

Active behaviour change safety interventions in the construction industry:

A systematic review

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ABSTRACT

The aims of this paper were to systematically review the evidence for the effectiveness of active behaviour change safety interventions in the construction industry; and to determine the intervention characteristics most commonly associated with effectiveness in reducing injury rates and improving safety behaviour – intensity/frequency/duration, behaviour change techniques (BCTs) and theory-base. An electronic literature search (June 2014) was conducted to identify eligible interventions: those involving active involvement from workers/management in the construction industry; targeted one/both of the primary outcomes. All intervention designs involving construction workers aged >18 years, published in English and in a peer-reviewed journal were included. Fifteen studies were included, half of which successfully improved injury rates. Longer interventions and those that included active/volitional BCTs (feedback/monitoring rather than instruction/information) were more effective. The methodological quality of the interventions was poor and use of theory was inconsistent and infrequent. Despite some positive results, very few interventions achieved all their aims. More rigorous, theory-driven research is needed to structure intervention efforts and determine the mechanism of action of effective interventions.

Keywords: Systematic review, construction, injury/accident prevention, safety, behaviour change techniques

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1. INTRODUCTION

Workplace injuries are widespread; in the UK from 2010-2011 nearly 150 people were killed in workplace accidents, 27 million working days were lost, and societal costs approximated £14 billion (Health and Safety Executive, 2013). In the USA, the cost of all work-related injuries in 2011 was \$189 billion (National Safety Council, 2013). The construction industry ranks as one of the highest for work-related injuries (International Labour Organization, 2011), accounting for 27% of fatal injuries and 10% of major injuries in the UK, despite representing only 5% of workers. In the USA in 2002, costs of injuries in the construction industry were estimated to be \$11.5 billion.

A 2008 review of construction-related injuries interventions identified only five eligible studies (Lehtola et al., 2008). The major finding was that the introduction of safety legislation alone was not effective in reducing injuries (Lehtola et al., 2008). The remaining interventions were effective but poor methodological quality and significant heterogeneity meant that the means by which these interventions changed behaviour was unclear. In an updated review in 2012 (13 studies; van der Molen et al., 2012), it was similarly concluded that there was no evidence that the introduction of safety legislation/regulations alone or that regionally-oriented interventions such as inspections or training were effective in reducing injuries. There was, however, low-level evidence that company-oriented interventions (e.g., multifaceted safety campaign, drug-free workplace) resulted in reduced injuries (van der Molen et al., 2012). Another review of three interventions specifically to reduce falls in the construction industry also found limited evidence for effectiveness (Rivara & Thompson, 2000).

The purpose of the present review was to extend the previous reviews (Lehtola et al., 2008; van der Molen et al., 2012), firstly by including interventions that targeted safety

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behaviours in addition to those that solely measured injury rates; and secondly, by focusing more explicitly on the intervention characteristics (e.g., use of theory, behaviour change techniques (BCTs), and intensity/frequency/duration) that were most commonly associated with effectiveness. Indeed, this was identified as a limitation of the previous review (van der Molen et al., 2012) and thus represents an important research question. Given the lack of evidence for the effectiveness of legislation in reducing injuries (Lehtola et al., 2008; van der Molen et al., 2012), the specific focus of the current review was on interventions that *actively* involved workers or management in changing their behaviour. Thus, interventions that involved legislation/regulations or environmental modifications as their sole method of changing behaviour were excluded. Additional impetus for this work comes from research demonstrating that behaviour change interventions are more effective if they are based on a theoretical understanding of the behaviour, and are designed using theory to select the BCTs with which to target relevant factors (Webb, Joseph, Yardley, & Michie, 2010). Indeed, several theory-based interventions in other health-related behaviours developed using this method have been shown to be effective (Kothe, Mullan, & Butow, 2012; Milton & Mullan, 2012; Sainsbury, Mullan, & Sharpe, 2013).

1.1. Research questions

- What active/behaviourally-focused safety interventions have been conducted in the construction industry?
- What is the effectiveness of these safety interventions in: (1) reducing the incidence of injuries; (2) prompting improvements in safety behaviours, which may, in turn, reduce injuries (e.g., increased use of personal protective equipment or adherence to safety regulations)?
- Was effectiveness related to the frequency, intensity, or duration of the interventions?

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- What theoretical basis, if any, underpins these interventions?
- Were particular BCTs more strongly related to effectiveness than others?
- What is the quality of the evidence reviewed?

2. METHOD

2.1. Search Strategy

In June 2013 (updated in June 2014) a systematic literature review was conducted based on the PRISMA guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009) and the Cochrane Handbook for Systematic Reviews of Interventions (Higgins & Green, 2011). Electronic literature searches were performed in PsychINFO, Medline, Web of Science, and PubMed. Key word search terms included the following: (Injuries OR Industrial Accidents OR Occupational Injury) AND (Health Promotion OR Accident Prevention OR Injury prevention) AND (Intervention study OR Intervention research); (Construction) AND (Health Promotion OR Accident Prevention OR Injury Prevention) AND (Occupational Safety OR Work Safety).

2.2. Eligibility criteria

All peer-reviewed studies including randomised-controlled trials (RCTs), cluster-RCTs, controlled pre-post studies, and interrupted time-series (a design in which data is collected over a period of time, including prior to the introduction of an intervention, in order to determine whether the introduction led to changes over and above any existing trends over time; Ramsay, Matowe, Grilli, Grimshaw, & Thomas, 2003) were eligible for inclusion. There was no specific time-based (pre- or post-introduction of intervention) criterion for the inclusion of interrupted time-series studies. Only studies in English were included. The target population consisted of adult (aged >18 years) workers in construction and construction-related industries (e.g., metal workers, tilers, roofers, road workers, and labourers). Eligible

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studies were interventions in which construction workers or management actively participated, conducted in a real-life setting, and that targeted injury rates within the workplace and/or the uptake of safety behaviours. Passive interventions (e.g., introduction of safety legislation/regulations or environmental modifications/ equipment) without an active training component were excluded.

Extracted data included type of construction, participant and intervention characteristics, study design, control/comparison group, injury type/safety behaviour targeted, and results. Studies were coded for their use of a theoretical framework (theory-based vs. non-theory-based), and intervention descriptions were examined and coded for the use of BCTs using 'The BCTs Taxonomy (v1)' (Michie et al., 2013) which contains 93 BCTs within 16 broad clusters (e.g., knowledge shaping, rewards and threat, feedback and monitoring).

2.3. Study selection

Two of the authors independently screened all identified records by title. Articles deemed eligible or cases where a decision could not be made were then screened by abstract and full-text, with any disagreements resolved through discussion. Reference lists of the final articles and papers identified in the previous reviews (Lehtola et al., 2008; van der Molen et al., 2012) were manually examined.

2.4. Assessment of risk of bias in included studies

The methodological quality of each study was independently assessed using either the Downs and Black Internal Validity Criteria Checklist (randomised and pre-post studies; Downs & Black, 1998) or the Cochrane Effective Practice and Organisation of Care review group's Quality Criteria Checklist (interrupted time-series studies; EPOC, 2009). Based on a

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lack of similarity between studies regarding design, sample, and outcome measures it was not possible to conduct a meta-analysis (Higgins & Green, 2008).

