1991/2), 59 (1992/3), 57 (1993/4), 51 (1994/5), 50 (1995/6), 56 (1996/7), 46 (1997/8), 38 (1998/9), 47 (1999/0), 60 (2000/1), 44 (2001/2), 38 (2002/3), 36 (2003/4), 35 (2004/5)
Notes	Intervention independent of other changes: NOT DONE Intervention unlikely to affect data collection: DONE Blinded assessment of primary outcome measure: DONE Reliable primary outcome measure: DONE Completeness of data set: DONE

	Intervention effect pre-specified: DONE Rationale for number and spacing data points: NOT DONE Reliable ITS statistical analysis based on re-analysis: DONE

Bena 2009

Methods	ITS based upon 6 times before and 7 times after intervention; quarterly data
Participants	Construction workers of a high speed railway line (Torino to Milano) in Italy area Piemonte (N = 2795 workers)
Interventions	Training programme where in October 1, 2004 (88% of the workers had been trained) Target: worker (team), organisation Form: training 2 sessions of 2 h each (project 2002 to 2006)
Outcomes	Non-fatal injuries per 100 person-years 22.7 (2003.1), 27.0 (2003.2), 28.8 (2003.3), 18.5 (2003.4), 18.1 (2004.1), 26.7 (2004.2), 26.8 (2004), 16.1 (2004.4), 13.7 (2005.1), 20.2 (2005.2), 11.2 (2005.3), 10.6 (2005.4), 8.0 (2006.1)
Notes	The training intervention did not occur at the same time for all subjects Intervention independent of other changes: NOT CLEAR Intervention unlikely to affect data collection: DONE Blinded assessment of primary outcome measure: NOT CLEAR Reliable primary outcome measure: DONE Completeness of data set: DONE Intervention effect pre-specified: DONE Rationale for number and spacing data points: NOT DONE Reliable ITS statistical analysis and re-analysis: DONE

Derr 2001

Methods	ITS based upon 5 years before and 5 years after intervention; monthly data
Participants	Construction workers (N = not clearly reported)
Interventions	Fall protection standard issued in 1995 Target: not reported, but probably same as reported in Lipscomb 2003 Form: compulsion by legislation
Outcomes	Fatal falls per 1,000,000 workers (per year) 50 (1990), 48 (1991), 45 (1992), 41 (1993), 45 (1994), 46 (1995), 45 (1996), 48 (1997), 40 (1998), 42 (1999)
Notes	Scaffolds, stairways and ladders were excluded in the standard Intervention independent of other changes: NOT CLEAR Intervention unlikely to affect data collection: DONE Blinded assessment of primary outcome measure: DONE Reliable primary outcome measure: DONE Completeness of data set: NOT DONE Intervention effect pre-specified: DONE

	Rationale for number and spacing data points: NOT DONE Reliable ITS statistical analysis based on re-analysis: DONE

Laitinen 2010

Methods	Controlled ITS based upon 7 years before and 10 years after intervention; yearly data
Participants	Construction workers in Finland (N = not clearly reported)
Interventions	Contest, campaign in 1997-2000 Target: worker (team), workplace, materials, organisation Form: information, persuasion (labour inspectorate) facilitation, contest
Outcomes	Non-fatal injuries per million m^3 construction volume (per year) Intervention: 1025 (1990), 1089 (1991), 787 (1992), 764 (1993), 662 (1994), 638 (1995), 581 (1996), 539 (1997), 544 (1998), 525 (1999), 535 (2000), 581 (2001), 585 (2002), 520 (2003), 638 (2004), 561 (2005), 464 (2006) Control: 393 (1990), 379 (1991), 385 (1992), 354 (1993), 333 (1994), 389 (1995), 372 (1996), 381 (1997), 362 (1998), 377 (1999), 367 (2000), 389 (2001), 416 (2002), 375 (2003), 336 (2004), 370 (2005), 392 (2006) Change: 632 (1990), 710 (1991), 402 (1992), 410 (1993), 329 (1994), 249 (1995), 209 (1996), 158 (1997), 182 (1998), 148 (1999), 168 (2000), 192 (2001), 169 (2002), 145 (2003), 302 (2004), 191 (2005), 72 (2006)
Notes	Intervention independent of other changes: NOT CLEAR Intervention unlikely to affect data collection: DONE Blinded assessment of primary outcome measure: DONE Reliable primary outcome measure: DONE Completeness of data set: DONE Intervention effect pre-specified: DONE Rationale for number and spacing data points: NOT DONE Reliable ITS statistical analysis based on re-analysis: DONE

Lipscomb 2003

Methods	ITS based upon 2 years before and 8 years after intervention, quarterly data
Participants	Carpenters (N = 16,215)
Interventions	Vertical Fall Arrest Standard issued in 1991 requiring personal protective equipment, fall protection plan, risk reducing activities Target: worker/work team, equipment, workplace, organisation Form: compulsion by legislation
Outcomes	Fall-related injuries per 100 person-years (per year) 3.85 (1989), 3.15 (1990), 2.85 (1991), 2.80 (1992), 2.31 (1993), 2.15 (1994), 1.86 (1995), 1.21 (1996), 1.58 (1997), 1.45 (1998)
Notes	Only union workers were included (N = not clearly reported) Intervention independent of other changes: NOT CLEAR

	Intervention unlikely to affect data collection: DONE Blinded assessment of primary outcome measure: DONE Reliable primary outcome measure: DONE Completeness of data set: DONE Intervention effect pre-specified: DONE Rationale for number and spacing data points: DONE Reliable ITS statistical analysis based on re-analysis: DONE

Miscetti 2008

Methods	ITS based upon 5 years before and 10 years after intervention; yearly data Authors wanted to show that thanks to the intensive inspection the increase of building activities did not lead to a higher number of injuries in construction industry This is an 'equivalence' study
Participants	Construction workers in Italy, district Assisi (N = 869 construction sites per year on average (range 188 to 1319) about 4 workers per construction site on average)
Interventions	Safety inspections and sanctions for violations of OSH law Target: workplace modification and organisation (design and management procedures) Form: inspection and sanctions by legislation/labour inspectorate/education
Outcomes	Non-fatal injuries per 100 workers (per year) 11.8 (1992), 10.9 (1993), 10.2 (1994), 11.9 (1995), 8.1 (1996), 9.3 (1997), 9.2 (1998), 6.5 (1999), 4.5 (2000), 5.8 (2001), 4.8 (2002), 7.9 (2003), 9.6 (2004), 7.8 (2005), 7.1 (2006)
Notes	Intervention independent of other changes: NOT DONE Intervention unlikely to affect data collection: DONE Blinded assessment of primary outcome measure: DONE Reliable primary outcome measure: DONE Completeness of data set: DONE Intervention effect pre-specified: DONE Rationale for number and spacing data points: NOT DONE Reliable ITS statistical analysis based on re-analysis: DONE

