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[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. There are a number of injury prevention interventions, yet their effectiveness is uncertain.

Objectives

To assess the effects of interventions for preventing injuries in construction workers.

Search methods

We searched the Cochrane Injuries Group's specialised register, CENTRAL (issue 3), MEDLINE, Embase and PsycINFO up to April 2017. The searches were not restricted by language or publication status. We also handsearched the reference lists of relevant papers and reviews.

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 their risk of bias. For ITS studies, 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

Seventeen studies (14 ITS and 3 CBA studies) met the inclusion criteria in this updated version of the review. The ITS studies evaluated the effects of: introducing or changing regulations that laid down safety and health requirements for the construction sites (nine studies), a safety campaign (two studies), a drug-free workplace programme (one study), a training programme (one study), and safety inspections (one study) on fatal and non-fatal occupational injuries. One CBA study evaluated the introduction of occupational health services such as risk assessment and health surveillance, one evaluated a training programme and one evaluated the effect of a subsidy for upgrading to safer scaffoldings. The overall risk of bias of most of 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. Therefore, we rated the quality of the evidence as very low for all comparisons.

Compulsory interventions

Regulatory interventions at national or branch level may or may not have an initial effect (effect size (ES) of −0.33; 95% confidence interval (CI) −2.08 to 1.41) and may or may not have a sustained effect (ES −0.03; 95% CI −0.30 to 0.24) on fatal and non-fatal injuries (9 ITS studies) due to highly inconsistent results (I^2 = 98%). Inspections may or may not have an effect on non-fatal injuries (ES 0.07; 95% CI −2.83 to 2.97; 1 ITS study).

Educational interventions

Safety training interventions may result in no significant reduction of non-fatal injuries (1 ITS study and 1 CBA study).

Informational interventions

We found no studies that had evaluated informational interventions alone such as campaigns for risk communication.

Persuasive interventions

We found no studies that had evaluated persuasive interventions alone such as peer feedback on workplace actions to increase acceptance of safe working methods.

Facilitative interventions

Monetary subsidies to companies may lead to a greater decrease in non-fatal injuries from falls to a lower level than no subsidies (risk ratio (RR) at follow-up: 0.93; 95% CI 0.30 to 2.91 from RR 3.89 at baseline; 1 CBA study).

Multifaceted interventions

A safety campaign intervention may result in an initial (ES −1.82; 95% CI −2.90 to −0.74) and sustained (ES −1.30; 95% CI −1.79 to −0.81) decrease in injuries at the company level (1 ITS study), but not at the regional level (1 ITS study). A multifaceted drug-free workplace programme at the company level may reduce 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 (95% CI −3.5 to −0.5) (1 ITS study). Introducing occupational health services may result in no decrease in fatal or non-fatal injuries (one CBA study).

Authors’ conclusions

The vast majority of interventions to adopt safety measures recommended by standard texts on safety, consultants and safety courses have not been adequately evaluated. There is very low-quality evidence that introducing regulations as such may or may not result in a decrease in fatal and non-fatal injuries. There is also very low-quality evidence that regionally oriented safety campaigns, training, inspections or the introduction of occupational health services may not reduce non-fatal injuries in construction companies. There is very low-quality evidence that company-oriented safety interventions such as a multifaceted safety campaign, a multifaceted drug workplace programme and subsidies for replacement of scaffoldings may reduce non-fatal injuries among construction workers. More studies, preferably cluster-randomised controlled trials, are needed to evaluate different strategies to increase the employers’ and workers’ adherence to the safety measures prescribed by regulation.

PLAIN LANGUAGE SUMMARY

Interventions to reduce injuries in construction workers

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

What is the aim of this review?

To find out which interventions are most effective for reducing on-the-job injuries in construction workers.

Key messages

We conducted a systematic search of the literature on preventing occupational injuries among construction workers. We included 17 studies in this updated review, rating the evidence as very low quality. Multifaceted interventions and company incentives for upgrading equipment may be effective in reducing injury. However, an evidence base is still needed for the vast majority of safety measures that safety manuals, consultants and safety courses routinely recommend.

What was studied in the review?

We looked at different types of workplace interventions, including the introduction of new regulations, safety campaigns, training, inspections, occupational health services, and company subsidies. We evaluated the quality of the studies and the effectiveness of interventions, rating the evidence as very low quality.

What are the main results of the review?

Introducing regulations alone may or may not be effective for preventing non-fatal and fatal injuries in construction workers. Regionally oriented interventions such as a safety campaigns, training, inspections or occupational health services may not be effective for reducing non-fatal injuries in construction workers. However, a multifaceted safety campaign and a multifaceted drug-free workplace programme at the company level, along with subsidies for replacement of scaffoldings, may be effective in reducing non-fatal injuries.

Additional strategies are needed to increase the employers' and workers' adherence to the safety measures that are prescribed by regulation.

How up-to-date is this review?

We searched for studies that had been published up to 1 April 2017.

SUMMARY OF FINDINGS FOR THE MAIN COMPARISON [Explanation]

Regulations versus no regulations for reducing injuries in the construction industry

Patient or population: workers in various occupations
Settings: construction Industry
Intervention: legislation
Comparison: no legislation

Outcomes	Impact [a] (95% CI)	No. of studies	Quality of the evidence (GRADE)
Fatal injuries Change in level	Effect size −0.13 (−1.51 to 1.25)	5 ITS	⊕○○○ Very low[b]
Fatal injuries Change in slope	Effect size −0.20 (−0.64 to 0.23)	5 ITS	⊕○○○ Very low[b]
Non-fatal injuries Change in level	Effect size −0.44 (−3.70 to 2.83)	5 ITS	⊕○○○ Very low[b]
Non-fatal injuries Change in slope	Effect size 0.14 (−0.26 to 0.54)	5 ITS	⊕○○○ Very low[b]

CI: confidence interval;**ITS**: interrupted time series.
GRADE Working Group grades of evidence
High quality: further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: we are very uncertain about the estimate.

[a] Effect size can be interpreted as follows: < 0.2: small effect, 0.2-0.8 moderate effect, > 0.8: large effect; negative sign means decrease in injuries.
[b] Observational studies start with low-quality evidence; we downgraded 2 levels: 1 for risk of bias and 1 for heterogeneity.

BACKGROUND

The construction industry is a vital component of the economies of all countries worldwide, employing a considerable workforce. Occupational injuries compromise construction workers' quality of life.

Description of the condition

According to the World Health Organization (WHO), injuries are caused by acute exposure to physical agents such as mechanical energy, heat, electricity, chemicals, and ionising radiation interacting with the body in amounts or at rates that exceed the threshold of human tolerance. In some cases (for example, drowning and frostbite) injuries result from the sudden lack of essential agents such as oxygen or heat (Baker 1992). Most fatal injuries in construction result from falls from heights and being struck by moving vehicles, while most non-fatal injuries result from falls from heights, slips and trips, and being struck by a moving or falling object (Atique 2012; 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 2.5 compared with the general workforce (Arndt 2004). The reported risk of a fatal accident in construction workers is five times more likely than in other industries (Aksorn 2008).

Numerous studies from around the world have reported on poor attention to safety during construction and associated fatal and non-fatal occupational injuries, including in the USA (Bondy 2005; Hoonakker 2005; Evanoff 2016), the UK (Haslam 2005), Taiwan (Chi 2005), Australia (Larsson 2002), the Netherlands (Afrian 2011), and Japan (Ohdo 2014). The estimated rates of fatal injury incidence in 2003 were 4 per 100,000 construction workers in the UK and 11.7 per 100,000 in the USA (Dong 2004b; Haslam 2005). In the UK, this rate is five times higher than the average rate across all industries. In addition, reports show a rate of non-fatal major injury (for example, fractures or eye penetration) of 375 per 100,000 construction workers in the UK from 2002 to 2003 (Haslam 2005), plus an annual injury incidence rate for any injury leading to absenteeism of 7% in the Netherlands in 2010 (Afrian 2011). In one study, 16% of German construction workers were granted a disability pension over the course of 10 years of follow-up (Arndt 2004). Eurostat reports the construction industry as the sector with the highest fatal and non-fatal accidents at work (Eurostat 2016).