3. RESULTS

3.1. Study selection

The search strategy yielded 6355 hits (see Figure 1), of which, 13 met the inclusion criteria. Agreement between the two reviewers was high at both the title (95.8%), and abstract (96.2%), stages. Examination of the 13 reference lists and assessment of the degree of overlap with previous reviews (Lehtola et al., 2008; van der Molen et al., 2012), yielded an additional 11 studies, two of which met criteria. Thus, fifteen studies were included in the review (see Table 1 for a summary of sample and intervention characteristics). Reasons for exclusion included: the intervention did not involve active BCTs (Aires, Gamez, & Gibb, 2010; Beal, 2007; Lipscomb, Li, & Dement, 2003; Mirka, Monroe, Nay, Lipscomb, & Kelaher, 2003; Mohr & Clemmer, 1989; Saruda, Whitaker, Bloswick, Philips, & Seseck, 2002), published in a language other than English (Miscetti & Bodo, 2008) and not published in a peer-reviewed journal (Tyers et al., 2007).

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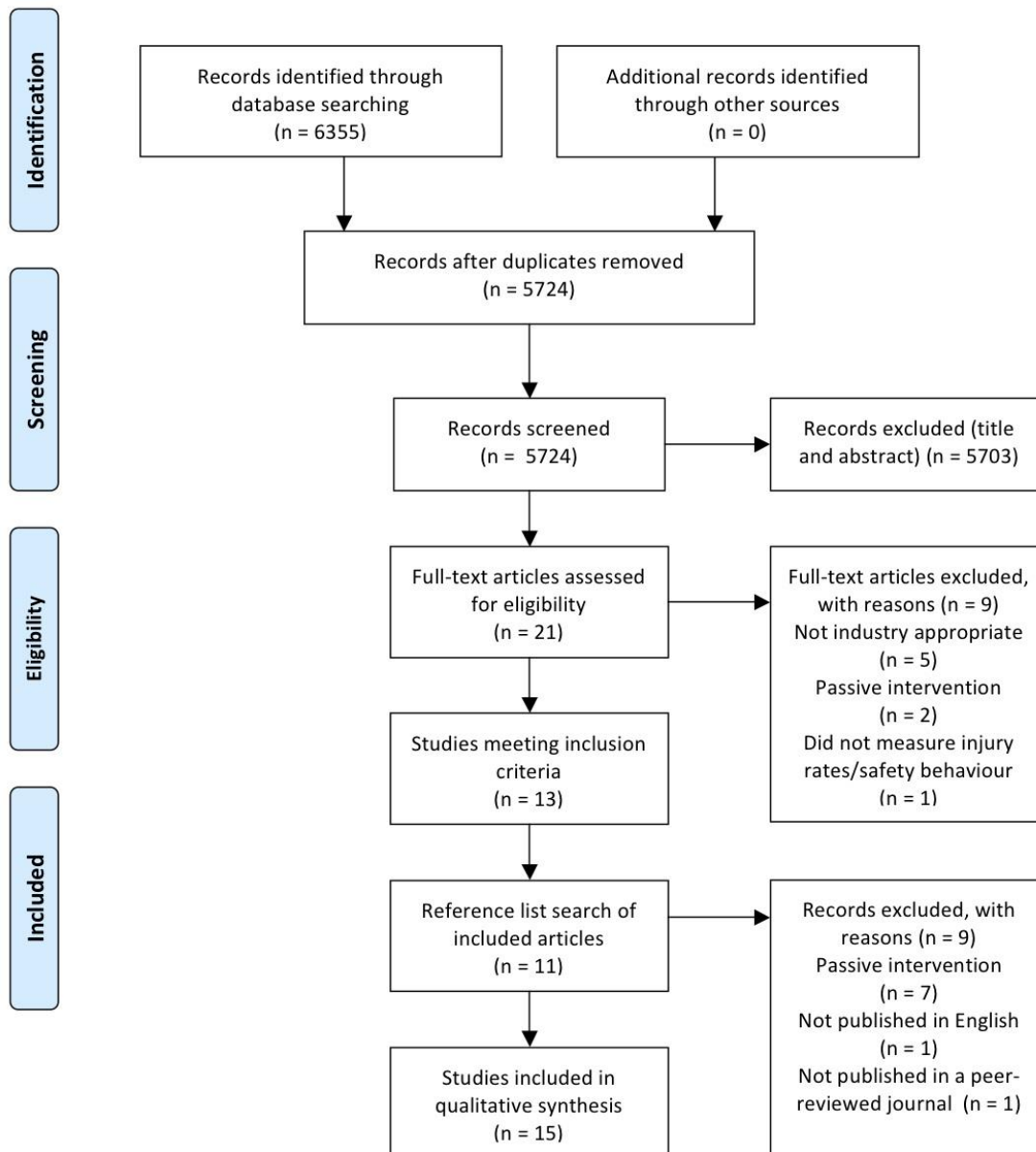


Figure 1. Flow Diagram of study selection

3.2. Study characteristics

Reported sample sizes ranged from 175 to 507262; in eight studies the exact sample size was not reported either because the number of workers present for each day/session of the intervention period differed, or the number of work sites rather than participants was

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reported (see Supplementary Table 1 for detailed descriptions of each study including intervention and control group materials). The type of construction work varied, from specific trades (e.g., carpentry, roofing, tiling, concrete, floor laying) to larger scale industries (e.g., metal/steel/aluminium work, stone quarry, railways). Six studies were conducted in the USA (Becker, Fullen, Akladios, & Hobbs, 2001; Darragh, Stallones, Bigelow, & Keefe, 2004; Forst et al., 2013; Kerr, Savik, Monsen, & Lusk, 2007; Lusk et al., 1999; Sokas, Jorgensen, Nickels, Gao, & Gittleman, 2009), three in Denmark (Kines, Andersen, Andersen, Nielsen, & Pedersen, 2013; Kines et al., 2010; Spangenberg, Mikkelsen, Kines, Dyreborg, & Baarts, 2002), two in Italy (Bena, Berchiolla, Coffano, Debernardi, & Icardi, 2009; Mancini et al., 2005), and one each in Hong Kong (Lingard & Rowlinson, 1997), India (Adams et al., 2013), Spain (Lopez-Ruiz et al., 2013), and Finland (Laitinen & Päiväranta, 2010).

Only one study employed a conventional RCT design where the unit of randomisation was the individual (Kerr et al., 2007). A further three studies used a cluster-RCT design where the unit of randomisation was the construction company/site (Kines et al., 2013; Kines et al., 2010; Spangenberg et al., 2002); and one study used a four-group Solomon design with participants randomised by naturally occurring training groups (Lusk et al., 1999). Two studies used a pre-post design with a control group but were not classified as RCTs due to non-random assignment to conditions (Becker et al., 2001) or comparison with non-matched convenience samples (Mancini et al., 2005). Two studies used a pre-post design with no control group (Forst et al., 2013; Sokas et al., 2009); three studies used an interrupted time-series design with (Laitinen & Päiväranta, 2010) or without a control group (Darragh et al., 2004; Spangenberg et al., 2002); and two studies used a mixed-approach including both pre-post and time-series analyses with (Lopez-Ruiz et al., 2013) or without a control group (Bena et al., 2009). The final study employed a within-groups design where four different

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behaviours were targeted in a staggered fashion and the same group of participants served as the intervention and control groups (Lingard & Rowlinson, 1997).