Spangenberg 2002

Methods	ITS based upon 3 years before and 3 years during intervention, yearly data
Participants	Construction workers (N = 4250 person-years) involved in demolition, excavation, tunnels, bridges and finishing
Interventions	Multifaceted safety campaign issued in 1996 including attitudinal and behavioural aspects (e.g. newsletter, best practices, safety inspections, financial safety award, themes on injury risks) Target: worker/work team, organisation Form: information, facilitation (feedback), enforcement (inspection)

Outcomes	Injuries per 100 person-years (per year) 2.98 (1993), 3.70 (1994), 6.86 (1995), 5.34 (1996), 3.74 (1997), 4.80 (1998)
Notes	Majority of construction workers had project assignment less than 1 year Intervention independent of other changes: NOT CLEAR Intervention unlikely to affect data collection: DONE Blinded assessment of primary outcome measure: NOT CLEAR Reliable primary outcome measure: NOT CLEAR Completeness of data set: DONE Intervention effect pre-specified: DONE Rationale for number and spacing data points: NOT DONE Reliable ITS statistical analysis based on re-analysis: DONE

Suruda 2002

Methods	ITS based upon 6 years before and 6 years after intervention; yearly data
Participants	Construction workers about 5 million
Interventions	Trench and excavation standard issued in 1990 Target: not reported Form: compulsion by legislation
Outcomes	Fatal injuries per 1,000,000 workers (per year) 15.59 (1984), 16.29 (1985), 13.50 (1986), 13.73 (1987), 10.94 (1988), 10.94 (1989), 9.54 (1990), 5.82 (1991), 5.82 (1992), 6.52 (1993), 7.45 (1994), 5.35 (1995)
Notes	Construction firms fewer than 11 workers were exempt from routine legislative inspections Intervention independent of other changes: NOT CLEAR Intervention unlikely to affect data collection: DONE Blinded assessment of primary outcome measure: DONE Reliable primary outcome measure: DONE Completeness of data set: NOT CLEAR Intervention effect pre-specified: DONE Rationale for number and spacing data points: NOT DONE Reliable ITS statistical analysis based on re-analysis: DONE

Tyers 2007

Methods	Controlled before-after (CBA) study
Participants	Construction companies in 2 geographical areas in the UK Leicestershire (intervention group; N = 870) or Avon (control group; N = 602)
Interventions	Introduction to and raise awareness of occupational health issues in construction industry. An occupational health service was developed especially for this project and offered to all construction companies in Leicestershire Services offered were: site visits, risk assessments, document reviews, training of staff and management, health

	surveillance by nurse, case management of persons on sick leave by occupational health service professionals. Follow-up time was 19 to 23 months During Oct 2004 to 2006 Target: workplace modification, organisation Form: OHS through information, education, facilitation
Outcomes	The following outcomes were used and did either not significantly differ between the control and the intervention group or were in favour of the control group in the analysis in which baseline differences were accounted for: • experienced accidents or injuries in the last 2 years (at work): non-significant • experienced non-serious injuries in last 2 years (at work): non-significant • frequency of non-serious injuries in last 2 years: favoured control group • experienced injuries requiring up to 3 days off work in last 2 years: favoured control group • frequencies of injuries requiring < 3 days off work: non-significant • experienced other injuries of > 3 days off work: favoured control group • experienced fractures of injuries resulting in hospital stay: non-significant
Notes	Downs and Black's (Downs 1998) quality list, section internal validity Total score: 3/13 = 23% Same follow-up intervention and control: YES Recruitment over same time period: YES Loss to follow-up taken into account: YES

Wickizer 2004

Methods	Controlled ITS based upon 3 years before, 3 years during and 1 year after intervention; quarterly data
Participants	Construction workers (at follow-up: intervention group n=3,305 person-years; control group n=65,720 person-years)
Interventions	Drug-free workplace programme issued in 1996 including formal policy, drug testing, treatment, worker assistance, education workers, supervisors and managers Target: worker / work team, organisation Form: information, education, facilitation (financial incentives), enforcement (drug testing),
Outcomes	Injuries per 100 person-years (per year) Intervention; 29.03 (1994), 28.09 (1995), 26.28 (1996), 24.21 (1997), 18.08 (1998), 20.90 (1999), 20.53 (2000) Control; 30.58 (1994), 27.68 (1995), 25.92 (1996), 26.48 (1997), 26.21 (1998), 25.42 (1999), 26.62 (2000) Change; 1.55 (1994), -0.41 (1995), -0.37 (1996), 2.26 (1997), 7.34 (1998), 4.52 (1999), 6.08 (2000)
Notes	Enrolment in the study was awarded with 5% discount in workers' compensation premiums for up to 3 years 43% methodological score on internal validity scale of Downs and Black's (Downs 1998) quality checklist of controlled studies Intervention independent of other changes: NOT CLEAR Intervention unlikely to affect data collection: DONE Blinded assessment of primary outcome measure: DONE Reliable primary outcome measure: DONE Completeness of data set: DONE Intervention effect pre-specified: DONE Rationale for number and spacing data points: NOT DONE

	Reliable ITS statistical analysis based on re-analysis: DONE

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Altayeb 1992	Before-after study without a control group
Darragh 2004	Before-after study without a control group
Dong 2004	Retrospective cohort study, but measurements did not take place before the intervention
Gerber 2002	Before-after study without a control group
Halperin 2001	Not possible to retrieve necessary information from authors
HSA 2006	Time series with less than 3 before and after outcome measurements
Johnson 2002	Before-after study without a control group
Kines 2010	No injury outcome, only measurement of safety features
Kinn 2000	Retrospective cohort study; unclear if measurements were taken before and after the intervention
Lipscomb 2008	Yearly cross-sectional surveys (2005 to 2007) of tool use and injuries. No clear intervention moment in time
Lipscomb 2010	Update of Lipscomb 2008 with additional data from 2008
Marcucci 2010	Before-after study without a control group
Nelson 1997	Retrospective cohort study
Salminen 2008	Before-after study without a control group
Spangenberg 2005	Not preventive intervention
Williams 2010	Before-after study without a control group
Yassin 2004	Not possible to retrieve necessary information from authors

Characteristics of ongoing studies *[ordered by study ID]*

Pedersen 2010

Trial name or title	Pedersen 2010
Methods	Mixed methods
Participants	Construction Industry
Interventions	Leader-based interventions
Outcomes	Safety behaviour, injuries
Starting date	
Contact information	
Notes	Pedersen BH, Dyreborg J, Kines P, Mikkelsen KL, Hannerz H, Andersen DR, Spangenberg S. Protocol for a mixed-methods study on leader-based interventions in construction contractors' safety commitments. Injury Prevention 2010;16(3):e2

DATA AND ANALYSES

Comparison 1. Introduction of regulation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Level	7		Effect Size (Random, 95% CI)	0.79 [0.00, 1.58]
1.1 Fatal Injuries	3		Effect Size (Random, 95% CI)	0.51 [-1.23, 2.25]
1.2 Non-fatal injuries	4		Effect Size (Random, 95% CI)	0.99 [0.42, 1.55]
2 Slope	7		Effect Size (Random, 95% CI)	0.23 [0.03, 0.43]
2.1 Fatal injuries	3		Effect Size (Random, 95% CI)	0.21 [0.08, 0.34]
2.2 Non-fatal injuries	4		Effect Size (Random, 95% CI)	0.24 [-0.23, 0.72]