Construction injuries have significant financial implications (Afrian 2011). During a large construction project in the USA, direct workers' compensation costs due to slips, trips and falls ranged from USD 0.04 in insulation work to USD 20.56 in roofing, with an average of USD 4.3 per USD 100 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 underlines the importance of implementing 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.

According to Haslam 2005, the levels of involvement of key factors in accidents in construction are: problems arising from workers or the work team (70% of accidents), workplace issues (49%), shortcomings with equipment (including PPE) (56%), problems with suitability and condition of materials (27%), and deficiencies with risk management (84%).

Description of the intervention

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 target areas for interventions according to the elements of a typical construction project: worker and work team, workplace, materials, equipment, and organisation. Regardless of which of these five areas are targeted, there are two major approaches for interventions. These consist of the actual safety measures, such as: protective personal equipment, adequate equipment for working at heights, and risk management; and the strategies used to implement these measures into practice (Van der Molen 2005). The latter can be further categorised as: compulsory (e.g. regulation), educational (e.g. training in safety procedures), informational (e.g. campaigns for risk communication), persuasive (e.g. peer feedback on workplace actions to increase acceptance of safe working methods), facilitative (e.g. subsidies) or multifaceted (a combination of two or more approaches) intervention strategies.

How the intervention might work

To reduce workers' injuries, different stakeholders in the construction industry (employers, workers, regulatory authorities, suppliers, manufacturers, owners) should implement and adopt safe working methods, workplaces, materials and equipment. Eventually, construction workers and their management should understand safety risks and measures, be motivated to reduce the safety risks, have the skills to adopt safe working methods, and actually adopt safe working methods and circumstances.

Informational and educational interventions might reduce injuries by fostering new knowledge and skills about safer working methods. Compulsory and persuasive interventions might reduce injuries by changing attitudes of workers and management to use safer working methods and implement safe working circumstances. Facilitative interventions might reduce injuries by supportive activities to implement safe materials, equipment and construction design. Multifaceted interventions might reduce injuries by combining abovementioned interventions.

Why it is important to do this review

Different authors have proposed and studied various interventions to prevent occupational injuries (Becker 2001; Darragh 2004; Hale 2012; Schoenfisch 2017; Suruda 2002; Winn 2004; Yoon 2013). However, the evidence base for interventions to prevent injuries remains unclear (Lipscomb 2003; Lipscomb 2014). Other reviews have attempted to summarise the effectiveness of safety interventions; however, these are not kept up-to-date and focus on the prevention of one event, for example, falling (Hsiao 2001; Rivara 2000), on one injury type (Lipscomb 2000), or 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 for preventing injuries in construction workers.

METHODS

Criteria for considering studies for this review

Types of studies

Randomised controlled trials (RCTs), cluster-randomised controlled trials (cRCTs), controlled before-after (CBA) studies and interrupted time series (ITS) studies were eligible for inclusion in this review.

We did not consider random allocation 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 experimenting and evaluating interventions to improve health and safety. Thus, we decided to consider also non-randomised ITS and CBA designs.

An ITS study was eligible for inclusion when there were at least three time points before and after the intervention, irrespective of the statistical analysis used, and 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-after studies without a control group and retrospective cohort studies. We did not include these studies in the Results but describe and compare them with the results of the included studies in the Discussion.

Types of participants

The population was limited to construction workers (company or self-employed workers). For the purposes of this review, we defined construction workers as people working at a construction site for building/housing/residential sectors, road/highway/civil engineering, offices/commercial projects or industrial installation (for example, ventilation, pipelines and siding).

Construction work is generally managed at an office or other fixed place of business, but construction activities may be performed at multiple project sites. Construction work 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 buildings, engineering projects, and plumbing, heating, ventilation and air conditioning work.

Types of interventions

We included all interventions aimed at preventing occupational injuries. We distinguished six categories of intervention strategies.

- Compulsory.
- Educational.
- Informational.
- Persuasive.
- Facilitative.
- Multifaceted.

Types of outcome measures

Primary outcomes

We included all studies that had measured the effectiveness of interventions on the rate of fatal or non-fatal occupational injuries. We used the following modified definition of injury, from WHO's *The Injury Chartbook* (Baker 1984; Peden 2002): "[n]on-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."

We included injuries resulting from traffic crashes if they occurred during the workers' commute to or from their construction work. We considered all sources of injury data, including self-report.

Secondary outcomes

If an included study reported injuries as a primary outcome measure, we also considered the following secondary outcomes if reported.

- Number of lost working days.
- 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 April 2017 as described in Appendix 1.

- Cochrane Injuries Group's specialised register.
- Cochrane Central Register of Controlled Trials (CENTRAL; 2017 Issue 3).
- MEDLINE (from 1966).
- Embase (from 1988).
- PsycINFO (from 1983).

Data collection and analysis

Selection of studies

Three review authors (PB, PH and HM) independently screened titles and abstracts to identify potentially relevant studies. PB screened all references, and the other two review authors (PH and HM) independently screened a portion. Two review authors (PB and HM) assessed the full texts of potentially relevant articles 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 we resolved these by discussion. In the cases where a disagreement persisted, a third review author (JV) made the final decision. We had articles published in languages other than English translated by a native speaker.

Data extraction and management

Two review authors (PB and HM) independently extracted data in the same way as we had included the studies. We used a data extraction form developed for that purpose, collecting the following information.

- Study design (RCT, cRCT, CBA or ITS).
- Participants (number, trade, age, sex and exposure).
- Intervention target (worker and work team, workplace, materials, equipment or organisation), type (information, compulsion, education, facilitation or persuasion) and content.
- Outcome (primary and secondary outcome, methods used to assess outcome measures and duration of follow-up).
- Setting (size of the company, culture, country, industry subsector, trade and job).

Assessment of risk of bias in included studies

Two review authors (HM and PB) independently assessed the risk of bias of the included studies. Again, there was disagreement about items of risk of bias in about 10% of the cases, but we were able to resolve these by discussion. For ITS studies, we used the criteria developed by the EPOC Review Group (EPOC 2006; EPOC 2012). In total, we assessed eight categories for risk of bias: 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, and reliability of ITS statistics based on re-analysis. We formulated these categories as checklist questions; answered them as 'done', 'not clear' or 'not done'; and presented our judgements in the 'Notes' field of the Characteristics of included studies table.
For controlled before-after studies, we used the internal validity scale of Downs and Black, with 13 categories to assess their risk of bias (Downs 1998). As with the ITS studies, the two review authors resolved disagreement on these points by discussion.
If we are able to include RCTs in future updates of this review, we will use the standard Cochrane risk of bias tool as described in the in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011).

Measures of treatment effect

To obtain comparable and reliable effect sizes from included ITS studies, we extracted and re-analysed data from original papers according to recommended methods for analysing ITS designs 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, we applied a first-order autoregressive time series model to the data using a modification of the parameterisation of Ramsay 2003. Details of the mode specification are as follows.

$Y = ß0 + ß1time + ß2 (time-p) I(time > p) + ß3 I(time > p) + E$, $E \sim N(0, s2)$

For time = 1,...,T, where p is the time of the start of the intervention, $I(time \geq p)$ is a function that takes the value 1 if time is p or later and zero otherwise, and 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.

We performed the statistical analysis in Stata 13 for Windows (StataCorp 2013).

