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Literature Review and Environmental Scan for Better Translation of Research to Practice in Residential Construction

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Literature Review and Environmental Scan for Better Translation of Research to Practice in Residential Construction

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Executive Summary

The estimated size of the residential construction workforce (8.2 m) and the severity of the injury and disease problem support the need for greater safety efforts. This project's purpose was to review existing data and information and to develop efficient and workable strategies to translate more research to practice in order to improve safety and health among the residential building construction workforce. This review investigated ways to get to the "next step" of getting safer work practices much more widely adopted.

METHODS:

To identify relevant papers, the reviewer used currently available tools to search both the published literature and the "grey literature" of unpublished manuscripts and reports. Original research articles were reviewed, summarized, and evaluated. Findings of review articles and meta-analyses were also included. Very little research has been done that directly addressed safety research to practice in residential construction, therefore a broader net was cast that captured a larger number of studies that were judged to be relevant.

RESULTS AND DISCUSSION:

This review failed to locate any articles that described classical research to practice studies such as efforts to diffuse safety innovations across dozens to hundreds of firms in the US residential construction industry. As a result, we investigated related areas. There were a few studies that fit the classical research to practice paradigm and monitored the diffusion of technical innovations but they were unrelated to safety across the residential construction industry (described on page 72 in #5 - What works best to diffuse non-occup. safety innovations and get them adopted in construction?). The seven questions below review research that was judged relevant to improving the translation of research to practice in residential construction.

What are the best ways to identify and recruit firms in research to practice intervention studies? The largest problem was figuring out the best way to identify and reach the small firms and sole proprietor firms that are subcontracted to do actual work on projects run by larger firms. A promising resource is Hoover's, a for purchase, online database that contains a list of most US companies including many smaller subcontractor firms and that can be searched by NAICS code, number of employees, sales last year, and geographic location.

What helps or hinders adoption of safety innovations in construction and what barriers are often cited? Few studies of safety research to practice barriers were identified. However, barriers to better safety often cited by employers, employees, and other stakeholders in construction or residential construction included: 1) the nature of the work – temporary, exposed to the elements, and where the worksite itself must be built, and 2) the structure of the industry with its wide range of types of tasks and needed skills

along with the huge barrier posed by the extensive subcontracting of much of the work, mostly to very small subcontractors and sole proprietor operations. Other barriers included: 3) a lack of awareness of problems and solutions by both controlling firms and employees, and 4) perceived high costs or uncertain costs for adopting safer practices.

What works best to diffuse safety innovations to get them adopted in construction? There were more than two dozen studies judged relevant to understanding what works best for diffusing information and determining whether safety innovations get adopted in the construction industry. There was controversy in the review articles about which research studies met basic quality control criteria for intervention evaluation and about which of those studies that met the criteria actually worked to get changes adopted and to reduce injuries. According to one 2012 critical review, most high quality diffusion studies have not worked to reduce injuries except for one large, multi-employer worksite safety campaign coupled with worksite inspections and one drug-free workplace program.

What works best to diffuse safety innovations to get them adopted in other industries? There was good evidence from other industries that governmental regulation and enforcement can work to get worksite hazards identified and changes made that reduce injuries. In agriculture, a regulatory approach to tractor rollovers succeeded in reducing injuries. Among small businesses, evidence supported the value of regulation, worksite inspections, and engineering controls.

What works best to diffuse non-occupational health innovations and get them adopted in construction? There were theoretical and observational studies about the influence of various factors on the development and diffusion of technical innovations in the residential construction industry and the construction industry overall. Many of these studies appeared relevant to improving the translation of occupational health and safety research to practice and suggested that the development and diffusion of safer innovative products and practices in residential construction could benefit from a more dynamic and more open commercialization processes that encouraged greater involvement and more active roles for all of the actors and stakeholders up and down the commercialization and marketing chain including the end user employee.