Comparison 2. Safety campaign

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Level: non-fatal injuries	2		Effect Size (Random, 95% CI)	Totals not selected
1.1 At company level	1		Effect Size (Random, 95% CI)	0.0 [0.0, 0.0]
1.2 At regional level	1		Effect Size (Random, 95% CI)	0.0 [0.0, 0.0]
2 Slope: non-fatal injuries	2		Effect Size (Random, 95% CI)	Totals not selected
2.1 At company level	1		Effect Size (Random, 95% CI)	0.0 [0.0, 0.0]
2.2 At regional level	1		Effect Size (Random, 95% CI)	0.0 [0.0, 0.0]

Comparison 3. Drug-free workplace programme

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Level: non-fatal injuries	1		Effect Size (Random, 95% CI)	Totals not selected
2 Slope: non-fatal injuries	1		Effect Size (Random, 95% CI)	Totals not selected

Comparison 4. Training

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Level: non-fatal injuries	1		Effect Size (Random, 95% CI)	Totals not selected
2 Slope: non-fatal injuries	1		Effect Size (Random, 95% CI)	Totals not selected

Comparison 5. Inspections

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Level: non-fatal injuries	1		Effect Size (Random, 95% CI)	Totals not selected
2 Slope: non-fatal injuries	1		Effect Size (Random, 95% CI)	Totals not selected

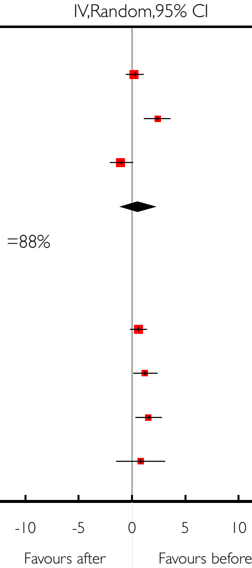
Analysis 1.1. Comparison 1 Introduction of regulation, Outcome 1 Level.

Review: Interventions to prevent injuries in construction workers

Comparison: 1 Introduction of regulation

Outcome: 1 Level

Study or subgroup	Effect Size (SE)	Effect Size IV,Random,95% CI	Weight	Effect Size IV,Random,95% CI
1 Fatal Injuries				
Beal 2007	0.27 (0.43)		17.2 %	0.27 [-0.57, 1.11]
Derr 2001	2.386 (0.6374)		13.9 %	2.39 [1.14, 3.64]
Suruda 2002	-1.0431 (0.5598)		15.1 %	-1.04 [-2.14, 0.05]
Subtotal (95% CI)			**46.2 %**	**0.51 [-1.23, 2.25]**
Heterogeneity: Tau^2 = 2.08; Chi^2 = 16.43, df = 2 (P = 0.00027); I^2 =88%				
Test for overall effect: Z = 0.57 (P = 0.57)				
2 Non-fatal injuries				
Aires 2010˙Austria	0.64 (0.41)		17.5 %	0.64 [-0.16, 1.44]
Aires 2010˙Belgium	1.24 (0.6)		14.5 %	1.24 [0.06, 2.42]
Aires 2010˙Germany	1.56 (0.62)		14.2 %	1.56 [0.34, 2.78]
Lipscomb 2003	0.7959 (1.1633)		7.7 %	0.80 [-1.48, 3.08]



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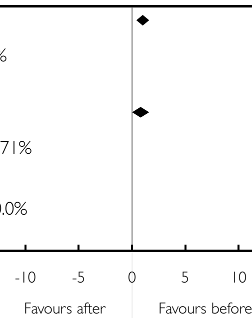
Study or subgroup	Effect Size (SE)	Effect Size IV,Random,95% CI	Weight	Effect Size IV,Random,95% CI
Subtotal (95% CI)			**53.8 %**	**0.99 [0.42, 1.55]**
Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 1.78$, df = 3 (P = 0.62); $I^2 = 0.0\%$				
Test for overall effect: Z = 3.43 (P = 0.00061)				
Total (95% CI)			**100.0 %**	**0.79 [0.00, 1.58]**
Heterogeneity: $Tau^2 = 0.76$; $Chi^2 = 20.45$, df = 6 (P = 0.002); $I^2 = 71\%$				
Test for overall effect: Z = 1.97 (P = 0.049)				
Test for subgroup differences: $Chi^2 = 0.26$, df = 1 (P = 0.61), $I^2 = 0.0\%$				



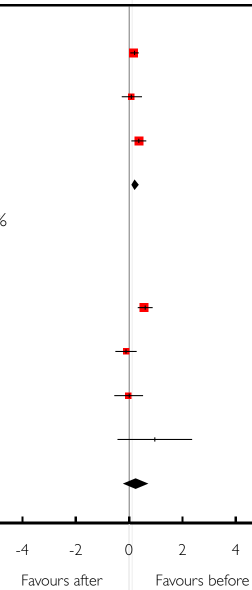
Analysis 1.2. Comparison 1 Introduction of regulation, Outcome 2 Slope.

Review: Interventions to prevent injuries in construction workers

Comparison: 1 Introduction of regulation

Outcome: 2 Slope

Study or subgroup	Effect Size (SE)	Effect Size IV,Random,95% CI	Weight	Effect Size IV,Random,95% CI
1 Fatal injuries				
Beal 2007	0.18 (0.08)		24.9 %	0.18 [0.02, 0.34]
Derr 2001	0.0819 (0.1959)		13.8 %	0.08 [-0.30, 0.47]
Suruda 2002	0.3636 (0.1483)		17.9 %	0.36 [0.07, 0.65]
Subtotal (95% CI)			**56.6 %**	**0.21 [0.08, 0.34]**
Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 1.64$, df = 2 (P = 0.44); $I^2 = 0.0\%$				
Test for overall effect: Z = 3.10 (P = 0.0019)				
2 Non-fatal injuries				
Aires 2010˙Austria	0.59 (0.14)		18.7 %	0.59 [0.32, 0.86]
Aires 2010˙Belgium	-0.13 (0.2)		13.5 %	-0.13 [-0.52, 0.26]
Aires 2010˙Germany	-0.02 (0.27)		9.3 %	-0.02 [-0.55, 0.51]
Lipscomb 2003	0.9592 (0.7143)		1.8 %	0.96 [-0.44, 2.36]
Subtotal (95% CI)			**43.4 %**	**0.24 [-0.23, 0.72]**



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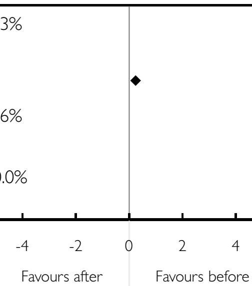
Study or subgroup	Effect Size (SE)	Effect Size IV,Random,95% CI	Weight	Effect Size IV,Random,95% CI
Heterogeneity: $Tau^2 = 0.15$; $Chi^2 = 11.16$, df = 3 (P = 0.01); $I^2 = 73\%$				
Test for overall effect: Z = 1.00 (P = 0.32)				
Total (95% CI)			**100.0 %**	**0.23 [0.03, 0.43]**
Heterogeneity: $Tau^2 = 0.03$; $Chi^2 = 13.52$, df = 6 (P = 0.04); $I^2 = 56\%$				
Test for overall effect: Z = 2.30 (P = 0.021)				
Test for subgroup differences: $Chi^2 = 0.02$, df = 1 (P = 0.88), $I^2 = 0.0\%$				



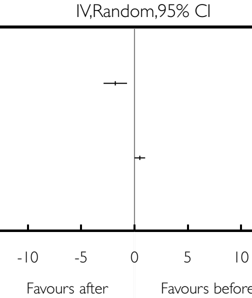
Analysis 2.1. Comparison 2 Safety campaign, Outcome 1 Level: non-fatal injuries.