Data on observations over time were derived from published tables of results (Aires 2010_Austria; Aires 2010_Belgium; Aires 2010_Germany; Beal 2007; Choe 2016; Farina 2013; Rubio-Romero 2015; Spangenberg 2002), graphs (Derr 2001; Miscetti 2008; Schoenfisch 2017; Wickizer 2004), or directly from the study authors (Bena 2009; Laitinen 2010; Lipscomb 2003; Suruda 2002). We standardised data on fatal injuries into fatal injuries per 1,000,000 workers per year (Beal 2007: yearly data; Choe 2016: yearly data; Derr 2001: monthly data; Farina 2013: yearly data; Suruda 2002: yearly data). We regarded the outcome from Farina 2013, concerning serious injuries including deaths and injuries involving permanent disability or more than 30 days of absence from work, as a fatal outcome. We standardised data from studies reporting non-fatal injuries into injuries per 100 person-years (Aires 2010_Austria: yearly data; Aires 2010_Belgium: yearly data; Aires 2010_Germany: yearly data; Bena 2009: quarterly data; Choe 2016: yearly data; Lipscomb 2003: quarterly data; Miscetti 2008: yearly data; Spangenberg 2002: yearly data; Wickizer 2004: quarterly data), with the exception of Laitinen 2010 (yearly data). The authors of that study standardised the outcome per million m^3 construction volume. For the study from the USA (Lipscomb 2003), we converted the denominator from working hours into person-years by assuming that one person-year equals 2000 working hours. For the Danish study (Spangenberg 2002), we converted the denominator 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: change in level, and change in slope of the regression lines before and after the intervention (Ramsay 2003). We estimated the ß parameters in the above regression model using the Prais-Winstein first-order autocorrelation version of generalised least squares (GLS) regression, as implemented in the Stata software package. We defined a change in level as the difference between the observed level at the first intervention time point and that predicted by the pre-intervention time trend. We defined a change in slope 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.

We standardised data by dividing the outcome and standard error by the pre-intervention standard deviation as recommended by Ramsay 2001 and entered the data into Review Manager 5 (RevMan 5) as effect sizes (RevMan 2011).

Unit of analysis issues

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

Dealing with missing data

We sought missing data from study authors and received it in some cases.

Assessment of heterogeneity

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

Data synthesis

We pooled results for studies that evaluated similar interventions, participants and outcomes with RevMan 2011. Where sufficient quantitative data were available, we performed meta-analyses. For ITS, we used the standardised change in level and change in slope as effect measures. Meta-analysis employed the generic inverse variance method under a random-effects model. We entered the standardised outcomes into RevMan 5 as effect sizes, along with their standard errors. Since we did not find any RCTs, there was no data synthesis conducted for this type of study.

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 workplaces according to worker and setting characteristics. However, we did not have sufficient data to perform any subgroup analyses.

Summary of findings table

We used the GRADE approach, which systematically assesses the factors important in interpreting the certainty of evidence and results. While the evidence can be different for each outcome, GRADE considers the evidence for each outcome and takes into account the magnitude of effect, ensuring the process is systematic and transparent.

We rated the evidence as follows: with interrupted time-series and controlled before-after studies we started at low quality. Then we downgraded the quality of evidence if we identified limitations in one or more of the following domains: risk of bias; heterogeneity; indirect PICO (**p**articipants, **i**ntervention, **c**omparator **o**utcome) and applicability; imprecision; and publication bias.

We upgraded the quality of evidence from interrupted time-series or controlled before-after studies if we detected a dose-response effect, large effect size or an opposite effect of confounding.
We constructed Summary of findings tables for every comparison using our two primary outcomes fatal and non fatal injuries.

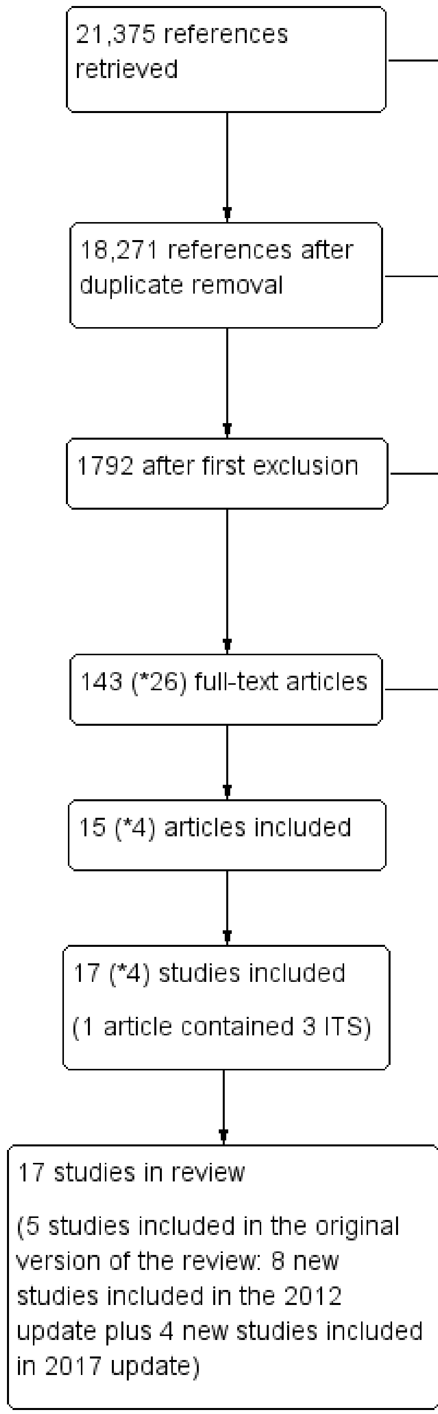
RESULTS

Description of studies

Results of the search

Overall, the search during the first version of the review yielded 7522 references: 7484 from electronic databases, 35 from websites and three from handsearching the reference lists of relevant papers. We retrieved an additional 6096 references for the update in 2011 and an additional 7757 references for the update in 2017, from the same databases in both cases, bringing the total number of references retrieved to 21,375. After excluding duplicate and irrelevant records from the latest search yield, we examined the full texts of 143 potentially eligible articles (see Figure 1), which described studies of interventions for preventing fatal or non-fatal occupational injuries or both in workers at construction sites. One article described the introduction of legislation in three different countries in Europe, and we divided these data into three different studies. In total, 17 studies met the inclusion criteria and are included in this updated review (Aires 2010_Austria; Aires 2010_Belgium; Aires 2010_Germany; Beal 2007; Bena 2009; Choe 2016; Derr 2001; Farina 2013; Laitinen 2010; Lipscomb 2003; Miscetti 2008; Rubio-Romero 2015; Schoenfisch 2017; Spangenberg 2002; Suruda 2002; Tyers 2007; Wickizer 2004).

Figure 1. PRISMA Study flow diagram (* numbers of 2017 update)



Included studies

Settings

Of the 17 included studies, six are from the USA (Choe 2016; Derr 2001; Lipscomb 2003; Schoenfisch 2017; Suruda 2002; Wickizer 2004), two from the UK (Beal 2007; Tyers 2007), three from Italy (Bena 2009; Farina 2013; Miscetti 2008), one from Denmark (Spangenberg 2002), one from Finland (Laitinen 2010), one from Austria (Aires 2010 Austria), one from Belgium (Aires 2010 Belgium), one from Germany (Aires 2010 Germany), and one from Spain (Rubio-Romero 2015). The study interventions took place in 1990, 1991, 1995 (two studies), 1996 (two studies), 1997 (two studies), 1998, 1999 (two studies), 2000, 2001, 2004 (two studies), 2000-2008 and 2009.

Study designs used

Of the 17 included studies, 14 used the interrupted time-series design (Aires 2010 Austria; Aires 2010 Belgium; Aires 2010 Germany; Beal 2007; Bena 2009; Choe 2016; Derr 2001; Farina 2013; Laitinen 2010; Lipscomb 2003; Miscetti 2008; Spangenberg 2002; Suruda 2002; Wickizer 2004). Three of the 14 ITS studies employed a control group (Farina 2013; Laitinen 2010; Wickizer 2004). The remaining three studies used the controlled before-after design (Rubio-Romero 2015; Schoenfisch 2017; Tyers 2007).