What can observational studies about construction injuries add? Observational studies provided evidence about the prevalence of workplace hazards, the injuries associated with them, and likely strategic directions for injury prevention and hazard reduction. More widespread adoption of measures through research to practice translations or safety interventions inspired by observational studies appeared to be able to help prevent, for example, residential construction roof fall injuries and nail gun injuries.

What can economic analysis of intervention studies add to understanding adoption? Safety interventions were not often subjected to careful economic analysis of both their costs and their benefits. The studies

reviewed here argued for paying greater and more specific attention to what costs were incurred, and who experienced the costs of workplace injury and thus, who had a material interest in interventions designed to help prevent and control injuries at work. For small firms and sole proprietor firms engaged in residential construction, the costs of injury typically fell on the employer/firm owner, the employee, and the worker compensation insurer. All these actors, especially the builder in charge of the project, appear to have clear incentives to act if they can be appropriately informed and empowered.

RECOMMENDATIONS

The findings of this review suggest there are a number of viable strategies for translating research to practice more widely. First, researchers need to be aware of the trade-offs between “big science” and “little science.” Researchers can also benefit by promoting what can become “self-accomplishing” instead of relying on regulatory enforcement or academic research studies. Researchers may benefit by promoting research to practice ideas and projects that both benefit the bottom line and clearly reduce injuries and hazards first and then working back toward ideas that improve safety where the bottom line is neutral or worse. For the foreseeable future, researchers will also need to prioritize the promotion of interventions and innovations through agents like the industry leaders and industry organizations on the national, regional, and local level.

Introduction

Purpose: The purpose of this literature review and environmental scan, as defined in the research agreement requesting it, was to review existing data and information in order to develop efficient and workable strategies to reach employers and to improve safety and health among the residential building construction workforce by investigating ways to get to the "next step" in moving more research to practice and to get safer practices much more widely adopted across the US residential building construction industry.

Objectives: This is a literature review of research relevant to research to practice (r2p) in residential construction work that attempts to answer the questions:

1) how do we identify and develop lists of builders and subcontractors including sole proprietor operations?
2) what helps and what hinders the adoption of innovations?
3) what ways exist to expand the availability and use of effective interventions? and
4) what do we know (and not know) about effective dissemination of information and diffusion of innovations?

The research to practice problem in residential construction: Little is known about the degree to which:

1) residential builders and general contractors (i.e. residential building construction firms-NAICS code 2361) or
2) the firms they employ as subcontractors to do much of the work (specialty trade contractors-NAICS code 238 and other types of firms and individuals)

have adopted best practices for safer workplaces or what barriers exist that prevent or limit adoption. There is virtually no research data about which information sources that either builders or specialty contractors used and trusted in the last year for learning about more efficient or safer practices. Furthermore, little is known about what safety and health resources, including assistance, training materials, or other informational resources or services to which residential construction firms would like to have access (Gillen,2010; Boatman et al., 2007). To better understand the fundamental nature of the r2p problem in residential construction, a short description of the industry follows immediately below.

Size of the residential construction workforce and its injury and disease problem

Workforce size: The US Bureau of Labor Statistics estimated that there were 617,100 individuals employed in residential building construction (NAICS 2361) in 2010 (see TABLE 1).

There were also 3,591,800 individuals employed as specialty trade contractors (NAICS 238) performing a variety of tasks and some proportion of these individuals also participated in residential building construction work. There were also known to be workers not captured by the US BLS system working in residential construction an estimated 2.5 million additional self-employed, sole proprietor, or "one person" businesses without other paid employees in 2005 (NIOSH, 2008). Assuming there were still the same 2.5 million workers not counted by BLS estimation methods in 2010 as in 2005, this brings the total US construction workforce up from 5,701,000 to 8,201,000 in 2010. Some percent of the uncounted self-employed, sole proprietor or one person businesses without other paid employees worked in the residential construction sector. These individuals were difficult to classify and may not be captured by reporting systems.