Review: Interventions to prevent injuries in construction workers

Comparison: 2 Safety campaign

Outcome: 1 Level: non-fatal injuries

Study or subgroup	Effect Size (SE)	Effect Size IV,Random,95% CI	Effect Size IV,Random,95% CI
1 At company level			
Spangenberg 2002	-1.82 (0.55)		-1.82 [-2.90, -0.74]
2 At regional level			
Laitinen 2010	0.47 (0.26)		0.47 [-0.04, 0.98]



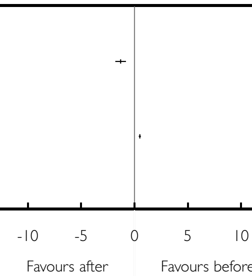
Analysis 2.2. Comparison 2 Safety campaign, Outcome 2 Slope: non-fatal injuries.

Review: Interventions to prevent injuries in construction workers

Comparison: 2 Safety campaign

Outcome: 2 Slope: non-fatal injuries

Study or subgroup	Effect Size (SE)	Effect Size IV,Random,95% CI	Effect Size IV,Random,95% CI
1 At company level			
Spangenberg 2002	-1.3 (0.25)		-1.30 [-1.79, -0.81]
2 At regional level			
Laitinen 2010	0.46 (0.05)		0.46 [0.36, 0.56]



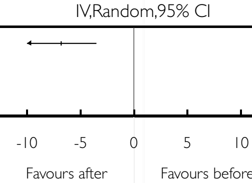
Analysis 3.1. Comparison 3 Drug-free workplace programme, Outcome 1 Level: non-fatal injuries.

Review: Interventions to prevent injuries in construction workers

Comparison: 3 Drug-free workplace programme

Outcome: 1 Level: non-fatal injuries

Study or subgroup	Effect Size (SE)	Effect Size IV,Random,95% CI	Effect Size IV,Random,95% CI
Wickizer 2004	-6.78 (1.65)		-6.78 [-10.01, -3.55]



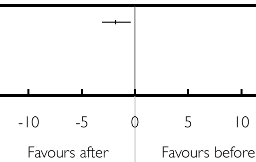
Analysis 3.2. Comparison 3 Drug-free workplace programme, Outcome 2 Slope: non-fatal injuries.

Review: Interventions to prevent injuries in construction workers

Comparison: 3 Drug-free workplace programme

Outcome: 2 Slope: non-fatal injuries

Study or subgroup	Effect Size (SE)	Effect Size IV,Random,95% CI	Effect Size IV,Random,95% CI
Wickizer 2004	-1.76 (0.69)		-1.76 [-3.11, -0.41]



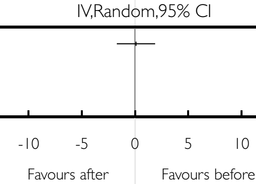
Analysis 4.1. Comparison 4 Training, Outcome 1 Level: non-fatal injuries.

Review: Interventions to prevent injuries in construction workers

Comparison: 4 Training

Outcome: 1 Level: non-fatal injuries

Study or subgroup	Effect Size (SE)	Effect Size IV,Random,95% CI	Effect Size IV,Random,95% CI
Bena 2009	0.1 (0.94)		0.10 [-1.74, 1.94]



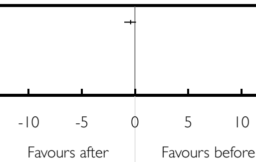
Analysis 4.2. Comparison 4 Training, Outcome 2 Slope: non-fatal injuries.

Review: Interventions to prevent injuries in construction workers

Comparison: 4 Training

Outcome: 2 Slope: non-fatal injuries

Study or subgroup	Effect Size (SE)	Effect Size IV,Random,95% CI	Effect Size IV,Random,95% CI
Bena 2009	-0.43 (0.27)		-0.43 [-0.96, 0.10]



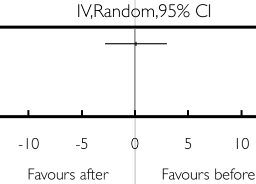
Analysis 5.1. Comparison 5 Inspections, Outcome 1 Level: non-fatal injuries.

Review: Interventions to prevent injuries in construction workers

Comparison: 5 Inspections

Outcome: 1 Level: non-fatal injuries

Study or subgroup	Effect Size (SE)	Effect Size IV,Random,95% CI	Effect Size IV,Random,95% CI
Miscetti 2008	0.07 (1.48)		0.07 [-2.83, 2.97]



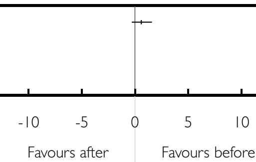
Analysis 5.2. Comparison 5 Inspections, Outcome 2 Slope: non-fatal injuries.

Review: Interventions to prevent injuries in construction workers

Comparison: 5 Inspections

Outcome: 2 Slope: non-fatal injuries

Study or subgroup	Effect Size (SE)	Effect Size IV,Random,95% CI	Effect Size IV,Random,95% CI
Miscetti 2008	0.63 (0.5)		0.63 [-0.35, 1.61]



ADDITIONAL TABLES

Table 1. Characteristics of excluded before-after and retrospective studies

Study ID	Methods	Participants	Interventions	Outcome per 100 person-years
Altayeb 1992	Before-after study	Construction workers (31 companies, no control group)	Drug testing programmes issued during 1985 to 1988 in US	Number of injuries: before: 11.2; after: 9.1; absolute change: 2.1
Darragh 2004	Before-after study	Residential construction workers (97 companies, no control group)	Safety education and training programme, issued in 1997 in US (also booklet, focused inspection and financial incentives were used)	Number of injuries: before: 17.4; after: 14.7; absolute change: 2.7 Number of LWDI: before: 5.8; after: 3.5; absolute change: 2.3 Number of LWDI and medical cost: before: 3.8; after: 2.2; absolute change: 1.6
Gerber 2002	Before-after study	Construction workers (49 companies, no control group)	Drug-testing programmes issued during 1985 to 1999 in US	Number of injuries: before: 8.9; after: 4.4; absolute change: 4.5
HSA 2006	Before-after study (not enough data points)	Construction workers (142,100 in 1999 to 206,000 in 2004)	Construction regulations for safe work environments issued in 2001 in Ireland	Number of injuries: in 1999: 0.4; in 2004: 0.7; absolute change: 0.3 Number of fatal injuries per 1,000, 000 person-years: in 1999:

Table 1. Characteristics of excluded before-after and retrospective studies *(Continued)*

				113; in 2004: 73; absolute change: 40
Johnson 2002	Before-after study	Carpenters and drywall tapers from variety of ethnic backgrounds (5 administrators plus 50 workers, no control group)	A job safety programme (toolbox, training, stress management techniques) issued in 1998 in US	Number of injuries: before: 26.8; after: 12.9; absolute change: 13.9 Number of lost days: before: 23.5; after: 2.4; absolute change: 21.1
Marcucci 2010	Before-after study	Electricians in Ontario Canada	Multi-faceted electrical burn prevention programme (starting in 2004) consisting of education, facilitation: • survey to understand the multimeter problem, best practice review, technical research • awareness raise • behavioural change through proper safety precautions • influence product design • new product design and stimulate market place	No denominator reported Non-fatal injuries, i.e. electrical burns through multimeters Before (1998 to 2005): 26 electrical burn injuries caused by multimeters After (2006 to 2008): 0 electrical burn injuries caused by multimeters
Nelson 1997	Retrospective cohort study	Construction workers (784 employers, control group of 8301 employers)	Washington State fall protection standard, violation during 1991 to 1992 in US	Number of fall injuries: before intervention group: 1.8; before control group: 1.0; after intervention group: 1.4; after control group: 1.0; absolute change difference between intervention and control group: 0.4
Salminen 2008	Before-after study	Company 1: 172 drivers/electricity workers Company 2: 179 drivers/electricity workers	Company 1: group discussions (3) for 45 to 60 min Company 2: 1-day course in anticipatory driving	Company 1 Number of work-related road injuries: before: 10.5; after: 2.9; absolute change: 7.6 Number of other occupational injuries: before: 42.4; after: 48.8; absolute change: 6.4 Company 2 Number of work-related

Table 1. Characteristics of excluded before-after and retrospective studies *(Continued)*

				road injuries: before: 2.2; after: 3.4; absolute change: 1.2 Number of other occupational injuries: before: 23.5; after: 28.5; absolute change: 5.0
Williams 2010	Before-after study	Latino day labourers in US	Training safety and health awareness of 1 day based on active learning and problem solving through peer trainers. Training materials adapted from OSHA curriculum and pilot	No denominator reported Non-fatal injuries leading to stop with work Any serious injury last 6 months: before: 21% (N = 64); after: 24% (N = 16) At least 2 serious injuries last 6 months: before: 16% (N = 36); after: 1.5% (N = 1)

LWDI: lost work day injuries; OSHA: Occupational Safety & Health Administration.

Table 2. Results from re-analysis of the ITS studies; non-standardised data

Study	Pre-int level (SD)	Change level (SE)	Pre-int slope (SE)	Change slope (SE)	Autocorrelation
Fatal injuries / 1 million person-years					
Derr 2001	45.80 (3.42)	8.16 (2.18)	-1.97 (0.51)	0.28 (0.67)	-0.64
Suruda 2002	14.01 (2.09)	-2.18 (1.17)	-1.10 (0.23)	0.76 (0.31)	-0.37
Beal 2007	73.60 (15.31)	4.21 (6.61)	-4.52 (0.84)	2.79 (1.23)	0.22
Non-fatal injuries / 100 person-years					
Spangenberg 2002	3.34 (2.06)	-3.75 (1.13)	2.17 (0.43)	-2.67 (0.52)	-0.82
Lipscomb 2003	3.50 (0.49)	0.39 (0.57)	-0.70 (0.35)	0.47 (0.35)	-0.08
Wickizer 2004: intervention	27.80 (1.40)	-4.62 (2.43)	-0.79 (0.98)	0.13 (1.01)	-0.70
Wickizer 2004: control	28.06 (2.35)	2.93 (0.61)	-2.25 (0.24)	2.01 (0.25)	-1.25
Wickizer 2004: int-con	-0.26 (1.12)	-7.59 (1.85)	-1.50 (0.75)	-1.97 (0.77)	-0.83

Table 2. Results from re-analysis of the ITS studies; non-standardised data *(Continued)*

Miscetti 2008	10.92 (1.44)	0.11 (2.13)	-0.94 (0.62)	0.90 (0.72)	0.46
Bena 2009	23.6 (4.58)	0.46 (4.33)	-0.57 (0.98)	-1.97 (1.22)	-0.14
Aires 2010 Austria	8.10 (2.08)	1.33 (0.86)	-1.44 (0.27)	1.22 (0.29)	-0.13
Aires 2010 Belgium	9.20 (0.87)	1.08 (0.52)	-0.50 (0.17)	-0.11 (0.17)	-0.40
Aires 2010 Germany	10.28 (0.73)	1.13 (0.45)	-0.57 (0.20)	-0.01 (0.20)	-0.63
Non-fatal injuries / million m^3 construction volume					
Laitinen 2010: intervention	792.29 (195.12)	105.15 (50.18)	-86.75 (9.12)	87.39 (10.18)	-0.35
Laitinen 2010: control	372.1 (21.57)	17.58 (23.54)	-3.43 (4.35)	3.52 (5.09)	0.06
Laitinen 2010: int-con	420.14 (187.75)	87.57 (49.28)	-84.11 (8.97)	85.43 (9.96)	-0.46

Pre-int: pre-intervention; SD: standard deviation; SE: standard error.

APPENDICES

Appendix 1. Search strategy for MEDLINE in PubMed

Preliminary searches were done in PubMed to define useful terms for the search strategy. This revealed that searches could be made sensitive but not specific enough to decrease the total amount of references retrieved to a manageable number, which we set at about 10,000. We developed the definitions described below.

Search terms for types of participants: working at construction sites.
The search term construction is truncated as construction* according to the industry name not as construct*, since many other things can be constructed for example, vectors or plasmids in the biochemistry field. The terms "construction industry" or "construction worker" are not used in order to make the search not too specific.

Many articles mentioned the word building instead of the term construction, which is why the term building* was added as a search term.

It is possible that there are articles including neither construction nor building. This is why the most important job titles (trades) were included in the search strategy used in the study by Koningsveld and Van der Molen (Koningsveld 1997). In addition we added the following job titles that appeared many times in the articles found in the preliminary searches: laborer/labourer and contractor.

The terms construction, building and job titles like carpenter are also used for other purposes such as a surname or in a company or street name (location), and that is why the search words concerning the population are followed by a search tag [tiab] (title abstract) or [tw] (text word).

Search terms for outcome: injury.
The primary outcome in the search strategy was defined as an injury and the term is truncated as injur* to make it sensitive enough.

Also the terms accident and safety were taken into account. Accident was truncated as accident* to make it sensitive enough.

Search terms for interventions
Intervention in the search strategy was defined as any kind of intervention related to safety management, risk management or accident prevention applied to decrease the rate or severity of injuries. Terms resembling these kinds of interventions were selected for this part of the search strategy.