Compulsory interventions

Regulation

The regulatory interventions implemented were compulsory, requiring construction companies to execute safety measures. They targeted (where reported) workers or work teams, materials, equipment, workplace and organisation. The contents of these regulations aimed to set in motion a complex set of preventive measures to be taken by employers and employees as well as to maintain safety standards to protect 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 USA. States could opt for implementing their own plan or adopting 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. State and national administrative databases were the sources for outcome data. For more information on the specific content of the regulation, see the Occupational Safety & Health Administration (OSHA) 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, USA, 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, and outcome data came 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 in the USA. Outcome data were obtained from national administrative databases. For more information on the standard, see: Occupational Safety and 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. Investigators obtained outcome data from national administrative databases. For more information on the content of the legislation, see: legislation.gov website.

Aires and colleagues 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 (Aires 2010 Austria; Aires 2010 Belgium; Aires 2010 Germany). 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. Investigators obtained outcome data from a European administrative database.

Farina 2013 was an ITS that evaluated the effects of a European directive that laid down safety and health requirements for construction sites in Italy. This regulation also focused on organisational procedures, characterised by a high degree of coordination between the owner and the coordinator for execution of the construction project. Outcome data came from the Italian National Social Security Institute.

Choe 2016 was an ITS that evaluated OSHA's revised steel erection standard aimed to protect employees from the steel erection hazard in the USA. The steel erection standard included activities like hoisting, laying out, placing, connecting and welding, along with improvement of structural components like column anchorage.

Safety inspection

Miscetti 2008 was an ITS study that evaluated the effect of safety inspections and sanctions for violations of occupational safety and health 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 1997 earthquake 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. Investigators obtained outcome data from building site notifications and national administrative databases.

Educational interventions

Training

Bena 2009 was an ITS that evaluated the effect of a training programme on non-fatal injuries in the Piemonte area of Italy. The training consisted of two 2-hour sessions targeted towards 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 workers learned how to work safely using methods applicable to the everyday context. Outcome data came from regional administrative databases.

Schoenfisch 2017 was a CBA study that evaluated the effectiveness of OSHA outreach training in Washington State, USA. Based on the longitudinal cohort of union carpenters from 2000 to 2008, the study explored the effect of OSHA outreach training on rates of reported workers's claims, including lost days and costs. The training did not occur at the same time for all carpenters. Outcome data came from an administrative database.

Informational interventions

We found no studies that had evaluated informational interventions alone such as campaigns for risk communication.

Persuasive interventions

We found no studies that had evaluated persuasive interventions alone such as peer feedback on workplace actions to increase acceptance of safe working methods.

Facilitative interventions

Subsidy for scaffolding

Rubio-Romero 2015 was a CBA study that evaluated an occupational health and safety intervention via subsidy for scaffolds in the construction sector of Andalusia, Spain. The study compared fall injuries in 179 companies that received a subsidy for scaffolds and in 6022 that did not. Due to the large difference in baseline injury rates, this review presents the baseline and follow-up injury rates separately. Outcome data came from an administrative database.

Multifaceted interventions

Safety campaigns

Spangenberg 2002 was an ITS that evaluated the effect of a company-level safety campaign at that used informative (leaflets, newsletters and notice boards), facilitative (feedback about injury rates) and enforcing (safety inspections) implementation strategies to address the risk of non-fatal injuries in construction workers. The campaign focused on workers, work teams and organisations. 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 information on the 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 came from the company's records.

Laitinen 2010 was a controlled ITS that evaluated the effect of a safety campaign on non-fatal injuries in the Uusimaa region of Finland. The safety campaign (1997 to 2000) consisted of a contest and the involvement of the labour inspectorate, and it targeted workers, workplaces, materials and organisations. Outcome data came 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 organisations 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 came from state 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, staff and management training, health surveillance by nurses, and case management of people on sick leave by OHS professionals. Investigators obtained outcome data from employers' questionnaires.

See the Characteristics of included studies table for further details.

Excluded studies

Of the 128 studies excluded after full-text assessment, we describe 21 that were closest to meeting our review's inclusion criteria in the Characteristics of excluded studies table. One study was not about preventive measures (Spangenberg 2005), one study assessed safety features but had no injury outcome (Kines 2010), one reported only a small proportion of injuries (self-reported falls) (Evanoff 2016), and one described a study protocol (Pedersen 2010). In two studies, we were unable to obtain necessary information from the authors (Halperin 2001; Yassin 2004), two studies did not measure injury rates before and after the intervention (Dong 2004a; 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), one study did not have at least three required time points before and after the intervention (Ohdo 2014), and two studies were retrospective cohort studies (Kim 2016; 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 from changes other than the intervention itself and the lack of rationale about the number and spacing of data points. We present the methodological features of each study in the 'Notes' section of the Characteristics of included studies. In this section we discuss the included studies' methodological quality. This is because of the instruments we used to assess how well the studies had been planned and conducted (Downs 1998; EPOC 2006) use this term instead of risk of bias, which is nowadays the norm. Generally speaking, a study that scores high in methodological quality has a low risk of bias and vice versa.

Overall, the methodological quality of the nine regulation studies was less than 88% of the total quality score for ITS studies (EPOC 2006). The quality scores were 63% for six studies meeting five out of the eight quality criteria (Aires 2010 Austria; Aires 2010 Belgium; Aires 2010 Germany; Choe 2016; Derr 2001; Suruda 2002), 75% for two studies meeting six out of the eight quality criteria (Beal 2007; Farina 2013), and 88% for one study meeting seven out of the eight quality criteria (Lipscomb 2003). The ITS study that evaluated the multifaceted safety campaign at the company level, Spangenberg 2002, met four of the eight quality criteria, meriting a methodological quality score of 50% (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 it scored 75% according to the 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 used a non-equivalent concurrent comparison group (Wickizer 2004). Therefore it was possible to classify this study also as a CBA study. According to the Downs 1998 internal validity scale for controlled cohort studies and the EPOC 2006 ITS quality checklist, the methodological quality score was 46% and 75%, respectively.

Bena 2009, an ITS study evaluating a training programme, and Miscetti 2008, an ITS study assessing an inspection programme, had methodological scores of 63% and 75%, respectively (EPOC 2006).

The CBA study that evaluated the introduction of occupational health services, Tyers 2007, had a methodological score of 23% (Downs 1998). The other two CBAs, Schoenfisch 2017 (evaluating the effectiveness of OSHA outreach training) and Rubio-Romero 2015 (evaluating a subsidy policy for scaffolds) had methodological scores of 45% and 38%, respectively (Downs 1998).

Only one of the ITS studies (Farina 2013) sufficiently clarified that the intervention was independent from other changes. We re-analysed all ITS studies with the methods described in the Measures of treatment effect 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 therefore less than in the formal assessment of the studies (EPOC 2006).

Effects of interventions

See: **Summary of findings for the main comparison** Summary of findings: introduction of regulations; **Summary of findings 2** Summary of findings: safety campaign; **Summary of findings 3** Summary of findings: drug-free campaign programme; **Summary of findings 4** Summary of findings: training; **Summary of findings 5** Summary of findings: inspection; **Summary of findings 6** Summary of findings (Subsidy for Scaffolding)

Primary outcomes

1. Compulsory intervention versus no intervention

Regulation

Nine ITS studies evaluated regulations (Aires 2010˙Austria; Aires 2010˙Belgium; Aires 2010˙Germany; Beal 2007; Choe 2016; Derr 2001; Farina 2013; Lipscomb 2003; Suruda 2002). With the exception of Choe 2016, 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). Most studies showed no significant effect in change of level or slope. However, one study showed a significant decrease in level, two studies a significant decrease in slope, three studies a significant increase in level and three studies a significant increase in slope after the intervention (Analysis 1.1; Analysis 1.2). We judged the nine studies to be sufficiently homogeneous for meta-analysis because we assumed that the mechanism of the intervention (regulation) had a similar effect for both fatal and non-fatal injuries. However, the changes in both level and slope were statistically heterogeneous (I^2 = 95% and 82%, respectively). Most of the included studies had rather short time-series and were fairly small, which could explain the variation in the results.