Injuries and Illnesses: In 2010, the rate of nonfatal injuries in the residential building construction industry was higher than that for all US industries including state and local governments (4.2 injuries per 100 employees per versus 3.6) (SEE TABLE 1). The rate for specialty trade contractors was also higher than for all US industries (4.1 vs. 3.6). (See TABLE 1). Rates of fatal injury were available for only the construction industry as a whole (NAICS 23) and that rate was 9.8 per 100,000 full time equivalent employees versus 3.8 for all US industries including state and local government. On the other hand, occupational disease rates were lower than the rate for all US industries (21.1) for both residential building construction firms (4.6) and for specialty trade contractors (14.6). A consensus of research findings supports musculoskeletal disorders as the primary reason for disability and lost work time in the construction industry (CPWR, 2013).

Special characteristics of the residential construction industry and workforce

Direct employment versus subcontract: Like many other industries in the US, the residential building construction sub-sector of the construction industry has continued to consolidate over the last twenty years so that the average firm size has become much larger. In 2009, the overwhelming majority of both residential building firms (82%) and residential specialty trade firms (83%) were small employers with fewer than 50 employees (MLR, 2010). Almost two-thirds of the residential building firms in the US had less than $1m in annual receipts in 2007, while 31% generated between $1-$10m and 4% generated over $10m (Melman, 2010). Residential construction firm employee wages have fallen compared to those in nonresidential construction over the period between 2004 and 2009 (Moehrle, 2010).

Unlike some industries, there has been little “vertical” integration in residential building construction. Instead, nearly all general contracting firms (and larger firms in particular) have increased their use of subcontractors. As a result, the structure of the US residential construction industry has moved away from the model where a single builder and general contractor directly employs (as permanent employees) all the workers required to complete a single family or multiple family dwelling. Instead, most residential construction work is now overseen by a single builder and general contractor with much, if not all, of the actual work accomplished by a number of subcontracted firms and independent or sole proprietor employees. A 2003 survey of the industry (Ahluwalia, 2003) showed that two-thirds of all the residential builders and general contractors surveyed were contracting more than 75% of the total cost of their single family construction projects. In fact, 30% of those builders and general contractors reported subcontracting 100% of the total cost. Larger builders subcontracted more than smaller builders. In addition, those larger builders and general contractors also tended to purchase much if not most of the materials used by their subcontractors.

In a survey of builders and general contractors conducted in 2002, more than 90% reported that the types of work that they always sub-contracted included carpeting, electrical wiring, plumbing, security systems, brick work, foundations, and dry wall. Between 80 to 90% always subcontracted roofing, wood flooring, fireplaces, bathrooms, kitchen cabinets, kitchen countertops, exterior siding, painting, and concrete work. Twenty-six subcontractors were used on an average home. Large builders (building100 or more units) tended to use more subcontracting (i.e. an average of 29 subcontractors that year) (NAHB Economics Group, 2002).

In a more recent example, a 2007 survey showed that residential builders and general contractors directly employed mostly carpenters (48%), laborers (20%) and first line supervisors and managers (13%). The rest of the work was contracted out to subcontractors. Total employment in residential construction was estimated to be 949,000 for builders and general contractors compared to 2,272,000 for specialty trade contractors (ERD, 2011). These studies provide evidence that residential builders typically self-accomplish little and that larger builders tend to self-accomplish the least. Efforts to improve the translation of research to practice so as to improve job-related safety and health in residential construction will need to address the divide between builders who control the worksite and the subcontracted workforce that accomplishes the work.

Undercounted firms and workforce: US Bureau of Labor Statistics workforce estimates are believed to fail to reflect the actual numbers of individuals employed in residential construction. Many of the smallest firms consist of independent individual employees or sole proprietors who are not likely to be counted because they are independent family firms with only one employee.