Two studies reported on both injury rates and the uptake of safety behaviours (Adams et al., 2013; Laitinen & Päivärinta, 2010). Five studies reported on injury rates alone (Bena et al., 2009; Darragh et al., 2004; Lopez-Ruiz et al., 2013; Mancini et al., 2005; Spangenberg et al., 2002), and eight studies reported on the uptake of safety behaviours alone (Becker et al., 2001; Forst et al., 2013; Kerr et al., 2007; Kines et al., 2013; Kines et al., 2010; Lingard & Rowlinson, 1997; Lusk et al., 1999; Sokas et al., 2009). Most studies measured general/overall injuries (Bena et al., 2009; Darragh et al., 2004; Laitinen & Päivärinta, 2010; Lopez-Ruiz et al., 2013; Spangenberg et al., 2002), although two focused specifically on eye/ocular injuries (Adams et al., 2013; Mancini et al., 2005). Safety behaviours targeted included: falls prevention practices (Becker et al., 2001; Sokas et al., 2009), electrical safety hazard practices (Sokas et al., 2009), compliance with protective eyewear (Adams et al., 2013; Mancini et al., 2005), use of hearing protection devices (Kerr et al., 2007; Lusk et al., 1999), and safety-related communication. (Kines et al., 2010) Several studies used a general/overall measure of safety behaviour such as a safety index, which included the rating of various safety behaviours (Kines et al., 2013; Laitinen & Päivärinta, 2010; Lingard & Rowlinson, 1997) – for example, use of personal protective equipment (Kines et al., 2013; Lingard & Rowlinson, 1997), scaffolding (Laitinen & Päivärinta, 2010; Lingard & Rowlinson, 1997), and housekeeping (Lingard & Rowlinson, 1997) or order and tidiness (Kines et al., 2013; Laitinen & Päivärinta, 2010).

Interventions used a range of methods to change behaviour including educational/information sessions (Adams et al., 2013; Bena et al., 2009; Darragh et al., 2004; Forst et al., 2013; Sokas et al., 2009), the distribution of educational material (e.g., booklet,

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TV broadcasts; Darragh et al., 2004; Lusk et al., 1999; Mancini et al., 2005; Spangenberg et al., 2002), site inspections/audits/follow-up visits (Adams et al., 2013; Becker et al., 2001; Laitinen & Päivärinta, 2010; Lopez-Ruiz et al., 2013), coaching (Kines et al., 2010), goal setting (Lingard & Rowlinson, 1997), problem solving (Kines et al., 2013), providing feedback (Kines et al., 2010; Lingard & Rowlinson, 1997; Spangenberg et al., 2002), and administrative strategies such as management meetings, warning letters, and the development of recommendations and sanctions (Lopez-Ruiz et al., 2013; Spangenberg et al., 2002). One study involved participants playing a computer game that incorporated health messages (Kerr et al., 2007); and two consisted of a safety campaign (Spangenberg et al., 2002) or contest (Laitinen & Päivärinta, 2010) between different construction companies/sites, both of which employed incentives and penalties.

3.3. Intervention Effectiveness

3.3.1 Injury Rates

Amongst the seven relevant studies, two found a significant improvement/reduction in injuries relative to the control group (Lopez-Ruiz et al., 2013; Mancini et al., 2005). Notably, however, in the former study, the intervention and control groups were non-equivalent at baseline as assignment to the intervention condition was based on having elevated injury rates in the period prior to the intervention being introduced, while the control condition included companies with any level of injury rates (Lopez-Ruiz et al., 2013). While ethically it was probably necessary to target those sites, methodologically this design makes it difficult to draw firm conclusions about the effectiveness of the intervention as injury rate at baseline was not controlled for. Similarly in another study, the injury reduction rate in the contest region was greater than for the corresponding time period in the non-contest/comparison region; however, the absolute injury rate remained higher than in the comparison region

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(Laitinen & Päivärinta, 2010). Another study found that although there was an overall significant decrease in injury rates from baseline to post-intervention, the difference between the two intervention groups (standard education vs. enhanced education) was not significant (Adams et al., 2013). This study did not, however, include a no-treatment control group and did not utilise a time-series analysis so it is not possible to determine whether the reduction in injuries observed was greater than any existing secular trend. Indeed, a further two studies utilising a single sample within-group design showed a significant reduction in injury rates using pre-post analyses; however, the time-series analyses failed to confirm this pattern (Bena et al., 2009; Darragh et al., 2004). The final time-series study found that injuries decreased following the introduction of the intervention; however, the reduction was only significant when controlling for the type of construction, with light construction work having lower injury rates than heavy construction work (Spangenberg et al., 2002).

3.3.2. Uptake of Safety Behaviours

Of the ten relevant studies four found a significant improvement in behaviour compared to the control group: improved safety audit scores (Becker et al., 2001), use of hearing protective devices (Lusk et al., 1999), safety knowledge, safety involvement (Kines et al., 2013), safety-related communication, and safety performance (overall score; Kines et al., 2010). Five further studies found significant improvements from baseline to post-intervention in compliance with protective eyewear (Adams et al., 2013), the use of hearing protection devices, benefits/barriers, self-efficacy (Kerr et al., 2007), knowledge (Forst et al., 2013; Sokas et al., 2009), and safety indices (overall score; Laitinen & Päivärinta, 2010). In this latter study the observed improvements plateaued during the one year that the contest did not run, and resumed when the contest was reintroduced the following year (Laitinen & Päivärinta, 2010). Similarly, one study used a within-group design and found significant

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improvements in housekeeping safety, which decreased again following removal of the intervention (Lingard & Rowlinson, 1997).

Two of the above studies stated in their methods that they had measured “self-reported safety behaviour” (Sokas et al., 2009) or “behavioural change” (Forst et al., 2013) but then only reported results concerning attitudes and/or knowledge, so it was not possible to determine the effect of the intervention on actual safety behaviour. Finally, although not directly analysed, the findings of two of the above studies in which both injury rates and safety behaviours were assessed suggested that improvements in safety behaviour were successfully translated into reduced injury rates (Adams et al., 2013; Laitinen & Päivärinta, 2010).

Overall, despite mixed results in many of the studies, all relevant interventions resulted in improvements in at least one safety behaviour/outcome. For this reason and given the variability in behavioural measures and design, it was not possible to calculate effect sizes, and nor did any of the papers report effect sizes. Unfortunately, this meant that comprehensive comparisons according to intensity/duration/frequency, theoretical basis, and use of BCTs could not be conducted for the safety behaviour studies.

3.4. Intensity, duration, and frequency of the interventions

Seven of the interventions were delivered over either one (Adams et al., 2013; Darragh et al., 2004; Kerr et al., 2007; Lusk et al., 1999) or two sessions (Bena et al., 2009; Forst et al., 2013; Sokas et al., 2009), one of which also included follow-up visits for six months (Adams et al., 2013). Another four involved the active delivery of intervention components for between eight and 26 weeks (Kines et al., 2013; Kines et al., 2010; Lingard & Rowlinson, 1997; Mancini et al., 2005), while four involved ongoing monitoring/inspections for between one-and-a-half and four years (Becker et al., 2001;

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Laitinen & Päivärinta, 2010; Lopez-Ruiz et al., 2013; Spangenberg et al., 2002). Amongst the interventions that measured injury rates (Adams et al., 2013; Bena et al., 2009; Darragh et al., 2004; Laitinen & Päivärinta, 2010; Lopez-Ruiz et al., 2013; Mancini et al., 2005; Spangenberg et al., 2002), those that were delivered over an extended time period were more likely to be effective (all four resulted in significant reductions, although one only when controlling for light vs. heavy construction work; Laitinen & Päivärinta, 2010; Lopez-Ruiz et al., 2013; Mancini et al., 2005; Spangenberg et al., 2002) than those that involved only one or two sessions (1/4 resulted in a significant reduction in pre-post analyses, although the time-series analysis was non-significant; Bena et al., 2009). In the study that involved the comparison of a standard and enhanced educational program, there were reductions in injuries in both groups over the six-month study period (7% and 12% respectively), but the difference between them did not reach statistical significance (Adams et al., 2013).