The meta-analyses of the change in level and slope showed no significant effects, with effect sizes of −0.33 (95% CI −2.08 to 1.41) and −0.03 (95% CI −0.30 to 0.24), respectively. 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 nine studies at considerable risk of bias indicated that there is very low-quality evidence that regulation may result in no initial or sustained reduction of fatal and non-fatal injuries.

Inspections

One ITS study by Miscetti 2008 showed no significant initial or sustained intervention effect of safety inspections plus sanctions for violations on non-fatal injuries, with effect sizes of 0.07 (95% CI −2.83 to 2.97; Analysis 2.1) and 0.63 (95% CI −0.35 to 1.61; Analysis 2.2), respectively). The intention of the study was to show that in spite of increased construction volume there would not be an increase in injury rate, so it was actually a so-called non-inferiority or equivalence study. Even though there were no significant changes in level or slope of the injury trend, the CI values were very wide. Therefore the study provides no evidence of the rates before and after the increase of inspections being equivalent.

2. Educational intervention versus no intervention

One ITS study by Bena 2009 showed no significant initial or sustained intervention effect of a training programme for non-fatal injuries, with effect sizes of 0.10 (95% CI −1.74 to 1.94; Analysis 3.1) and −0.43 (95% CI −0.96 to 0.10; Analysis 3.2), respectively. Another CBA study by Schoenfisch 2017 showed no significant intervention effect (odds ratio 0.87, 95% CI 0.72 to 1.06; Analysis 3.3).

3. Informational intervention versus no intervention

We found no studies that had evaluated informational interventions alone such as campaigns for risk communication.

4. Persuasive intervention versus no intervention

We found no studies that had evaluated persuasive interventions such as peer feedback on workplace actions to increase acceptance of safe working methods.

5. Facilitative interventions versus no intervention

Effect of subsidy policy for scaffolds

A CBA study evaluated injury rates resulting from falls to a lower level before and after offering subsidies to companies for replacing their scaffolding with safer ones (Rubio-Romero 2015). Baseline risk of injuries from falls to a lower level was higher in companies that were later subsidised compared to companies that did not receive subsidies (risk ratio (RR) 3.89, 95% CI 2.32 to 6.52). At follow-up there was no difference between the subsidised and non-subsidised companies (RR 0.93, 95% CI 0.30 to 2.91; Analysis 6.1).

6. Multifaceted intervention (i.e. combined strategies) versus no intervention

Safety campaigns

Two studies evaluated the effect of a safety campaign aimed at promoting positive attitudes towards safety and behavioural safety aspects at work (Laitinen 2010; Spangenberg 2002). Spangenberg 2002 evaluated the effect of a campaign within one company, showing an initial reduction in non-fatal injuries of 3.75 per 100 person-years (effect size −1.82, 95% CI −2.90 to −0.74; Analysis 5.1; Table 2), along with a sustained reduction of 2.67 non-fatal injuries per 100 person-years (effect size −1.30, 95% CI −1.79 to −0.81; Analysis 5.2).

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; Analysis 5.1) and 0.46 (95% CI 0.36 to 0.56; Analysis 5.2), respectively.
In conclusion, very low-quality evidence exists for the effectiveness of a company-oriented multifaceted safety campaign to prevent non-fatal injuries. One low-quality study of a regional multifaceted safety campaign to prevent non-fatal injuries provided evidence of no reduction in injuries.

Drug-free workplace programme

One study 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 (Wickizer 2004); the study showed a downward trend in injuries over time (Table 2). There was a sustained effect of the intervention, with an injury rate difference of −1.97 per 100 person-years between the intervention and control group. This yielded effect sizes of −6.78 (95% CI −10.01 to −3.55; Analysis 6.1) and −1.76 (95% CI −3.11 to −0.41; Analysis 6.2) for initial and sustained effect, respectively.
For the intervention group alone, we found an initial effect of a drug-free workplace programme, with a reduction in non-fatal injuries of −4.62 per 100 person-years. We detected no sustained intervention effect.
In conclusion, there is very low-quality evidence based on one study that a multifaceted drug-free workplace programme prevents non-fatal injuries.

Effect of occupational health services on non-fatal injuries

One study evaluated an intervention offering occupational health services in the construction industry but it found no significant difference between injury rates in the intervention and the control group (Tyers 2007). Investigators assessed injuries with a seven-item questionnaire and analysed the results using multivariate analysis. We could not extract any data 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.

ADDITIONAL SUMMARY OF FINDINGS [*Explanation*]

Safety campaign versus no campaign for reducing injuries in construction industry			
Patient or population: workers in various occupations **Settings**: construction Industry **Intervention**: safety campaign **Comparison**: no campaign			
Outcomes	**Impact[a] (95% CI)**	No. of studies	**Quality of the evidence (GRADE)**
Fatal injuries	No available data		
Non-fatal injuries Change in level (company)	Effect size −1.82 (−2.90 to 0.74)	1 ITS	⊕○○○ Very low[b]
Non-fatal injuries Change in slope (company)	Effect size −1.30 (−1.79 to −0.81)	1 ITS	⊕○○○ Very low[b]
Non-fatal injuries Change in level (regional)	Effect size 0.47 (−0.04 to 0.98)	1 ITS	⊕○○○ Very low[b]
Non-fatal injuries Change in slope (regional)	Effect size 0.46 (0.36 to 0.56)	1 ITS	⊕○○○ Very low[b]
CI: confidence interval;**ITS**: interrupted time series. GRADE Working Group grades of evidence **High quality**: further research is very unlikely to change our confidence in the estimate of effect. **Moderate quality**: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate. **Low quality**: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate. **Very low quality**: we are very uncertain about the estimate.			

[a] Effect size can be interpreted as follows: < 0.2: small effect, 0.2-0.8 moderate effect, > 0.8: Large effect; negative sign means decrease in injuries.

[b] Observational studies start with low-quality evidence; we downgraded 2 levels: 1 for risk of bias, 1 for imprecision (1 study).

Drug-free workplace programme versus no programme for reducing the risk of occupational injuries

Patient or population: employees of the companies with Washington Drug-Free Workplace (WDFW) Program
Settings: various construction companies
Intervention: drug-free campaign programme
Comparison: non-WDFW programme

Outcomes	Impact[a] (95% CI)	No. of studies	Quality of the evidence (GRADE)
Fatal injuries	No available data		
Non-fatal injuries Change in level	Effect size −6.78 (-10.01 to −3.55)	1 ITS	⊕○○○ Very low[b]
Non-fatal injuries Change in slope	Effect size −1.76 (−3.11 to −0.41)	1 ITS	⊕○○○ Very low[b]

CI: confidence interval;**ITS**: interrupted time series.
GRADE Working Group grades of evidence
High quality: further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: we are very uncertain about the estimate.

[a]Effect size can be interpreted as follows: < 0.2: small effect, 0.2-0.8 moderate effect, > 0.8: large effect; negative sign means decrease in injuries.
[b] Observational studies start with low-quality evidence; we downgraded 2 levels: 1 for risk of bias and 1 for imprecision (1 study) and upgraded with 1 for large effect size.

Training versus no training for reducing work-related injuries

Patient or population: workers in the construction industry
Settings: union members in the USA and construction workers in railway construction project
Intervention: OSHA outreach training; safety and health training for railway workers
Comparison: no training

Outcomes	Impact[a] (95% CI)	No. of studies	Quality of the evidence (GRADE)
Fatal injuries	No available data		
Non-fatal injuries	OR 0.87 (0.72 to 1.06)	1 CBA study	⊕○○○ Very low[b]
Non-fatal injuries Change in level	Effect size 0.10 (−1.74 to 1.94)	1 ITS	⊕○○○ Very low[b]
Non-fatal injuries Change in slope	Effect size −0.43 (−0.96 to 0. 10)	1 ITS	⊕○○○ Very low[b]

CI: confidence interval;**OR**: odds ratio; **ITS**: interrupted time series.
GRADE Working Group grades of evidence
High quality: further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: we are very uncertain about the estimate.