Implications for improved research to practice: As in most industries, it is the small firms and the individuals working independently that are least likely to be well-equipped to recognize or deal with workplace health or hazard risks in an effective way. They are also most likely to face the strictest cost pressures in their employment arrangements so safety may be perceived as "a luxury they can't afford". Unless the "umbrella firms" that control each residential construction worksite (usually the residential builder and general contractor), can be held accountable and forced to extract compliance from the subcontracting firms and independents, improvements in research to practice that improve safety and health will be difficult.

Legally, the lead firm, typically a single builder and general contractor, is responsible for providing a safe place to work for all employees, including those employed by subcontracting firms or those employees working independently. When a general contractor is used, he or she and all sub-contractors may be held liable since it is their duty to ensure a safe workplace and warn workers of hazards. General contractors also have a legally-mandated responsibility to hire competent workers and to comply with safety regulations (OSHA, 2013):

> "§ 1926.16 - Rules of construction.
>
> (a) The prime contractor and any subcontractors may make their own arrangements with respect to obligations which might be more appropriately treated on a jobsite basis rather than individually. Thus, for example, the prime contractor and his subcontractors may wish to make an express agreement that the prime contractor or one of the subcontractors will provide all required first-aid or toilet facilities, thus relieving the subcontractors from the actual, but not any legal, responsibility (or, as the case may be, relieving the other subcontractors from this responsibility). In no case shall the prime contractor be relieved of overall responsibility for compliance with the requirements of this part for all work to be performed under the contract.
>
> (b) By contracting for full performance of a contract subject to section 107 of the Act, the prime contractor assumes all obligations prescribed as employer obligations under the standards contained in this part, whether or not he subcontracts any part of the work.

(c) To the extent that a subcontractor of any tier agrees to perform any part of the contract, he also assumes responsibility for complying with the standards in this part with respect to that part. Thus, the prime contractor assumes the entire responsibility under the contract and the subcontractor assumes responsibility with respect to his portion of the work. With respect to subcontracted work, the prime contractor and any subcontractor or subcontractors shall be deemed to have joint responsibility.

(d) Where joint responsibility exists, both the prime contractor and his subcontractor or subcontractors, regardless of tier, shall be considered subject to the enforcement provisions of the Act." (OSHA, 2013)

Table 1. Size of the workforce and rates of injury and disease, US construction workforce, 2010

Industry (and NAICS code)	Average annual employment (in 000s)	Nonfatal injuries (per 100 employees/yr)	Illnesses (per 10,000 employees/yr)	Fatal injuries (per 100,000 FTE/yr)
All US industries including state and local government	124,868.5	3.6	21.1	3.8
Construction (23)	5,701.5	3.9	12.3	9.8
Construction of buildings (236)	1,282.3	3.4	6.7	-
Residential building construction (2361)	617.1	4.2	4.6	-
Specialty trade contractors (238)	3,591.8	4.1	14.6	-
Foundation, structure, and building exterior contractors (2381)	714.0	5.0	22.1	-
Poured concrete foundation & structure contractors (23811)	152.0	4.4	8.7	-
Structural steel and pre-cast concrete contractors (23812)	69.0	4.7	43.7	-
Framing contractors (23813)	59.5	5.5	-	-
Masonry contractors (23814)	144.8	4.8	12.5	-
Glass and glazing contractors (23815)	52.1	5.8	-	-
Roofing contractors (23816)	164.5	5.5	37.9	-
Siding contractors (23817)	33.6	5.1	-	-
Building equipment contractors (2382)	1,671.3	4.1	9.2	-
Electrical contractors (23821)	735.5	3.6	6.6	-
Plumbing, heating, and air-conditioning contractors (23822)	816.3	4.7	12.5	-
Other building equipment contractors (23829)	119.5	3.3	2.6	-
Building finishing contractors (2383)	678.2	3.7	8.5	-
Drywall and insulation contractors (23831)	217.4	4.9	10.6	-
Painting and wall covering contractors (23832)	173.1	2.7	13.4	-
Flooring contractors (23833)	63.9	-	-	-
Tile and terrazzo contractors (23834)	44.8	1.4	7.3	-
Finish carpentry contractors (23835)	117.8	3.7	-	-
Other building finishing contractors (23839)	61.2	3.6	-	-
Other specialty trade contractors (2389)	528.3	3.5	30.3	-
Site preparation contractors (23891)	268.6	3.4	19.4	-
All other specialty trade contractors (23899)	259.6	3.7	42.2	-