Search terms for study design
For study design, two search strategies were used to find (cluster) randomised controlled trials and prospective non-randomised controlled trials or interrupted time series; for the discussion section the last strategy, search #7, will also be used to find before-after studies and case-reference studies. For randomised controlled trials we will use the strategy described by Robinson and Dickersin (Robinson 2002) and for non-randomised studies the strategy described by Verbeek et al. (Verbeek 2005).
We used search terms that covered the concepts of 'construction workers' (participants), 'injury' (primary outcome measure), 'safety' (interventions) and 'study design' to identify studies in the electronic databases
We used the following search strategy adapted as appropriate to the specifications of each database:
#1 construction*[tiab] OR building*[tw] OR builder*[tiab]OR laborer* [tw] OR labourer* [tw] OR contractor* [tw] OR supervisor*[tw] OR "machine driver"[tw] OR "machine drivers"[tw] OR "machine operator"[tw] OR "brick mason"[tw] OR "pile driver"[tw] OR "pile drivers"[tw] OR "concrete worker"[tw] OR "concrete workers"[tw] OR "metal worker"[tw] OR "metal workers"[tw] OR "road builder"[tw] OR "road builders"[tw] OR "pipe driver"[tw] OR "pipe drivers"[tw] OR "tower crane"[tw] OR fitter*[tw] OR carpenter* [tw] OR rammer* [tw] OR scaffolder* [tw] OR bricklayer* [tw] OR pointer* [tw] OR plasterer* [tw] OR plasterpainter* [tw] OR roofer* [tw] OR plumber* [tw] OR glazier* [tw] OR screeder* [tw] OR electrician* [tw] OR tiler* [tw] OR painter* [tw] OR paviour* [tw] OR pavier*[tw] OR ironwork*[tw] OR metalwork*[tw] OR asphalt*[tw] OR roofing[tw] OR painting[tw] OR "construction materials"[MeSH] OR "facility design and construction"[MeSH]
#2 injur*[tw] OR accident*[tw] OR "accidents, occupational"[MeSH] OR "wounds and injuries"[MeSH] OR harm*[tw] OR wound*[tw] OR fall[tw] OR falling*[tw] OR burn*[tw] OR slipper*[tw] OR poison*[tw] OR fatal*[tw] OR "injuries"[MeSH Subheading]
#3 Safety[MeSH] OR "Safety Management"[MeSH] OR "prevention and control"[MeSH Subheading] OR safet*[tw] OR prevent*[tw] OR control*[tw] OR risk[tiab] OR "risk"[MeSH Term] OR "risk management"[MeSH Terms] OR "accident prevention"[MeSH Terms]
#4 = #1 AND #2 AND #3
#5 (randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized controlled trials[mh] OR random allocation[mh] OR double-blind method[mh] OR single-blind method[mh] OR clinical trial[pt] OR clinical trials[mh] OR "clinical trial"[tw] OR ((singl*[tw] OR doubl*[tw] OR trebl*[tw] OR tripl*[tw]) AND (mask*[tw] OR blind*[tw])) OR "latin square"[tw] OR placebos[mh] OR placebo*[tw] OR random*[tw] OR research design[mh:noexp] OR comparative study[mh] OR evaluation studies[mh] OR follow-up studies[mh] OR prospective studies[mh] OR cross-over studies[mh] OR control*[tw] OR prospectiv*[tw] OR volunteer*[tw]) NOT (animal[mh] NOT human[mh])
#6 = #4 AND #5
#7 (effect* [tw] OR control* [tw] OR evaluation* [tw] OR program* [tw]) NOT (animal[mh] NOT human[mh])
#8 = #4 AND #7

#9 = #6 OR #8

Appendix 2. Search strategy for CENTRAL

#1 construction*:ti,ab OR building* OR builder*:ti,ab OR laborer* OR labourer* OR contractor* OR supervisor* OR “machine driver” OR “machine drivers” OR “machine operator” OR “brick mason” OR “pile driver” OR “pile drivers” OR “concrete worker” OR “concrete workers” OR “metal worker” OR “metal workers” OR “road builder” OR “road builders” OR “pipe driver” OR “pipe drivers” OR “tower crane” OR fitter* OR carpenter* OR rammer* OR scaffolder* OR bricklayer* OR pointer* OR plasterer* OR plasterpainter* OR roofer* OR plumber* OR glazier* OR screeder* OR electrician* OR tiler* OR painter* OR paviour* OR pavier* OR ironwork* OR metalwork* OR asphalt* OR roofing OR painting
#2 MeSH descriptor Construction Materials explode all trees
#3 MeSH descriptor Facility Design and Construction explode all trees
#4 #1 OR #2 OR #3
#5 Search injur* OR accident* OR harm* OR wound* OR fall OR falling* OR burn OR slipper* OR poison* OR fatal*
#6 MeSH descriptor Accidents, Occupational explode all trees
#7 MeSH descriptor Wounds and Injuries explode all trees
#8 #5 OR #6 OR #7
#9 safet* OR prevent* OR control* OR risk:ti,ab
#10 MeSH descriptor Accident Prevention explode all trees
#11 MeSH descriptor Risk Management explode all trees
#12 MeSH descriptor Risk explode all trees
#13 #9 OR #10 OR #11 OR #12
#14 #4 AND #8 AND #13

Appendix 3. Search strategy for EMBASE (embase.com)

#1 ’building industry’/exp OR ’building’/exp OR ’construction work’/exp OR ’building material’/exp OR ’painting’/exp OR ’driver’/exp OR ’chimney’/exp OR builder?:ab,ti OR laborer* OR labourer* OR contractor* OR supervisor* OR ’machine driver’ OR ’machine drivers’ OR ’machine operator’ OR ’brick mason’ OR ’pile driver’ OR ’pile drivers’ OR ’concrete worker’ OR ’concrete workers’ OR ’metal worker’ OR ’metal workers’ OR ’road builder’ OR ’road builders’ OR ’pipe driver’ OR ’pipe drivers’ OR ’tower crane’ OR fitter* OR carpenter* OR rammer* OR scaffolder* OR bricklayer* OR pointer* OR plasterer* OR plasterpainter* OR roofer* OR plumber* OR glazier* OR screeder* OR electrician* OR tiler* OR painter* OR paviour* OR pavier* OR ironwork* OR metalwork* OR asphalt* OR roofing
#2 ’injury’/exp OR ’accident’/exp OR injur*:ab,ti OR accident*:ab,ti OR harm* OR wound* OR ’fall’/exp OR falling* OR burn* OR slipper* OR poison* OR fatal*
#3 #1 AND #2
#4 ’risk management’:de,ab,ti OR ’prevention and control’/exp OR ’danger, risk, safety and related phenomena’/exp OR safet*:ab,ti OR prevent*:de,ab,ti OR control*:de,ab,ti OR risk:ab,ti OR ’accident prevention’/exp
#5 #3 AND #4
#6 ’randomized controlled trial’/exp OR ’controlled clinical trial’/exp OR ’randomized controlled trials’/exp OR ’random allocation’/exp OR ’double-blind method’/exp OR ’single-blind method’/exp OR ’clinical trial’/exp OR ’clinical trials’/exp OR (singl* OR doubl* OR trebl* OR tripl* AND (mask* OR blind*)) OR ’latin square’ OR ’placebos’/exp OR placebo* OR random*:ab,ti OR ’research design’/exp OR ’comparative study’/exp OR ’evaluation studies’/exp OR ’follow-up studies’/exp OR ’prospective studies’/exp OR ’cross-over studies’/exp OR control*:ab,ti OR prospectiv*:ab,ti OR volunteer*:ab,ti
#7 #5 AND #6
#8 effect*:de,ab,ti OR control*:de,ab,ti OR evaluation*:de,ab,ti OR program*:de,ab,ti
#9 #5 AND #8
#10 #7 OR #9
#11 #10 AND [embase]/lim NOT [medline]/lim