[a] Effect size can be interpreted as follows: < 0.2: small effect, 0.2-0.8 moderate effect, > 0.8: large effect; negative sign means decrease in injuries.
[b] Observational studies start with low-quality evidence; we downgraded 2 levels: 1 for risk of bias and 1 for imprecision (1 study).

Inspection versus no inspection of construction site

Patient or population: workers of reconstruction site
Settings: reconstruction site after earthquake
Intervention: accidents in building site
Comparison: no inspection

Outcomes	Impact[a] (95% CI)	No of Studies	Quality of the evidence (GRADE)
Fatal injuries	No available data		
Non-fatal injuries Change in level	Effect size 0.07 (−2.83 to 2.97)	1 ITS	⊕⊕○○ Very low[b]
Non-fatal injuries Change in slope	Effect size 0.63 (−0.35 to 1.61)	1 ITS	⊕⊕○○ Very low[b]

CI: confidence interval;**ITS**: interrupted time series.
GRADE Working Group grades of evidence
High quality: further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: we are very uncertain about the estimate.

[a] Effect size can be interpreted as follows: < 0.2: small effect, 0.2-0.8 moderate effect, > 0.8: large effect; negative sign means decrease in injuries.
[b] Observational studies start with low-quality evidence; we downgraded with two levels: 1 for risk of bias and 1 for imprecision (1 study).

Subsidy for scaffolding versus no subsidy for injuries due to falls to a lower level

Patient or population: population working in construction companies
Settings: construction company
Intervention:subsidy for scaffolds
Comparison: no subsidy for scaffolds

Outcomes	Impact (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)
Fatal injuries	No available data		
At baseline	RR 3.89 (2.32 to 6.52)	(1 CBA Study)	⊕○○○ Very low[a]
At follow-up (2 years)	RR 0.93 (0.30 to 2.91)	(1 CBA Study)	⊕○○○ Very low[a]

CBA: controlled before-after; **CI**: confidence interval; **RR**: risk ratio.
GRADE Working Group grades of evidence
High quality: further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: we are very uncertain about the estimate.

[a] Observational studies start with low-quality evidence; we downgraded 2 levels: 1 for risk of bias, 1 for imprecision (1 study).

DISCUSSION

Summary of main results

Meta-analyses provided very low-quality evidence that introducing regulations may or may not prevent non-fatal and fatal injuries in the construction industry. Very low-quality evidence also showed that a regional safety campaign, training, inspections and the introduction of occupational health services may or may not reduce non-fatal injuries in construction work. For a multifaceted safety campaign at company level, a multifaceted drug-free workplace programme and a facilitative subsidy policy for safe scaffoldings, we found very low-quality evidence that these interventions may reduce non-fatal injuries in the construction industry.

Overall completeness and applicability of evidence

Systematic searching in multiple databases makes it very likely that we located most published studies.

Due to the scarce description of most of the interventions and their implementation, it was not possible to characterise all interventions precisely or to draw firm conclusions about their potential effectiveness.

No information was available on how and to what extent the regulatory interventions were implemented at worksites. Likewise, studies did not provide information about the extent to which employers and workers were motivated to adhere to 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 of injury. Lipscomb 2003, for example, stated in their Discussion section that informational and educational programmes could accompany regulation. Health and work ability studies also argue that legislation or regulation alone may not be powerful enough to change attitudes and behaviour in the desired direction (Ilmarinen 2006). Our analyses revealed that introducing regulation may lead to no significant decrease in fatal or non-fatal injuries. This can be explained by variation in implementation of preventive measures. Other authors have reported that stakeholders start preparing for compliance even before the new regulation is effective (LaMontagne 2004). This would mean that the actual interruption of the time-series does not take place at the moment the regulation is introduced. However, since we have no data about adherence to regulations in the construction industry, this hypothesis must remain speculative.

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 in detail. Spangenberg 2002 also provided information about the familiarity and perception of the safety campaign, but authors provided no information 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 is associated with several ethical and legal controversies. Both multifaceted intervention studies used multiple and continuing activities targeted to the whole work organisation (that is, workers, staff and employers), implemented through various strategies (Spangenberg 2002; Wickizer 2004). Informational and facilitative strategies that influence the safety culture at worksites, combined with persuasive or compulsory interventions such as worksite inspection or mandatory drug testing, were components of these multifaceted interventions. Other studies (for example, Neal 2000) have confirmed an association between safety climate and individual safety behaviour. 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 the existing workers' right for privacy and protection against unreasonable drug testing (Altayeb 1992).

A facilitative subsidy policy was successful in terms of decreasing accidents - falls to a lower level - for higher risk companies (Rubio-Romero 2015). Since Robson 2001 argued that different pre-intervention values make it possible for the hypothesis about rate ratios to be true but rate differences to be false, we presented both risk estimates at baseline and follow-up for Rubio-Romero 2015. 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. Regarding the subsidy policy for safe scaffoldings, we can assume that the interventions were implemented in the intervention companies. 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. Likewise, the introduction of regulations could have encouraged companies to pay further attention to injuries, resulting in an apparent increase in incidents due to improved reporting.

Although the authors of two regulation studies from the USA reported significant reductions in injury rates in their original articles (Derr 2001; Lipscomb 2003), the overall injury rate in the USA construction industry also dropped considerably in that time period (BLS 2007; Hoonakker 2005). Re-analysis with autoregressive time-series revealed no short-term (level) or long-term (slope) regulatory intervention effects on injuries.

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

Quality of the evidence

We did not identify any RCTs that assessed interventions for preventing injuries in the construction industry. According to our assessment, the methodological quality of all 17 included studies (14 ITS studies and 3 CBA studies) was low. In other words their risk of bias is high. Safety research in the construction industry is not easy to perform. However, the more recently published studies followed the recommended ITS analysis referred to in this review (Bena 2009; Choe 2016; Farina 2013).

Although the quality scores of the re-analysed ITS studies showed moderate scores, most studies suffered from bias due to uncertainty about the independence of the intervention from other changes, and there was high statistical heterogeneity. Therefore, we rated the evidence from ITS studies as being of very low quality. We rated the evidence from the individual CBA studies as being of very low quality due to lack of randomisation, a high risk of bias and imprecision, as particular outcomes were reported only by single studies.

In total, 17 studies identified from database searching were eligible for inclusion. It was encouraging that more recent studies evaluated interventions recommended by standard texts on safety, safety consultants and safety courses. Examples of such interventions are training courses (Bena 2009; Schoenfisch 2017), inspections (Miscetti 2008), and subsidies (Rubio-Romero 2015). 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, pre-planning 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 that they are.

This Cochrane review shows that the ITS design offers a good opportunity for evaluating rare or stochastic events such as fatal and non-fatal injuries when (randomised) controlled trials are not possible. However, investigators should analyse data from ITS studies appropriately (Ramsay 2003). With the exception of Bena 2009, Choe 2016 and Farina 2013, the included ITS studies 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 autocorrelation among repeated measurements over time, we re-analysed all ITS studies in this Cochrane review 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 studies in the construction industry should also take the variability of the construction process into account to increase 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 to prevent work-related injuries. It is necessary to define and measure process indicators designed for evaluating the implementation of the intervention in order to determine the extent to which the proposed intervention has actually been applied. Testing the association of determinants from underlying theories or models with intervention outcomes increases insight into potentially effective elements of the intervention. Measuring workers' behavioural change as a direct effect of the intervention along with injuries provides 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 affect 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. Furthermore, Choe 2016 reported that standardisation of preventive measures protects employees from steel erection hazards in the US iron and steel construction industry.

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 a main outcome variable for evaluating the effectiveness of the intervention; and
5. testing the association of behavioural changes with the main outcome measures.

Potential biases in the review process

Publication bias due to unpublished 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, we 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.

Although there were differences in the definition of outcome measures, we re-calculated all outcomes so that they were comparable, except for Laitinen 2010, where 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. For Choe 2016, we obtained fatal and non fatal injury numbers manually from the figure in the article; however, we believe these are accurate numbers.