3.5. Theoretical Basis of the Interventions

Five interventions were based on theory – namely, the PRECEDE-PROCEED model (Bena et al., 2009), Goal Setting Theory (Lingard & Rowlinson, 1997), Integrated Safety Management Theory (Kines et al., 2013), the Health Promotion Model (Lusk et al., 1999), and the Predictors of Use of Hearing Protection Model (Kerr et al., 2007). Use of theory was inconsistent. In only one of the five theory-based interventions were the components of the theory measured at baseline and post-intervention and used to test the model (Kerr et al., 2007). Here it was shown that the theoretical variables of past behaviour, social models, and benefits/barriers accounted for 58% of the variance in the use of hearing protection devices at post-intervention (Kerr et al., 2007). In one study the theory was used to conduct formative research to identify the determinants of accident/injury risk and inform the intervention targets (Bena et al., 2009), and in the other three studies it was suggested that the theory

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informed the intervention targets and/or methods but this was not clearly reported or measured (Kines et al., 2013; Lingard & Rowlinson, 1997; Lusk et al., 1999).

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Table 1. Theoretical basis and behaviour change techniques used in interventions

Study	Theory	Shaping knowledge/ natural consequences	Feedback and monitoring/ goals and planning	Rewards and threat and/or scheduled consequences	Other BCTs
Adams et al., (2013).	Nil	Provide instruction on how to perform the behaviour; Information about health consequences.			Social support (emotional; includes motivational interviewing)
Becker et al., (2001). Bena et al., (2009).	Nil Precede-Proceed	Instruction on how to perform the behaviour; Information about health consequences; Salience of consequences.	Monitoring of outcomes of behaviour without feedback. Feedback on behaviour.	Incentive (outcome).	
Darragh et al., (2004).	Nil	Provide instruction on how to perform the behaviour.		Material reward (behaviour); Incentive (outcome).	
Forst et al., (2013).	Nil	Provide instruction on how to perform the behaviour.			Demonstration of the behaviour; Identification of self as a role model.
Kerr et al., (2007).	Health Promotion Model: Predictors of Use of Hearing Protection Model (PUHPM)	Information about health consequences.			Behavioural practice/rehearsal.
Kines et al., (2013).	Integrated Safety Management Theory		Goal setting (behaviour); Goal setting (outcome); Problem solving; Review behavioural goals.		

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Kines et al., (2010).	Nil	Provide instruction on how to perform the behaviour.	Feedback on behaviour.		Behavioural practice/rehearsal.
Laitinen & Päivärinta (2010).	Nil		Monitoring of outcomes of behaviour without feedback.	Social reward/incentive; Reward (outcome).	
Lingard & Rowlinson (1997).	Goal setting theory		Goal setting (behaviour); Feedback on behaviour.		
Lopez-Ruiz et al., (2013).	Nil		Monitoring of behaviour without feedback; Monitoring of outcomes of behaviour without feedback.	Punishment.	
Lusk et al., (1999).	Health Promotion Model (derived from social learning theory).	Provide instruction on how to perform the behaviour; Information about health consequences.			Demonstration of the behaviour; Credible source.
Mancini et al., (2005).	Nil	Instruction on how to perform the behaviour; Information of health consequences; Salience of consequences.	Monitoring of behaviour without feedback.		Credible source.
Sokas et al., (2009).	Nil	Information about health consequences.		Material reward (behaviour).	Behavioural practice/reward.
Spangenberg et al., (2002).	Nil	Provide instruction on how to perform the behaviour.	Feedback on outcome of behaviour.	Incentive (outcome); Reward (outcome); Behaviour cost.	

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1 3.6. Use of BCTs

2 BCTs included in the interventions fell under the broad categories of feedback
3 and monitoring (8 studies; Becker et al., 2001; Bena et al., 2009; Kines et al., 2010;
4 Laitinen & Päivärinta, 2010; Lingard & Rowlinson, 1997; Lopez-Ruiz et al., 2013;
5 Mancini et al., 2005; Spangenberg et al., 2002), shaping knowledge (8 studies; Adams
6 et al., 2013; Bena et al., 2009; Darragh et al., 2004; Forst et al., 2013; Kines et al.,
7 2010; Lusk et al., 1999; Mancini et al., 2005; Spangenberg et al., 2002), natural
8 consequences (6 studies; Adams et al., 2013; Bena et al., 2009; Kerr et al., 2007; Lusk
9 et al., 1999; Mancini et al., 2005; Sokas et al., 2009), reward and threat (5 studies;
10 Becker et al., 2001; Darragh et al., 2004; Laitinen & Päivärinta, 2010; Sokas et al.,
11 2009; Spangenberg et al., 2002), repetition and substitution (3 studies; Kerr et al.,
12 2007; Kines et al., 2010; Sokas et al., 2009), goals and planning (Kines et al., 2013;
13 Lingard & Rowlinson, 1997), comparison of outcomes (Lusk et al., 1999; Mancini et
14 al., 2005), scheduled consequences (Lopez-Ruiz et al., 2013; Spangenberg et al.,
15 2002), social support,^{33, 37} comparison of behaviour (Forst et al., 2013; Lusk et al.,
16 1999; 2 studies each), and identity (1 study; Forst et al., 2013). Interventions used
17 between one and five distinct BCTs; the number of BCTs used did not appear to be
18 related to effectiveness.

19 In order to determine the BCTs most commonly associated with effectiveness,
20 interventions were coded in three ways according to the inclusion of BCTs from each
21 of the following broad categories, as specified in the BCT taxonomy v1 (Michie et al.,
22 2013). These particular categories were selected and grouped together based on the
23 frequency of use within the interventions, as well as distinguishing between the

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1 particular change targets (i.e., attitudes/knowledge vs. volitional control and
2 intrinsic/extrinsic motivation for behaviour).

- 3 • Shaping knowledge and/or natural consequences;
- 4 • Feedback and monitoring and/or goals and planning;
- 5 • Rewards and threat and/or scheduled consequences.

6 The interventions that used BCTs from the categories ‘shaping knowledge’
7 (predominantly instruction on how to perform the behaviour) and/or ‘natural
8 consequences’ (predominantly information about health consequences) as their main
9 method of changing behaviour were less likely to result in significant reductions in
10 injury rates than those that did not include these techniques. Specifically, of the five
11 studies that included ‘shaping knowledge’/‘natural consequences’ and targeted injury
12 rates (Adams et al., 2013; Bena et al., 2009; Darragh et al., 2004; Mancini et al., 2005;
13 Spangenberg et al., 2002), only one showed a significant reduction in injury rates
14 (Mancini et al., 2005) compared to both studies that utilised alternate BCTs (e.g.,
15 rewards, incentives, punishment, feedback/monitoring; Laitinen & Päivärinta, 2010;
16 Lopez-Ruiz et al., 2013). It should, however, be noted that amongst the former
17 interventions (shaping knowledge/natural consequences), improvements were
18 observed in pre-post analyses but were not significantly different to the lower
19 intensity control group (standard education; Adams et al., 2013), time-series analyses
20 failed to confirm the pattern (Bena et al., 2009; Darragh et al., 2004), or the reduction
21 was only significant when controlling for other factors (light vs. heavy construction
22 work; Spangenberg et al., 2002).