a. US Bureau of Labor Statistics. Table SNR05. Incidence rate and number of nonfatal occupational injuries by industry and ownership, 2010 and Table SNR08. Incidence rates of nonfatal occupational illness, by industry and category of illness, 2010 at http://www.bls.gov/iif/oshsum.htm and Table A-1. Fatal occupational injuries by industry and event or exposure, All United States, 2010 at http://www.bls.gov/iif/oshwc/cfoi/cftb0250.pdf

Methods:

Locating and selecting papers:

To complete this literature review and environmental scan, the reviewer searched out available published papers, along with unpublished reports and other literature relevant to moving occupational safety and health research into practice in construction and residential construction in particular. Search terms included: residential construction, construction, intervention, injury, and safety. The following sources were used:

1. Occ-Env-Med-L Internet Mail List (Association of Occupational & Environmental Clinics, Univ. of North Carolina <http://occhealthnews.net/occ-env-.htm>)
2. Pub Med (US National Library of Medicine, National Institutes of Health < http://www.ncbi.nlm.nih.gov/pubmed >)
3. Google Scholar (http://scholar.google.com/)
4. CPWR website (<http://www.cpwr.com/>)
5. Occupational Safety and Health Administration, US Department of Labor website (<http://www.osha.gov/doc/index.html>
6. National Institute of Occupational Safety and Health, US Department of Health and Human Services construction website (<http://www.cdc.gov/niosh/topics/construction/>)
7. YouTube website (<www.youtube.com/ ->)
8. National Association of Home Builders website (<http://www.nahb.org/>)
9. Google website (<>)

The first three sources were checked for relevant publications up through June 2nd, 2013 (e.g. Occ-Env-Med-L Internet Mail List, PubMed, and Google Scholar). Studies were examined and their results incorporated into this review. The “gold standard” is double blind control trials; although few papers in the occupational health literature manage this. This review does include papers with deficiencies in the intervention evaluation methods that they used, so long as evident limitations could be described and noted as limiting factors (for criteria for intervention evaluation methods see Robson et al., 2001 and Van der Molen et al., 2012). We point out some of the methodological problems in intervention administration and intervention evaluation in the text. Readers are referred to the papers themselves for the exact details of each study.

How the studies were evaluated and the conventions used in writing the report and constructing the tables:

How the papers were evaluated: All papers deemed relevant were acquired in full and the electronic documents were stored as pdf files. The papers were categorized by review

question(s) and incorporated into the narrative. Those papers judged to be most relevant to residential construction research to practice or injury intervention research were included in text tables where, in some cases, portions of their abstracts or text appear. In some cases, the text of critical review commentaries was quoted verbatim in the manuscript.

Conventions used in writing the report and constructing the tables: For the purpose of this report, much of the text in many of the tables consists almost exclusively of verbatim extracts from the abstracts or the bodies of the papers. Within these tables, we made a few revisions (such as parenthetical references to tables within the papers that this review's table text came from were dropped, and British spelling replaced with American English). When studies were described in the body of this literature review and environmental scan, the details of the studies being discussed were paraphrased by the author, unless the directly cited text has been set off by quotation marks and/or smaller margins.

Definitions

What is research to practice (r2p) and what is safety intervention research? – do they overlap and how?