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. We are aware of Robson 2012, covering training and education, and Mullan 2015, evaluating behaviour change to prevent injuries. 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 we used in the review both for misinterpreting the outcome of their included regulatory study and for not making better use of qualitative studies. Interpreting ITS studies is not straightforward and is prone to bias. In many studies, authors judge time trends purely based on looking at the data. Therefore we think that a standardised statistical analysis will decrease the risk of bias. In their study, Lipscomb 2003 specified an effect of regulation three years after implementing 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 apart from immediately following the intervention or as an increased downward trend. We believe that we should be careful with attributing the effects of interventions to changes in trends over time. In our opinion, introducing new or changed regulation does not impact on injury rates without sufficient implementation. Verbeek 2009 has also shown this to be the case for regulation to prevent occupational noise-induced hearing loss.

AUTHORS' CONCLUSIONS

Implications for practice

Based on the nine included regulatory studies, there is insufficient evidence for or against the effectiveness of regulations to reduce fatal and non-fatal injuries among construction workers. Nor is there sufficient evidence in the included studies that regionally oriented safety interventions such as campaigning, training, inspections or new occupational health services are effective for 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 campaigns at company level or a drug-free workplace programme, or safety standard and subsidy policy in case of high risk equipment, 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 worksites 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 randomised) studies are needed to establish the effect of various safety interventions on fatal and non-fatal injuries. Studies with ITS over several years with a high internal validity and a correct statistical analysis are feasible when controlled studies are not possible. Regulatory ITS studies should give more attention to adherence to regulation and enforcement aspects, both during the intervention and 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 on annual data from 4 years pre-intervention to 7 years postintervention
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)
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 on annual data from 4 years pre-intervention to 7 years postintervention
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)
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 on annual data from 3 years pre-intervention to 8 years postintervention
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)
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 on annual data from 10 years pre-intervention to 10 years postintervention
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)
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 on 6 quarterly data pre-intervention and 7 postintervention
Participants	Construction workers of a high speed railway line (Torino to Milano) in Piemonte region (Italy) (N = 2795 workers)
Interventions	Training programme, which had trained 88% of workers by 1 October 2004 Target: worker (team), organisation Form: education by training 2 sessions of 2 h each (project 2002 to 2006)
Outcomes	Non-fatal injuries per 100 person-years
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

Choe 2016

Methods	ITS, based on annual data of fatal and non-fatal injuries from 5 years pre-intervention to 5 years postintervention
Participants	Construction workers (all steel and iron workers in the USA for which injuries are reported to OSHA) Average pre-intervention fatality rate 68/100,000 workers and post intervention 53/100,000 workers. Days away rate: 612/10,000 workers pre-intervention and 283/10,000 workers postintervention
Interventions	Occupational Safety and Health Administration (OSHA) revised the steel erection standard designed to protect employees from steel erection activities like hoisting, laying out, placing, connecting and welding as well as improvement of structural components like column anchorage Target: construction workers (iron and steel workers) Form: compulsion by legislation that directly affected the general contractors and special trade contractors in the construction industry
Outcomes	Fatality rate per 100,000 workers and days away rates: total number of days away with an injuries divided by average number of employees per 10,000 workers
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: NOT DONE Rationale for number and spacing data points: NOT CLEAR Reliable ITS statistical analysis based on re-analysis: DONE

Derr 2001

Methods	ITS, based on monthly data from 5 years pre-intervention to 5 years postintervention
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)
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

Farina 2013

Methods	Controlled ITS, based on annual data from 5 years pre-intervention to 5 years postintervention
Participants	1/15 of all male construction workers registered by the Italian National Social Security Institute (INPS) and the Italian Workers Compensation Authority (INAIL) between 1994 and 2005, not including self-employed and publicly employed individuals. (N = total construction workers per year)
Interventions	2 laws: Decree 494/96 and Decree 528/99 enacted in Italy, laying down safety and health requirements for the construction sites as an implementation of the EU directive 92/57/EEC and introducing a requirement for coordinators to draw up a safety coordination plan Target: construction workers Form: compulsion by legislation
Outcomes	All injuries recognised as being occupational and leading to more than three days of absence from work, excluding commuting accidents
Notes	Intervention independent of other changes: 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: NOT DONE Rationale for number and spacing data points: NOT CLEAR Reliable ITS statistical analysis based on re-analysis: DONE

Laitinen 2010

Methods	Controlled ITS, based on annual data from 7 years pre-intervention to 10 years postintervention
Participants	Construction workers in Finland (N = not clearly reported)
Interventions	Contest, campaign in 1997-2000 Target: worker (team), workplace, materials, organisation Form: multifaceted by information, persuasion (labour inspectorate) facilitation, contest
Outcomes	Non-fatal injuries per million m^3 construction volume (per year)
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 on quarterly data from 2 years pre-intervention to 8 years postintervention
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)
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 on annual data from 5 years pre-intervention to 10 years postintervention Authors wanted to show that thanks to the intensive inspection, the increase of building activities did not lead to a higher absolute number of injuries in the construction industry This is an 'equivalence' study (analysed as an effectiveness study)
Participants	Construction workers in Assisi district, Italy (mean 869 construction sites per year (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: compulsion by inspection and sanctions by legislation/labour inspectorate/education
Outcomes	Non-fatal injuries per 100 workers (per year)
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

Rubio-Romero 2015

Methods	Controlled before-after (CBA) study
Participants	179 companies that received subsidy for scaffolds (intervention group) and 6022 that did not
Interventions	Subsidy for scaffolds in the Andalusian construction sector. The subsidies were for the acquisition of standardised and certified scaffolds compliant with the norms UNE 76502:1990 or UNE EN 12810-1: 2005. The value of the grant was up to EUR 18,000, with a maximum financing percentage of 45% Target: companies using scaffolding in the Andalusian region, Spain Form: facilitation by government subsidy (598 companies in 2006, 428 companies in 2007, 378 companies in 2008 and 187 companies in 2009)
Outcomes	The accident rate involving falls from scaffolds involving at least 1 day off work but not commuting accidents as reported to the labour authority
Notes	Downs and Black's (Downs 1998) quality list, section internal validity Total score: 5/13 = 38% Study results based on data dredging made clear: YES Analysis adjust for length of follow-up: YES Compliance with the intervention reliable: YES Recruitment over same time period: YES Loss to follow-up taken into account: YES

Schoenfisch 2017

Methods	CBA study
Participants	17,106 carpenters who worked 99,411,000 union hours in Washington State in 2000-2008. Average age 43.1 years, 97.7% males who were union members and entitled to worker's compensation
Interventions	OSHA outreach training programme. Basic training for 10 hours and 30 hours for workers with safety responsibility. The training covers recognition and prevention of safety hazards with emphasis on falls from elevation, electrocutions, struck by events and caught in/between events Target: carpenters Form: education by OSHA Outreach Training
Outcomes	Workers compensation claims for injuries and workers compensation claims for time loss per 200,000 work hours (100 person years)
Notes	Downs and Black's (Downs 1998) quality list, section internal validity Total score: 7/13 = 54% Blinded measurement of the main outcome: YES Results based on data dredging made clear: YES Same follow-up intervention and control: YES Outcome measure used accurate: YES Recruitment from same population: YES Recruitment over same time period: YES Loss to follow-up taken into account: YES

Spangenberg 2002

Methods	ITS, based on annual data from 3 years pre-intervention to 3 years during intervention
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: multifaceted by information, facilitation (feedback), compulsion (inspection)
Outcomes	Injuries per 100 person-years (per year)
Notes	Most 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 on annual data from 6 years pre-intervention to 6 years postintervention
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)
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	CBA study
Participants	Construction companies in 2 geographical areas in the UK Leicestershire (intervention group; N = 870) or Avon (control group; N = 602)
Interventions	An occupational health service was developed especially for this project, with the aim of introducing and raising awareness on occupational health issues in the construction industry; 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 was 19 to 23 months (October 2004 to 2006) Target: workplace modification, organisation Form: multifaceted by OHS through information, education, facilitation
Outcomes	• Experienced accidents or injuries in the last 2 years (at work) • Experienced non-serious injuries in last 2 years (at work) • Frequency of non-serious injuries in last 2 years • Experienced injuries requiring up to 3 days off work in last 2 years • Frequencies of injuries requiring < 3 days off work • Experienced other injuries of > 3 days off work • Experienced fractures of injuries resulting in hospital stay
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

Tyers 2007 *(Continued)*

	Loss to follow-up taken into account: YES

Wickizer 2004

Methods	Controlled ITS, based on annual data from 3 years pre-intervention to 3 years postintervention
Participants	Construction workers (at follow-up: intervention group N = 3305 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: multifaceted by information, education, facilitation (financial incentives), compulsion (drug testing)
Outcomes	Injuries per 100 person-years (per year)
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

CBA: controlled before-after; **ITS**: interrupted time series; **OHS/OSH**: occupational health and safety (or safety and health); **OSHA**: Occupational Safety and Health Administration.