23 In contrast, interventions that included BCTs from the ‘feedback and
24 monitoring’ (predominantly monitoring of behaviour/outcome without feedback, and

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1 feedback on behaviour) and/or ‘goals and planning’ (e.g., goal setting, problem
2 solving, and review behavioural goals) categories appeared more likely to be effective
3 in reducing injury rates (3/5 interventions effective; Laitinen & Päivärinta, 2010;
4 Lopez-Ruiz et al., 2013; Mancini et al., 2005) than those that did not (neither
5 effective; Adams et al., 2013; Darragh et al., 2004). The two interventions that
6 included these techniques and had non-significant reductions did, however, evidence
7 improvements using pre-post analysis (Bena et al., 2009) and when controlling for
8 other factors (Spangenberg et al., 2002). Of the four former studies, three used
9 monitoring of behaviour/outcomes without feedback (Laitinen & Päivärinta, 2010;
10 Lopez-Ruiz et al., 2013; Mancini et al., 2005), suggesting that knowledge of being
11 monitored/observed may be sufficient to change behaviour even when feedback on
12 that behaviour is not provided.

13 There was no clear difference in effectiveness between the studies that used
14 BCTs from the ‘reward and threat’ (e.g., material incentive/reward, social
15 incentive/reward) and/or ‘scheduled consequences’ (e.g., punishment) categories (2/4
16 effective; one other effective when controlling for light vs. heavy construction;
17 Laitinen & Päivärinta, 2010; Lopez-Ruiz et al., 2013) and those that did not (1/3
18 effective; the other two evidenced reductions in pre-post analyses but time-series
19 failed to confirm/not significantly different to lower intensity control group; Mancini
20 et al., 2005). However, the only study that included these techniques but did not
21 include ‘feedback and monitoring’ techniques was not effective in improving injury
22 rates (Darragh et al., 2004), whereas the three that used BCTs from both categories
23 were effective (although one only when controlling for light vs. heavy; Laitinen &
24 Päivärinta, 2010; Lopez-Ruiz et al., 2013; Spangenberg et al., 2002).

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1 None of the four studies that used ‘repetition and substitution’ (behavioural
2 practice/rehearsal; Kerr et al., 2007; Kines et al., 2010; Lusk et al., 1999; Sokas et al.,
3 2009) targeted injury rates and all used this strategy in addition to ‘shaping
4 knowledge’ and/or ‘natural consequences’, meaning it was not possible to judge its
5 effectiveness in isolation. The two studies that used ‘comparison of outcomes’
6 (credible source; Lusk et al., 1999; Mancini et al., 2005) were effective in improving
7 safety behaviour and reducing injury rates respectively, but again this BCT was used
8 in combination with others (e.g., shaping knowledge, natural consequences,
9 monitoring and practice) so its effectiveness alone is unclear.

10 3.7. Study quality

11 The quality of interventions was variable and generally methodologically poor
12 (see Tables 2 and 3). Amongst the ten randomised and non-randomised studies, four
13 scored between 3-5 (maximum score of 11, higher scores indicate lower risk of bias;
14 Becker et al., 2001; Bena et al., 2009; Forst et al., 2013; Sokas et al., 2009), four
15 scored between 6-8 (Kines et al., 2010; Lopez-Ruiz et al., 2013; Lusk et al., 1999;
16 Mancini et al., 2005), two scored 9 (Kerr et al., 2007; Kines et al., 2013), and only one
17 achieved the maximum score (Adams et al., 2013). The four randomised studies
18 (Adams et al., 2013; Kerr et al., 2007; Kines et al., 2013; Lusk et al., 1999) were
19 generally of higher quality than the non-randomised studies, with only one scoring in
20 the lower ranges (Lusk et al., 1999). The main bias-related issue identified was the
21 failure to blind participants and assessors to the intervention (Kerr et al., 2007; Kines
22 et al., 2013; Lusk et al., 1999); this was similar for the six non-randomised studies
23 (Becker et al., 2001; Bena et al., 2009; Forst et al., 2013; Kines et al., 2010; Lopez-
24 Ruiz et al., 2013; Mancini et al., 2005; Sokas et al., 2009). Additional issues identified

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1 included the failure to account for loss-to-follow-up or unclear reporting (Becker et
2 al., 2001; Bena et al., 2009; Forst et al., 2013; Lopez-Ruiz et al., 2013; Mancini et al.,
3 2005), compromised compliance with the intervention (Becker et al., 2001; Bena et
4 al., 2009; Mancini et al., 2005), and failure to recruit participants from the same
5 population or over the same time period (Bena et al., 2009; Forst et al., 2013; Lusk et
6 al., 1999; Sokas et al., 2009).

7 Of the six interrupted time-series interventions (two also included in above
8 assessment because they combined pre-post and time-series analyses), three studies
9 scored 3 (maximum score of 6, higher scores indicate lower risk of bias; Darragh et
10 al., 2004; Laitinen & Päivärinta, 2010; Spangenberg et al., 2002), and the other three
11 studies scored 4 (Bena et al., 2009; Lingard & Rowlinson, 1997; Lopez-Ruiz et al.,
12 2013). The main identified issues were a high or unclear risk of bias concerning the
13 intervention being independent of other changes or selective/other biases (Bena et al.,
14 2009; Darragh et al., 2004; Laitinen & Päivärinta, 2010; Lingard & Rowlinson, 1997;
15 Lopez-Ruiz et al., 2013; Spangenberg et al., 2002), and incompleteness of the data set
16 (Darragh et al., 2004; Laitinen & Päivärinta, 2010).

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Table 2. Methodological assessment of randomised and non-randomised studies

Study	Attempt made to blind study participants to received intervention	Attempt made to blind outcome assessors measuring intervention	Any of results based on “data dredging” were made clear	Analyses adjusted for different follow-up lengths	Appropriate statistical tests used to assess main outcomes	Reliable compliance with intervention	Accurate use of main outcome measures	Participant recruitment in different intervention groups were from same population	Participants in different intervention groups were recruited over same time period	Participants were randomised to intervention groups	Loss of participants follow-up taken into account	Total
Adams (2013)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	11/11
Becker (2001)	Unable to determine	No	Yes	Yes	Unable to determine	No	Unable to determine	Yes	Yes	No	Unable to determine	4/11
Bena (2009)	No	No	Yes	Yes	Yes	No	Yes	No	No	No	Unable to determine	4/11
Forst (2013)	No	No	Unable to determine	No	Yes	Yes	Yes	Yes	No	No	No	4/11
Kerr (2007)	Unable to determine	Unable to determine	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9/11
Kines (2013)	Unable to determine	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9/11
Kines (2010)	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unable to determine	Yes	8/11
Lopez-Ruiz (2013)	Unable to determine	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Unable to determine	7/11
Lusk (1999)	Unable to determine	No	No	Yes	Yes	Yes	Yes	Unable to determine	Unable to determine	Yes	Yes	6/11
Mancini (2005)	Unable to determine	Unable to determine	Yes	Yes	Yes	Unable to determine	Yes	Yes	Yes	No	No	6/11
Sokas (2009)	No	No	Unable to determine	Yes	Yes	Yes	Yes	No	No	No	Yes	5/11

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Table 3. EPOC methodological quality assessment of ITS studies

Study	Intervention independent of other changes	Intervention unlikely to affect data collection	Blinded assessment of outcome variable	Incompleteness of data set	Reliable statistical analysis	Free of selective and/or other risks of bias?	Total
Bena (2009)	Unclear risk	Low risk	Low risk	Low risk	Low risk	High risk	4/6
Darragh (2004)	High risk	Low risk	Low risk	Unclear risk	Low risk	High risk	3/6
Laitinen (2010)	High risk	Low risk	Low risk	Unclear risk	Low risk	Unclear risk	3/6
Lingard (1997)	Unclear risk	Low risk	Low risk	Low risk	Low risk	Unclear risk	4/6
Lopez-Ruiz (2013)	Unclear risk	Low risk	Low risk	Low risk	Low risk	Unclear risk	4/6
Spangenberg (2002)	Unclear risk	Low risk	Unclear risk	Low risk	Low risk	Unclear risk	3/6