Research to practice is a fairly new term in the occupational safety and health scientific literature and very few of the existing papers reviewed for this manuscript made any mention of it. In this review, just six of the 153 references mention it in their titles (Fiske and Earle-Richardson, 2013; NIOSH, 2013; Lum, 2012; Gillen, 2010; Glasgow and Emmons, 2007; Bero et al., 1998). NIOSH has defined research to practice as a collaborative process that "combines the generation of knowledge with the adoption of that knowledge in the workplace to reduce worker injury and illness" (NIOSH, 2013). There are, of course, a very large number of intermediate steps between the generation of knowledge and the adoption of that knowledge (Fiske and Earle-Richardson, 2013). Because the research to practice label can cover any of these steps, from generation to adoption of knowledge, it is probably better conceptualized as a category covering a variety of types of work.

Safety interventions have been defined as "an attempt to change how things are done in order to improve safety. Within the workplace it could be any new program, practice, or initiative intended to improve safety (e.g., engineering intervention, training program, administrative procedure)" (Robson et al., 2001). The safety intervention studies that constitute most of the papers reviewed for this manuscript focus on determining whether adoption of new programs or practices occurs along with whether there are reductions in worker injuries and illnesses.

We made a decision to select, for this manuscript, safety intervention papers: 1) that "attempt(ed) to change how things are done in order to improve safety" (Robson et al., 2001) and measured health or hazard outcome changes, and 2) that made these kinds of efforts on a relatively large scale among multiple firms or projects or among large employee groups on a single project. We also decided to relegate the small scale studies of a dozen or fewer employees or laboratory subjects that tested the health, hazard or work performance measures of a new practice or engineering intervention or administrative procedure to Appendix #1. As a result, this manuscript represents a highly selective review of the literature. Essentially, we considered improvement in health and hazard outcomes among large groups or many firms to constitute the accomplishment of research to practice. This manuscript does not address some of the steps in the chain of events from research to practice such as 1) the process of nurturing experimentation and the development of innovations or 2) the research to market process of commercializing a proven innovation to make it easy to acquire and adopt (aside from the studies on page 71 in #5 What works best to diffuse non-occupational innovations and get them adopted in construction? – see Koebel, 2008; Ganguly et al., 2010; McCoy et al., 2010; 2009).

Results and Discussion

We failed to locate any articles that described classical research to practice studies such as efforts to diffuse safety innovations across dozens to hundreds of firms in the US residential construction industry. As a result, we investigated related areas. There were a few studies that fit the classical research to practice paradigm and monitored the diffusion of technical innovations unrelated to safety across the residential construction industry (described on p. 71 in #5 What works best to diffuse non-occupational safety innovations and get them adopted in construction?). Seven questions relevant to improving the translation of research to practice in residential construction guided the review process and the presentation of results.

1. What are the best ways to identify and recruit firms participate in research to practice intervention studies?

Difficulties identifying and recruiting firms

There are a number of difficulties one encounters when trying to find a sampling frame that representatively reflects the employees and firms working on typical residential construction worksites.

First, the firms and employees easiest to identify are likely doing very little of the work. The firms that are listed on the building permits as the lead builder and general contractor are likely to be self-accomplishing only a minority of the actual work, and may do none at all. Residential construction has evolved into a component industry where the controlling firms subcontract out most or all of the actual work to specialty trade contractors or to sole proprietor firms (as described in the Introduction above starting on p. 5).

Second, the specialty trade contractors and sole proprietor firms who accomplish much, if not most or even all of the work, are much harder to identify and track down. Building permits typically list only the lead firm, a builder and general contractor, on the residential building construction project record. Home builder industry associations are typically made up of lead firms like this, builders and general contractors, and include few or no specialty trades contractors or sole proprietor firms.

Third, there is no incentive for the least visible specialty trades contractors or sole proprietor firms to make themselves known or available for research purposes.