Appendix 4. Search strategy for PsycINFO (Ovid sp)

1 (construction* or building* or builder* or laborer* or labourer* or contractor* or supervisor* or "machine driver" or "machine drivers" or "machine operator" or "brick mason" or "pile driver" or "pile drivers" or "concrete worker" or "concrete workers" or "metal worker" or "metal workers" or "road builder" or "road builders" or "pipe driver" or "pipe drivers" or "tower crane" or fitter* or carpenter* or rammer* or scaffolder* or bricklayer* or pointer* or plasterer* or plasterpainter* or roofer* or plumber* or glazier* or screeder* or electrician* or tiler* or painter* or paviour* or pavier* or ironwork* or metalwork* or asphalt* or roofing or painting).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]

2 injuries/ or burns/ or electrical injuries/ or exp head injuries/ or wounds/ or falls/

3 (injur* or accident* or harm* or wound* or fall or falling* or burn* or slipper* or poison* or fatal*).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]

4 2 or 3

5 1 and 4

6 (safet* or prevent* or control* or risk).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]

7 safety/ or occupational safety/ or transportation safety/ or accident prevention/ or accident proneness/ or prevention/ or protective factors/ or risk management/ or risk perception/ or safety devices/ or warning labels/ or warnings/

8 6 or 7

9 5 and 8

10 ("clinical trials" or "clinical trial" or ((singl* or doubl* or trebl* or tripl*) and (mask* or blind*)) or "latin square" or placebos or placebo* or random* or "research design" or ((comparative or evaluation or "follow-up" or "cross-over") and (study or studies)) or control* or prospectiv* or volunteer*).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]

11 exp experimental design/

12 10 or 11

13 9 and 12

14 (effect* or control* or evaluation* or program*).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]

15 9 and 14

16 13 or 15

Appendix 5. Search strategy for Scopus

#1

((((ALL("building and construction") OR TITLE-ABS-KEY(builder* OR laborer* OR labourer* OR contractor* OR supervisor* OR "machine driver" OR "machine drivers" OR "machine operator" OR "brick mason" OR "pile driver" OR "pile drivers" OR "concrete worker" OR "concrete workers" OR "metal worker" OR "metal workers" OR "road builder" OR "road builders" OR "pipe driver" OR "pipe drivers" OR "tower crane" OR fitter* OR carpenter* OR rammer* OR scaffolder* OR bricklayer* OR pointer* OR plasterer* OR plasterpainter* OR roofer* OR plumber* OR glazier* OR screeder* OR electrician* OR tiler* OR painter* OR paviour* OR pavier* OR ironwork* OR metalwork* OR asphalt* OR roofing OR painting)) AND (TITLE-ABS-KEY(injur* OR accident* OR harm* OR wound* OR fall OR falling* OR burn* OR slipper* OR poison* OR fatal*))) AND (safet* OR prevent* OR control* OR risk)) AND ((TITLE-ABS-KEY("clinical trial" OR "clinical trials" OR "latin square" OR placebo* OR random* OR "research design" OR "study design" OR "comparative study" OR "evaluation studies" OR "evaluation study" OR "follow-up studies" OR "follow-up study" OR "cross-over studies" OR "cross-over study" OR control* OR prospectiv* OR volunteer*)) OR (TITLE-ABS-KEY((singl* OR doubl* OR trebl* OR tripl*) AND (mask* OR blind*))))) OR ((((ALL("building and construction") OR TITLE-ABS-KEY(builder* OR laborer* OR labourer* OR contractor* OR supervisor* OR "machine driver" OR "machine drivers" OR "machine operator" OR "brick mason" OR "pile driver" OR "pile drivers" OR "concrete worker" OR "concrete workers" OR "metal worker" OR "metal workers" OR "road builder" OR "road builders" OR "pipe driver" OR "pipe drivers" OR "tower crane" OR fitter* OR carpenter* OR rammer* OR scaffolder* OR bricklayer* OR pointer* OR plasterer* OR plasterpainter* OR roofer* OR plumber* OR glazier* OR screeder* OR electrician* OR tiler* OR painter* OR paviour* OR pavier* OR ironwork* OR metalwork* OR asphalt* OR roofing

OR painting)) AND (TITLE-ABS-KEY(injur* OR accident* OR harm* OR wound* OR fall OR falling* OR burn* OR slipper* OR poison* OR fatal*))) AND (safet* OR prevent* OR control* OR risk)) AND (TITLE-ABS-KEY(effect* OR control* OR evaluation* OR program*))) AND (LIMIT-TO(PUBYEAR, 2009) OR LIMIT-TO(PUBYEAR, 2010) OR LIMIT-TO(PUBYEAR, 2011))
#2
((safet* OR prevent* OR control* OR risk) AND (TITLE("construction sector" OR "construction industry" OR "building and construction" OR "construction and building") AND TITLE-ABS-KEY(injur* OR accident*))) AND (((TITLE-ABS-KEY("clinical trial" OR "clinical trials" OR "latin square" OR placebo* OR random* OR "research design" OR "study design" OR "comparative study" OR "evaluation studies" OR "evaluation study" OR "follow-up studies" OR "follow-up study" OR "cross-over studies" OR "cross-over study" OR control* OR prospectiv* OR volunteer*)) OR (TITLE-ABS-KEY((singl* OR doubl* OR trebl* OR tripl*) AND (mask* OR blind*)))) OR (TITLE-ABS-KEY(effect* OR control* OR evaluation* OR program*))) AND (LIMIT-TO(PUBYEAR, 2009) OR LIMIT-TO(PUBYEAR, 2010) OR LIMIT-TO(PUBYEAR, 2011))
#3
(((safet* OR prevent* OR control* OR risk) AND ((KEY("construction sector" OR "construction industry" OR "building and construction" OR "construction and building") AND TITLE-ABS-KEY(injur* OR accident*)) OR (KEY("construction safety")))) AND (KEY(econom* OR cost OR costs))) OR ((((TITLE-ABS-KEY("clinical trial" OR "clinical trials" OR "latin square" OR placebo* OR random* OR "research design" OR "study design" OR "comparative study" OR "evaluation studies" OR "evaluation study" OR "follow-up studies" OR "follow-up study" OR "cross-over studies" OR "cross-over study" OR control* OR prospectiv* OR volunteer*)) OR (TITLE-ABS-KEY((singl* OR doubl* OR trebl* OR tripl*) AND (mask* OR blind*)))) OR (TITLE-ABS-KEY(effect* OR control* OR evaluation* OR program*))) AND ((safet* OR prevent* OR control* OR risk) AND ((KEY("construction sector" OR "construction industry" OR "building and construction" OR "construction and building") AND TITLE-ABS-KEY(injur* OR accident*)) OR (KEY("construction safety"))))) AND (LIMIT-TO(PUBYEAR, 2009) OR LIMIT-TO(PUBYEAR, 2010) OR LIMIT-TO(PUBYEAR, 2011))
#4
#1 OR #2 OR #3