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4. DISCUSSION

The purpose of this review was to evaluate the effectiveness of active, behaviour change safety interventions in the construction industry, with a particular focus on determining the intervention characteristics associated with successful injury reduction/improved safety behaviour. Although most of the interventions that measured injuries did result in reductions in the intervention groups, methodological issues such as the lack of a control group and non-equivalence of conditions at baseline make it difficult to draw firm conclusions about effectiveness. Despite this, several factors did appear to be differentially related to the likelihood of success. Firstly, single session interventions were less effective than those that extended over longer periods, suggesting that future interventions should utilise long-term change strategies rather than single educational/informational sessions. Further, it was found that the removal of the active intervention resulted in the previously observed improvements plateauing or a return to previous injury rates/safety behaviour. Although based on only two studies (Laitinen & Päivärinta, 2010; Lingard & Rowlinson, 1997), this pattern strongly suggests that lasting change in the areas of safety and injury prevention is dependent upon encouraging the development of intrinsic motivation (i.e., motivated by enjoyment/interest in the task itself or its natural consequences rather than extrinsic motivation: motivated only by the prospect of an external reward/punishment) within construction workers rather than relying on short-term interventions to prompt and maintain positive workplace behaviour.

Research has found that behaviour change interventions based on theory tend to produce larger effects than those that lack a theoretical basis (Webb et al., 2010). In the current review, only a third of the interventions mentioned a theoretical

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framework; only one used the theory to inform the intervention targets and methods, and measured the components of the theory pre- and post-intervention (Kerr et al., 2007). This is consistent with research in other health behaviours, where it has been found that while many studies mention theory in the introduction, or measure the theoretical components, rarely is the theory explicitly used to select intervention targets or methods (Hardeman et al., 2002; Michie & Abraham, 2004; Michie & Prestwich, 2010). Interestingly, however, the one study that was truly theory-based (Kerr et al., 2007) was not only amongst the higher quality studies, but also resulted in significant improvements in the use of hearing protection devices and demonstrated that the theory did indeed account for significant variance in the target behaviour, suggesting that the application of theory to interventions in the construction field is an important future direction.

Interventions that included active BCTs such as monitoring, feedback and goal setting were more likely to be effective than those that relied on providing information about health consequences or how to perform the behaviour. Similarly, studies that used rewards, incentives and punishment were more effective than those that merely provided information; however, the limited evidence also suggested that these strategies worked best when combined with feedback and monitoring. These findings are consistent with the extensive body of literature on the gap between knowledge/intention and actual behaviour (Hornik, 1989; Sheeran, 2002), and suggest that strategies aimed at improving actual behaviour and ways to translate positive intention/knowledge into action rather than strategies to improve worker's motivation/intention to engage in safety behaviours are more likely to result in successful behaviour change amongst construction workers.

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It is widely known that behaviour change interventions based on inducing fear are only effective when also combined with techniques to improve self-efficacy (Peters, Ruiters, & Kok, 2013; Witte & Allen, 2000). Consistent with this, a study based on the extended parallel process model that was excluded from this review because it was laboratory-based rather than involving construction workers in a real-life setting (Basil, Basil, Deshpande, & Lavack, 2013), found that fear was highest when threat messages contained low self-efficacy, whereas the inclusion of self-efficacy lowered fear ratings and improved attitudes. Although this study did not include a measure of actual behaviour, its positive results suggest that in order for interventions containing information on health consequences (including fear) to be effective in improving safety behaviour and reducing injury rates, techniques to boost self-efficacy are needed. Indeed, the one study in this review that did measure self-efficacy found a significant improvement from pre- to post-intervention (Kerr et al., 2007), suggesting that efficacy can be successfully targeted in construction.

The present findings are also broadly consistent with the previous reviews (Lehtola et al., 2008; van der Molen et al., 2012), in that the evidence suggests that passive interventions that do not actively involve workers in behaviour change have limited effectiveness. A further reason why the interventions that used BCTs designed to change knowledge and attitudes may not have worked is that, in the absence of formative theory-driven research to determine the factors associated with non-compliance, it was unclear whether poor knowledge and/or negative attitudes were indeed causally related to behaviour/injury rates. The observation that monitoring alone (i.e., without feedback) also resulted in significant reductions in injury rates, may provide a potential solution as to how to promote lasting behaviour change

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amongst workers following intervention participation (although there is limited evidence to suggest that monitoring alone is sufficient), without relying on extrinsic motivation (i.e., rewards) which are unlikely to lead to internalisation of the desired behaviour.

Regarding the improved adoption of safety behaviours, the results were less clear than those concerning injury rates. None of the intervention characteristics (theory-base, BCTs, intensity/duration/frequency) reliably differentiated between effective and non-effective interventions because all interventions resulted in at least one improvement. Significant differences in the targeted behaviours and measurement also made comparisons difficult. Despite this, it is likely that the findings for injury rates (which were more uniformly measured) are also relevant considerations for future intervention design.

Overall, these results suggest that the evidence for the effectiveness of safety interventions in the construction industry is sparse and inconsistent. Further, the available interventions were generally poorly designed, which limited the conclusions that could be drawn from the data – for example, many studies lacked a control/comparison group and those that did were often not equivalent at baseline or were drawn from a different population than the intervention. While improvements in study design and evaluation are clearly needed to allow for firm conclusions regarding effectiveness to be drawn, it should be noted, however, that the dynamic and constantly changing nature of the construction industry means that RCT designs with individual-level randomisation (typically considered the gold standard and necessary for obtaining level 1 evidence) are unlikely to be practical or valid in this context. Similarly, it may be unrealistic to expect that behaviour change be independent of

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other changes or that reporting practices themselves do not impact injury rates and safety behaviour. Despite such contextual considerations, however, more methodologically rigorous but feasible and field-appropriate research is needed to determine the most effective means for improving safety and reducing injuries in the construction industry.

4.1. Limitations and conclusions

In addition to the identified limitations of the reviewed literature, there were limitations to the current review such as the inclusion of only published material and therefore potential exclusion of government or other documents and grey literature, and limiting the search to the English language. Finally, it was not possible to conduct a meta-analysis due to the heterogeneity in methods used to assess and describe injury rates as well as differences in the mechanism hypothesised to be responsible for the observed changes. Nonetheless, tentative recommendations that emerged from the available data, and previous evidence suggesting that the introduction of safety legislation/regulation is not sufficient (Lehtola et al., 2008; van der Molen et al., 2012), include the need for the conduct of formative theory-driven research to determine the significant predictors of poor workplace safety behaviour and the occurrence of workplace injuries; more rigorous and consistent use of theory in intervention design; the adoption of active/volitional BCTs; and the implementation of long-term strategies that overcome the limited effectiveness of single session interventions and also encourage the adoption of intrinsic rather than extrinsic motivation for continuing safe behaviour. Finally, the systematic testing of such interventions using RCT designs (albeit with site-level rather than individual-level randomisation) is necessary to determine the most effective means for reducing the

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negative impact that inadequate workplace safety has on society at the individual, site, and economic levels.