Methods used in previous work

One option, used by Koebel, 2008, has been to contact either the National Association of Home Builders or one of its local state or regional affiliates and request that their research unit develop a sampling frame of their members representing the parameters required by the study design (e.g. geographic location, operation type, and operation size) (Koebel, 2008). National Association of Home Builders sampling frames may or may not provide good representation of specialty contractors, likely under-representing the smallest scale firms and sole proprietor operations. Later on, (see p. 71 #5 What works best to diffuse non-occupational safety innovations and get them adopted in construction?), we describe a series of studies by Koebel and coauthors that used samples of builders from the National Association of Home Builders. Response rates were low, ranging from 5% to 16%.

Another method is to work though local Chambers of Commerce thinking they are more likely to have small construction subcontractors and general contractor firms enrolled as members than more expensive local, regional, or national associations of homebuilders. The advantage of using lists produced by the National Association of Homebuilders is that their database is more likely to include most if not all of the builder firms (although missing most of the subcontractors).

Methods with the best potential

What appears to be the best option is to use the database of national businesses maintained by Dunn and Bradstreet called Hoover's and is available online to paid subscribers at (http://www.hoovers.com/). Hoover's claims it maintains the world's largest database of company and industry information using an in-house editorial staff of industry experts to keep it up to date. Hoover's provides a searchable, online list of US companies that can be investigated by NAICS code, geographic location down to county and zip code, number of employees, and gross sales in the previous year. The database provides names and addresses of the operations as well as telephone numbers. This approach was suggested by a NIOSH researcher (Cunningham, 2013). No published or ongoing studies were identified that used Hoover's to develop samples for the study of residential construction firms. Other research using Hoover's is available (Carroll, 2013; Liu et al., 1997).

2. What helps or hinders adoption of safety innovations and what barriers are often cited?

Eight factors which influence residential construction safety (and perhaps research to practice)

Only one paper explicitly mentioned or focused on improving the translation of safety research to practice (r2p) (i.e. McCoy et al., 2012). A number of studies were available that identified factors believed to impede the adoption of better residential construction safety. They are briefly reviewed below. TABLE 2 lists studies that have identified factors believed to be, in part, responsible for the industry's high rates of injury and disease. Many of these same factors may hinder research to practice and the adoption of innovations. A short list of eight factors follows:

1. There are many small businesses with special vulnerabilities: This problem has been cited repeatedly by researchers and industry experts. "Smaller builders differ from larger construction firms…" "….shorter periods of employment, frequent changes in jobsites, high worker turnover, and a higher number of workers with sporadic work patterns." (Hung et al. 2011). Construction industry experts have characterized some of the problems facing the industry as including "…a preponderance of small employers, short term contracting and temporary employment, multi-employer worksites, multi-cultural workforce, and episodic exposure to risks" (Gillen and Gittleman, 2010).

2. There is a traditional culture that is at odds with valuing safety: As in some other industries (e.g. production agriculture), some proportion of construction industry workforce members and their immediate supervisors and managers may devalue attention to occupational safety (Wamuziri, 2013). Approaching high risk situations with caution and careful efforts to minimize risk may be, among individuals with this perspective, associated with feelings of being less admirable, less courageous, less worthy, or lacking in other ways. In fact, in some high hazard workplaces where injury risks are highly prevalent, the most courageous stand that an individual can is take may be the viewpoint that living with injury and disease risks is unacceptable. These and other aspects of "traditional culture that devalues safety" may contribute to some individuals being especially resistant to change or new thinking about how to attain greater safety at work (Kramer et al. 2010).

3. Control issues as they relate to safety: Other studies have cited problems stemming from the power differential between employees and the employer such as “supervisor pressure to work fast, workers’ necessity for work and fear of retaliation if they speak up about unsafe conditions, lack of training, and language and cultural differences” (Roelofs et al., 2011). The Roelofs study actually found that language barriers and cultural factors were less influential than factors related to power differentials. Subcontractors and employees may be faced with questions such as

1) are you/your firm expected to comply with safety and health regulations on the worksites you work on?