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 2004a	Retrospective cohort study, but measurements did not take place before the intervention
Evanoff 2016	Before-after study without control group

(*Continued)*

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
Kim 2016	Retrospective cohort study
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
Ohdo 2014	Before-after study without control group
Salminen 2008	Before-after study without a control group
Spangenberg 2005	Not a 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	Protocol for a mixed-methods study on leader-based interventions in construction contractors' safety commitments
Methods	Mixed methods
Participants	Construction Iindustry
Interventions	Leader-based interventions
Outcomes	Safety behaviour, injuries

Pedersen 2010 *(Continued)*

Starting date	-
Contact information	-
Notes	-

DATA AND ANALYSES

Comparison 1. Introduction of regulation (ITS)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Level	9		Effect Size (Random, 95% CI)	-0.33 [-2.08, 1.41]
1.1 Fatal injuries	5		Effect Size (Random, 95% CI)	-0.13 [-1.51, 1.25]
1.2 Non-fatal injuries	5		Effect Size (Random, 95% CI)	-0.44 [-3.70, 2.83]
2 Slope	9		Effect Size (Random, 95% CI)	-0.03 [-0.30, 0.24]
2.1 Fatal injuries	5		Effect Size (Random, 95% CI)	-0.20 [-0.64, 0.23]
2.2 Non-fatal injuries	5		Effect Size (Random, 95% CI)	0.14 [-0.26, 0.54]

Comparison 2. Inspections (ITS)

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)	0.07 [-2.83, 2.97]
2 Slope: non-fatal injuries	1		Effect Size (Random, 95% CI)	0.63 [-0.35, 1.61]

Comparison 3. Training (ITS, CBA)

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)	0.1 [-1.74, 1.94]
2 Slope: non-fatal injuries	1		Effect Size (Random, 95% CI)	-0.43 [-0.96, 0.10]
3 Non-fatal Injuries (CBA)	1		Odds Ratio (Fixed, 95% CI)	0.87 [0.72, 1.06]

Comparison 4. Subsidy for scaffolding (CBA)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Injuries from falls to a lower level	1		Risk Ratio (M-H, Fixed, 95% CI)	Subtotals only
1.1 Baseline	1	58019	Risk Ratio (M-H, Fixed, 95% CI)	3.89 [2.32, 6.52]
1.2 At 2 years follow-up	1	44619	Risk Ratio (M-H, Fixed, 95% CI)	0.93 [0.30, 2.91]

Comparison 5. Safety campaign (ITS)

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 6. Drug-free workplace programme (ITS)

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)	-6.78 [-10.01, -3.55]
2 Slope: non-fatal injuries	1		Effect Size (Random, 95% CI)	-1.76 [-3.11, -0.41]

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 from 1985 to 1988 in USA	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 USA (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
Evanoff 2016	Before-after study	1018 apprentice carpenters in residential construction (no control group)	Educational intervention: training utilised hands-on, participatory training methods preferred by the	Number of self-reported falls: before 18.2; after: 14.5; absolute change 3.7

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

			learners to address the safety gaps in the curriculum, including ladder use, leading edge work, truss setting, and use of scaffolding and personal fall arrest. Rolled out in USA in 2007	
Gerber 2002	Before-after study	Construction workers (49 companies, no control group)	Drug-testing programmes issued from 1985 to 1999 in USA	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: 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 USA	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
Kim 2016	Retrospective cohort study	1298 patients who suffered work-related fall injuries.	Preventive effects of safety helmets: emergency-department based occupational injury database with work-related injury patients who visited 10 emergency departments between July 2010 and October 2012 in Korea. Surveillance database was used to evaluate the extent to which safety helmets have an effect on reducing the risk of traumatic brain injury resulting from work related fall injuries by comparing the effect across different heights	Usage of helmets: 45% work-related fall injured patients were wearing safety helmets. Intracranial injury was high at 8.7% in the no safety helmet group and 4.6% in the safety helmet group. There was significant preventive effects of safety helmet on intracranial injury when the height of fall was less than 4 m OR 0.42 (95% CI 0.24 to 0.73)

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

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 USA	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
Ohdo 2014	Before-after study	-	Amended occupational safety and health regulations in Japan in 2009: installation of mid-rails, lower bars and other similar structures to prevent falls from the space between a guardrail and the work platform erected on scaffolds	Scaffold-related fall accidents: Decrease over years 1552 (2007), 1227 (2008), 828 (2009), 718 (2010), 871 (2011)
Salminen 2008	Before-after study	Company 1: 172 drivers/electricity workers Company 2: 179 drivers/electricity workers	Company 1: 3, 45-60 min group discussions 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 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 USA	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)

CI: confidence interval;**LWDI**: lost work day injuries; **OR**: odds ratio; **OSHA**: Occupational Safety and 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
Choe 2016	40.2 (4.92)	−9.05 (5.19)	1.96 (1.22)	−6.34 (1.60)	−0.74
Farina 2013	4.94 (0.37)	−0.38 (0.38)	−0.10 (0.08)	−0.29 (0.12)	0.17
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

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

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
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
Choe 2016	43.58 (3.47)	−21.78(1.71)	−0.76 (0.4)	−2.07(0.53)	−0.88
Non-fatal injuries/million m³construction 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.

WHAT'S NEW

Last assessed as up-to-date: 1 April 2017.

Date	Event	Description
30 January 2018	New citation required but conclusions have not changed	There were changes in the author team with the addition of Prativa Basnet and the removal of Hongwei Hsiao and Andrew Hale
25 October 2017	New search has been performed	A new search yielded four new studies. There is one new comparison. We added GRADE ratings and adapted the Background

(*Continued)*

19 November 2012	Amended	Author contact details amended.

HISTORY

Protocol first published: Issue 4, 2006

Review first published: Issue 4, 2007

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.
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.

Prativa Basnet was involved in screening the references, inclusion of studies, data extraction and writing of the second update of this review.

Peter Hoonakker, Marika Lehtola, Jorma Lappalainen, Roger Haslam 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 of the the two updates of the review.

Andrew Hale and Hongwei Hsiao are acknowledged for their contributions up to the first update of the review.

DECLARATIONS OF INTEREST

Henk F van der Molen: None known.

Prativa Basnet: None known.

Peter LT Hoonakker: None known.

Marika M Lehtola: None known.

Jorma Lappalainen: None known.

Monique HW Frings-Dresen: None known.

Roger Haslam: None known.

Jos H Verbeek: None known.

SOURCES OF SUPPORT

Internal sources

- Cochrane Work, Finland.
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- Coronel Institute of Occupational Health, Academic Medical Centre, Universiteit van Amsterdam, Netherlands.

External sources

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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 can produce misleading results, especially in the event of non-significant results (Verbeek 2011).

INDEX TERMS

Medical Subject Headings (MeSH)

*Construction Industry [legislation & jurisprudence; statistics & numerical data]; Accidents, Occupational [legislation & jurisprudence; mortality; *prevention & control]; Occupational Health [legislation & jurisprudence]; Occupational Injuries [mortality; *prevention & control]

MeSH check words

Humans