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Table 1. Summary of study characteristics

Study	Sample	Intervention methods	Follow up Periods	Outcome measure	Relevant Results
Adams et al., (2013).	N=204 quarry workers from six quarries (three randomised to each condition).	Participants in both conditions attended a 1-2 hour health information session including an education talk; a display and discussion of posters showing minor and major eye injuries and consequences; instructions regarding care, handling and usage of protective eyewear. The standard education group then received five follow-up visits over 6-months to replace protective eyewear, collect reports on compliance and clarify any questions. The enhanced education group received 11 sessions of decreasing frequency over 6-months on ocular injury prevention including recorded short street-plays and messages, regular use of protective eyewear; group motivational sessions; and individual counselling by health workers for workers not regularly using protective gear.	Data collected half way through the intervention period (3 months) and at the conclusion of the six-month intervention period.	Ocular/eye injury rates; expressed as % decrease in incidence from baseline to 3 months and 6 months; Compliance with protective eyewear.	Injury incidence: At 3 months, the incidence of eye injuries had decreased by 16% in the enhanced education group and 13% in the standard education group compared to baseline. The cumulative reduction in eye injuries at 6 months compared to baseline was 12% in the enhanced education group and 7% in the standard education group. This difference was not statistically significant. Compliance: Compared to the standard education group, the enhanced education group had 16% (3 months) and 25% (6 months) increased compliance with protective eyewear.

Becker et al., (2001).	Total N not reported; 10 contractors (50-250 workers pre contractor)	"Fall-Safe" intervention included the development of written, company-wide and site-specific fall prevention programs, 8 hours of fall prevention training (supervisors); 2 hours (workers); designation of company and site fall prevention competent persons (CP); daily inspections of all sites by supervisors; weekly inspections by company CPs; establishment of a jobsite fall-safe committee that conducts monthly inspections. The program also incorporated incentives for the participating contractors.	Quarterly during the 1.5 year intervention period	Changes in safety audit and hazard control scores from baseline to post-intervention.	The intervention contractors improved their mean hazard control scores by 11 percentage points compared to 5 percentage points in the control contractors. This difference just missed statistical significance ($p = .06$). The change in mean program audit scores was significantly higher for the intervention contractors (21 points) compared to the control contractors (8 points); $p = .02$.
Bena et al., (2009).	N=2795	Safety-training program consisted of a basic module (completed by all workers), and four specific modules, which were completed according to the relevance of each module to the specific job within the railway project. Specific modules: (1) drivers, excavating machine operators, wheel loader drivers, construction machinery operators; (2) carpenters, iron workers, pump operators, bricklayers; (3) crane operators; (4) mixed. Each module consisted of 2 x 2 hour parts, with participants being required to pass a learning test in order to progress to part 2 or the next module. The content of each module addressed the risks involved in each work activity.	The training scheme ran between 2002 and 2006; data concerning injuries was collected every time an injury occurred.	Overall injuries; expressed as frequency of injuries per 10 days.	At the end of the training program the incidence of injuries had decreased by 16% amongst the workers who completed the basic module, and by 25% amongst the workers who had passed the test of a specific module relevant to their job (both $p < .01$). Construction workers: 21% decrease for basic module; 26% decrease for specific modules. Decreases were also observed amongst machine operators (4%, 34%), maintenance workers (4%, 58%) and unskilled workers (22%); however these were not significantly different compared to pre-training. The interrupted time-series model showed that injuries decreased by 6% from pre-training but this difference was not significant.

Darragh et al., (2004).	Total N not reported; 97 residential trade companies participated. Company size ranged from sole proprietors to > 100 employees (most < 50 employees)	The HomeSafe Pilot Program consisted of a 3-hour safety training and program orientation class; distribution of a pocket-size booklet "Guide to Safe Work Practices for Home Builders: HomeSafe 10 Point List"; and access to optional OSHA Training Institute-approved 10 hr construction courses.	Pre HomeSafe injury rates were taken from the period Jan 1994 until when the training occurred (1997); Injuries following the training (1997) until December 1998 formed the post-training data.	Overall injury rates and severe injuries (those resulting in time off work); expressed as number of injuries per year per total person hours worked in that year.	There was a downward trend in overall injury rates from 1994-1997. Descriptive analysis showed a significant difference from pre to post, but the Poisson regression (controlling for time trends) was not significant. The pattern of results for severe injuries (resulting in time off work) was identical - downward trend but no significant effect of the intervention.
Forst et al., (2013).	N = 446	Two workers from each of eight worker centres were selected to become peer educators; they participated in a 16 hour 'train the trainer' course before delivering the program to groups of workers (20 workers in each session). The 10 hour program was run over two sessions and consisted of manualised instructions, diagrams, exercises, and small group activities designed to cover the content of the OSHA mandated 10-hour curriculum for injury prevention on construction sites.	Baseline, immediate post-training, 3 month follow up	Self-reported safety climate perceptions, hazard knowledge, intentions (baseline/post); behavioural change (not defined), injury status, how unsafe work activities had been handled since training, "what's wrong with this picture?" (critique picture of worker), "what should the worker do?" (vignette requiring safety response)	Post-training: significant increases in knowledge for 2/4 items; increased recognition of hazards (based on "what's wrong with this picture?" responses); increased ability to communicate about hazards (based on "what should worker do?" responses). 3-month follow-up: workers reported feeling more aware of hazards at worksites; more critically assessed worksites; working more slowly and deliberately; greater concern for fellow workers; increased confidence to address hazards with supervisors; use of personal protective equipment. Responses moved from "no planned change" to "individual action" or from "individual action" to "relational/climate action" (defined as a higher level of safety action).

Kerr et al., (2007).	N=343	Participants randomly assigned to 1 of 4 intervention groups: (1) tailored; (2) tailored + booster; (3) targeted; (4) targeted + booster. The intervention (all groups): single-session interactive multi-media game-format educational program: participants had to foil a noise villain by using hearing protection. Targeted version: generic messages incorporating components of the PUHP model; Tailored version: individualised messages based on worker responses to survey Qs assessing components of the model. Six months later, participants in the booster conditions received an informational handout reminding them of the game theme.	Baseline, 6 months: booster (if in selected group); 12 month follow up	Self-reported % of time workers used hearing protection when exposed to loud noise in their most recent job, job before that and in the preceding 12 months.	There was a significant time effect with HPD use rising from 42% to 50% (tailored improved by 8.3%, targeted improved by 6.1%). There was no difference in the degree of improvement between the tailored and targeted groups and no significant effects of the booster on HPD use. 58% of the variance in HPD use was explained by past behaviour, use of social models of HPD use and benefits and barriers (support for the model).
Kines et al., (2010).	Total N not reported; N=5-17 workers on any given day from 5 construction work gangs.	The intervention involved worksite foremen receiving 8 bi-weekly coaching sessions by members of the research team to include safety issues in their daily verbal exchanges with workers. Following weekly on-site interviews with workers, foremen were given bi-weekly feedback regarding the verbal exchanges.	The intervention period lasted 16 weeks. Data collection at baseline, post-intervention and follow-up (between 8 and 16 weeks).	Frequency of safety-related communication; safety performance as observed by research team on-site walk-rounds.	In intervention group 1, there was an increase in foremen-worker safety exchanges from 6% at baseline to 62% post intervention and 46% at follow-up ($p < .001$). No increases were seen in intervention group 2. There was a significant increase in safety performance for the two intervention groups combined. No significant changes were seen amongst the control groups in communication or performance.