Appendix 6. Search strategy for OSH Update

#1
GW{construction* OR building* OR builder* OR laborer* OR labourer* OR contractor* OR supervisor* OR "machine driver" OR "machine drivers" OR "machine operator" OR "brick mason" OR "pile driver" OR "pile drivers" OR "concrete worker" OR "concrete workers" OR "metal worker" OR "metal workers" OR "road builder" OR "road builders" OR "pipe driver" OR "pipe drivers" OR "tower crane" OR fitter* OR carpenter* OR rammer* OR scaffolder* OR bricklayer* OR pointer* OR plasterer* OR plasterpainter* OR roofer* OR plumber* OR glazier* OR screeder* OR electrician* OR tiler* OR painter* OR paviour* OR pavier* OR ironwork* OR metalwork* OR asphalt* OR roofing OR painting}
#2
GW{injur* OR accident* OR harm* OR wound* OR fall OR falling* OR burn* OR slipper* OR poison* OR fatal*} OR SW{falls}
#3
GW{safet* or prevent* or control* or risk}
#4
#1 AND #2 AND #3
#5
GW{"clinical trials" OR "clinical trial" OR ((singl* OR doubl* OR trebl* OR tripl*) AND (mask* OR blind*)) OR "latin square" OR placebos OR placebo* OR random* OR "research design" OR ((comparative OR evaluation OR "follow-up" OR "cross-over") AND (study OR studies)) OR control* OR prospectiv* OR volunteer*}
#6
GW{effect* or control* or evaluation* or program*}
#7
#4 AND (#5 OR #6)
#8
PY{2009 OR 2010 OR 2011}
#9
#7 AND #8

#10
DC{OUBIB OR OUCISD OR OUHSEL OR OUISST OR OUNIOS OR OUROSP OR OUINFT OR OUIRFT OR OUISBB}
#11
#9 AND #10
Databases:
OUBIB = International Bibliographic (Produced by Sheila Pantry Associates Ltd)
OUCISD = CISDOC (The Health and Safety Information Centre of The International Labour Office)
OUHSEL = HSELINE (UK Health and Safety Executive Information Services)
OUISST = IRSST (Institut de recherche Robert-Sauvé en santé et en sécurité du travail)
OUNIOS = NIOSHTIC-2 (US National Institute for Occupational Safety and Health)
OUROSP = RoSPA (UK Royal Society for the Prevention of Accidents Information Services)
OUINFT = International Collection (Full text documents from many worldwide authoritative sources)
OUIRFT = Irish Collection (Full text documents from the HSA, other Irish government departments and selected Irish organisations)
OUISBB = NSAI Bibliographic (References to all Irish Standards published by the NSAI)

Appendix 7. Search strategy for SCI (Web of Science)

#1
TS=(construction* OR building* OR builder* OR laborer* OR labourer* OR contractor* OR supervisor* OR "machine driver" OR "machine drivers" OR "machine operator" OR "brick mason" OR "pile driver" OR "pile drivers" OR "concrete worker"OR "concrete workers" OR "metal worker" OR "metal workers" OR "road builder" OR "road builders" OR "pipe driver" OR "pipe drivers" OR "tower crane" OR fitter* OR carpenter* OR rammer* OR scaffolder* OR bricklayer* OR pointer* OR plasterer* OR plasterpainter* OR roofer* OR plumber* OR glazier* OR screeder* OR electrician* OR tiler* OR painter* OR paviour* OR pavier* OR ironwork* OR metalwork* OR asphalt* OR roofing OR painting)
#2
TS=(injur* OR accident* OR harm* OR wound* OR fall OR falling* OR burn* OR slipper* OR poison* OR fatal*)
#3
TS=(safet* OR prevent* OR control* OR risk)
#4
#1 AND #2 AND #3
#5
TS=("clinical trial" OR "clinical trials" OR "latin square" OR placebo* OR random* OR "research design" OR "study design" OR "comparative study" OR "evaluation studies" OR "evaluation study" OR "follow-up studies" OR "follow-up study" OR "cross-over studies" OR "cross-over study" OR control* OR prospectiv* OR volunteer*)
#6
TS=((singl* OR doubl* OR trebl* OR tripl*) SAME (mask* OR blind'*))
#7
TS=(effect* OR control* OR evaluation* OR program*)
#8
#5 OR #6 OR #7
#9
#4 AND #8

WHAT'S NEW

Last assessed as up-to-date: 1 September 2011.

Date	Event	Description
31 October 2012	New citation required but conclusions have not changed	Eight new studies have been included in the review. The conclusions remain the same
31 October 2012	New search has been performed	The search has been updated to 1 September 2011.

HISTORY

Protocol first published: Issue 4, 2006

Review first published: Issue 4, 2007

Date	Event	Description
14 May 2008	Amended	Converted to new review format.
1 August 2007	Feedback has been incorporated	Review first published.

CONTRIBUTIONS OF AUTHORS

Henk van der Molen was involved in designing the study protocol, inclusion of studies, data extraction and writing the review.

Jos Verbeek designed and performed the data-analysis and was involved in writing the review.

Marika Lehtola, Jorma Lappalainen, Peter Hoonakker, Hongwei Hsiao, Roger Haslam, Andrew Hale commented on all drafts of the review and assisted with the data collection. In the first review, Marika Lehtola was involved in the conception of the protocol, designing and running the searches, the inclusion of studies and the data extraction.

Monique Frings-Dresen commented on the draft and assisted with the data collection of the updated review.

DECLARATIONS OF INTEREST

None known.

SOURCES OF SUPPORT

Internal sources

- Cochrane Occupational Safety and Health Review Group, Finland.
- Finnish Institute of Occupational Health, Finland.
- Coronel Institute of Occupational Health, Academic Medical Centre, Universiteit van Amsterdam, Netherlands.

External sources

- The office of the Australian Federal Safety Commissioner of the Commonwealth of Australia, Australia.

Financial support for the first version of the review

- Stichting Arbouw, Netherlands.

Financial support for the update of the review

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

In the first update of this review we refrained from using the levels of evidence system for synthesising study results because we could use all results for meta-analysis and the levels of evidence system has been shown to produce misleading results especially in the event of non-significant results (Verbeek 2011).

INDEX TERMS

Medical Subject Headings (MeSH)

*Industry; Accidents, Occupational [*prevention & control]; Wounds and Injuries [*prevention & control]

MeSH check words

Humans