Kines et al., (2013).	Total N not reported. Workers from 14 metal companies participated; each company had 10-19 employees	Four dialogue meetings between research team and site owner/manager; >2 owner/manager led dialogues with workers. Dialogue meetings focused on leadership role in increasing safety (communication, identifying problems, establish remediation activities/priorities, initiating safety activities, follow-up evaluating activities). Specific targets: more visible safety leader, greater focus on order/tidiness, increased use of PPE. Subsequent meetings focused on following-up goals, problem solving challenges, setting new goals/tasks.	The intervention period varied from 10-18 weeks. Follow-up reports were conducted following a 4-7 week period of no intervention.	Safety performance index	At follow-up the intervention group showed significant increases on six of the eight survey factors (control only increased on one). The difference between the control and intervention groups was only significant for safety knowledge and safety involvement. The intervention and control groups both improved their safety index from baseline to follow-up but the difference between the conditions was not significant.
Laitinen & Päivärinta (2010).	Total N not reported; N=16 construction companies were part of the contest in 1997; this had increased to 20 in 2006 so data was based on differing N depending on which year it was collected.	"Safer Construction 2000" was initially a 3-year contest between construction companies in Finland. It involved the observation and assessment of safety conditions (working habits, scaffolding and ladders, machines and equipment, protection against falling, lighting and electricity, order and tidiness) in unplanned site visits (so sites could not prepare), and the review of safety plans. Incentives to perform well included being recognised at a public seminar each year and other rewards. Following the success and acceptability of the contest it has since been implemented on a permanent annual basis.	Data collection for the contest was conducted over the period 1997 - 2006	Overall/general accidents; expressed as no. of accidents per volume of building in cubic metre by region; Uptake of safety behaviours in each of the specified areas: working habits, scaffolding and ladders, machines and equipment, protection against falling, lighting and electricity, order and tidiness.	Significant increases in safety indices were observed from baseline following the introduction of the contest ($p < .001$). This trend stopped during 2001, coinciding with the contest not being held that year, and then continued to improve from 2002-2006. In several areas these improvements were seen as early as the first year of the contest. There was a decrease in injuries that corresponded to the introduction of the contest. The rate of decrease was significantly greater in the contest region compared to the control region; however, the absolute rate of injuries remained higher in the contest region.

Lingard & Rowlinson (1997).	Total N not reported; participants were workers and site staff from 7 construction sites.	Baseline assessments of safety performance in the categories of housekeeping, access to heights, bamboo scaffolding, and personal protective equipment were conducted for 17 weeks prior to introduction of the intervention. The intervention consisted of participative goal setting and performance feedback - goal setting meetings were conducted by the researcher and involved showing a series of slides depicting good and bad practice; giving workers feedback from the period of baseline measurement; and setting a realistic goal for improvement. Progress was then monitored and weekly feedback given for a period of 8 weeks.	Measurement of safety outcomes was taken twice weekly for the duration of the 34 week intervention period.	% of non-compliance with safety regulations	Housekeeping: Significant improvements in safety scores were seen in 5 of the 7 sites. A significant deterioration in safety was seen in 4 sites following the removal of the feedback intervention. Access to heights: Significant improvements in 2 sites (a further 3 improved but NS). A significant deterioration was observed on one site following removal. Bamboo scaffolding: No significant improvements were seen following introduction of the intervention. No improvements were seen in the control condition.
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Lopez-Ruiz et al., (2013).	N=507,262 workers from 1189 companies.	<p>Preferential Action Plans (PAP) incorporating issuance of warning letters to companies with a high number of occupational injuries; meetings between labour authorities and company managers; coordinating preventative recommendations with companies' occupational risk prevention services and working compensation insurance company; official visits from a health and safety technician; reports describing preventative situation; evaluation of compliance with legal rules concerning preventative measures; solutions and technical support; deadlines to solve detected faults; proposing possible sanctions for non-fulfilment of recommendations</p>	<p>Companies were followed up between 1999 and 2007. The intervention ran over a period of 3 years (2000, 2001, 2002).</p>	<p>Number of non-fatal occupational injuries at work resulting in at least one lost workday; expressed as no. of injuries per number of person-years.</p>	<p>Injury rates decreased significantly in all 3 intervention groups (2000 group: 12% decline; 2001: 14%; 2002: 11%). The comparison group's injury rate declined by 5% but was not significant. The difference between the intervention and comparison groups was also significant. The declines were particularly evident in companies with less than 10 workers; construction activity sector; sick leave less than 15 days; and mechanical injuries. Note: although a control group was included in the comparison, the intervention and control groups were not equivalent at prior to intervention.</p>
Lusk et al., (1999).	N=1028	<p>20-minute video (discussion between worker/narrator and occupational health nurse; workers sharing hearing protection information with each other); 15-minutes of hands-on guided practice; written handouts; and samples of hearing protection devices.</p>	<p>The intervention was delivered in a single session; post-test measures were collected 10-12 months after completion of the intervention.</p>	<p>Use of HPD (earplugs or earmuffs); expressed as average of 5 questions asking about % of time workers used HPD.</p>	<p>There was a significant main effect of the intervention. Participants who completed the intervention evidenced a 20% improvement in HPD use compared to baseline. There was no effect according to whether participants had been pre-tested. There was also a main effect of trade group. The intervention did not have a significant effect on participant's intention to use HPD.</p>

Mancini et al., (2005).	Total N not reported; N=237 metal-ware factories participated	Educational campaign: tailored brochure about eye injuries in metal workers and technical/legal preventative measures (distributed to metal workers; vocational secondary schools, hospital emergency departments/waiting rooms, trade union offices, town halls). Evening local television/radio interviews with an ophthalmologist and occupational physician were broadcast providing expert advice on the importance of use of protective equipment for the prevention of injuries. Educational articles appeared in local newspaper and a free magazine. Following the 6-month active intervention period, unannounced official inspections were performed to reinforce the message of the campaign and to monitor secondary outcomes. This phase lasted 4 years.	Measurement for the study was conducted over the period 1988-2003. Pre (1988 - 1990), peri-intervention (1991-1992), post-intervention reinforcement (1993-1996), late post (1997-2000), and very late post (2001-2003) periods were measured.	Eye injuries; expressed as no. of eye injuries per no. of workers at risk.	Overall reductions were seen in eye and non-eye injuries over the study period. The sharpest reduction was eye injuries amongst metal workers (80% reduction during the study period 1988-2003). There was a greater reduction in eye injury rates compared to non-eye injury rates amongst metal workers. Metal workers had a fivefold increased risk of an eye injury. Reductions in eye injury rates amongst metal workers were sustained following the main intervention.
Sokas et al., (2009).	N=175 (92 included in pre-post analysis)	The intervention was part of a 10-hour hazard awareness training program, which includes classroom learning, hands-on controlled workshop activities, and actual on-the-job experience in work settings. Workers attended two training sessions. Details of the training program were not reported in the paper.	Data collected at baseline and three-month follow-up; the intervention was delivered over two sessions (between Nov 2004 and Jan 2006).	Knowledge and attitudes as measured using a purpose-designed questionnaire; self-reported safety practices.	There were significant increases in fall and electrical knowledge following participation in the training sessions. There was no change in attitudes overall; however, fewer workers said they would accept an extra \$50 per day to work with less safety after training. Due to the measure of safety practices it was not possible to compare pre- and post-scores. There were no improvements in safety climate ratings from pre to post intervention.

<p>Spangenberg et al., (2002).</p>	<p>Total N not reported; study group included all employees at the Danish land works.</p>	<p>The intervention included attitudinal (e.g., banners, leaflets, newsletter, notice boards advertising the campaign and providing examples of good safety practices, info on safety initiatives, and feedback on results of the campaign) and behavioural components (e.g., a twice yearly financial award for the safest site, specific themed campaigns aimed at workers). In addition, monthly safety meetings were held between the contractors and site owner. The campaign was implemented in 1996 and ran until completion of the project in 1998.</p>	<p>Data on injury rates was collected on a monthly basis between 1993 and 1998.</p>	<p>Overall/general injuries; expressed as no. of injuries per one million working hours.</p>	<p>There was a statistically non-significant reduction (21%) in the number of injuries following the introduction of the campaign. When controlling for the type of construction (light or heavy), this rate increased to a 25% reduction in injuries and was statistically significant. Heavy construction work was associated with a higher injury rate than light construction work.</p>
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