2) do you have the informational resources you feel you need to comply with worksite safety and health regulations,

3) do you have the material resources you feel you need to comply with worksite safety and health regulations?,

4) are you being paid enough to comply with safety and health regulations?, or

5) are you getting assistance from your home builder site manager so you can comply with safety and health regulations? (Albers, 2013).

Both larger and smaller firms and workforce members may experience a very limited ability to influence building design, material specifications, materials production, and site management (Entzel et al., 2007).

4. Cost, productivity and quality issues: Other barriers cited in recent papers included the “cost of innovations,” that “any productivity or quality advantages of safety are not sold well” (Kramer et al., 2010). There is a perception that detrimental effects on costs, productivity and product quality are barriers and that greater attention needs to be paid to producing evidence to counter this perception (Entzel et al., 2007; Kramer et al., 2010; Wanberg et al., 2013).

5. Other issues: Studies have reported perceptions that innovations with strong safety and productivity advantages “often seem too complex to adopt,” that “ the ease of adoption or compatibility of many innovations are not sold well.” Other studies have noted perceptions that “If other local construction firms aren’t already doing it, why should we?” Lack of awareness of safety as a problem has been cited along with system barriers, cultural barriers, lack of a competitive environment, and lack of awareness and knowledge of the innovation (Kramer et al., 2010; Esmaeili, 2012). Barriers to greater safety have included

cost, availability, safety, effects on productivity, impact on trade jurisdiction, worker knowledge and training, and jobsite conditions (Entzel et al., 2007).

6. A cross –industry comparison study: perceptions of barriers to accounting innovations in other industries: A review of seven cases in Sweden analyzed barriers to the adoption of accounting tools that improved profitability (Johanson,1997). Interviews were conducted with 96 managers from a range of industries (health care, telecommunications, local government, and banking). The interviews showed that the attitudes of the managers were uniformly supportive of the concept of using the new accounting tools to improve profits. On the other hand, it was clear the accounting tools had not been widely adopted. The author noted that this was an instance where "individual cognitive maps have been changed … but (the) organizations' habitual behavior remains unchanged. Why?" (Johanson, 1997). The four reasons these same managers most commonly cited were:

1) they said they hadn't heard about the specific accounting tool that was being promoted to their company,
2) they said the firm's information systems were at fault because they did not collect or present the types of information a manager would need to track the problems the accounting tools would help solve,
3) the managers said their firm did not capture and make available other information such as important indicators, standard costs, or causal relationships that could be used to document the need for better accounting tools (or their success once adopted),
4) managers said that there was no demand from top management for improvements of this type.

The type of situation in the accounting tool study previously mentioned may be highly relevant to efforts to improve safety research to practice and the diffusion of safety innovations among medium and smaller-sized residential construction firms. In Johanson (1997), the innovation was essentially pure profit once it was adopted – a better accounting tool that made money for your firm soon after it was adopted. But when the researcher tried to get the accounting tool adopted in 96 different firms from a range of types of private and public sector businesses, they failed. The researcher investigated what could have gone wrong. He learned that neither the opportunity for improved profits with the new tools, nor any of the drawbacks of continuing to use the old tools, ever "showed up on the radar" of the middle managers in charge. The barriers confronting research to practice change were deeply embedded in the management system and constituted a type of "institutional

blindness" to opportunities for improvement. This feature of the firms in the Johanson (1997) study may, along with other factors specific to construction, help explain what hinders occupational health and safety research to practice improvements in residential construction. Those wishing to implement innovations will need to address the system in which change will need to occur as well as the change itself.

The implications for better translation of safety research to practice in construction parallel the findings of the Johanson study about trying to improve translation of accounting research to practice. In many construction firms, one problem may be that no one in the organization is looking for ways to improve to begin with and, because safety is not a priority, no relevant data gets collected and presented about occupational safety problems, costs, or trends. Managers in these firms were essentially "wearing blinders" that kept them focused exclusively on other, non-safety-related outcome measures all the time. The recommendation for overcoming this barrier is for residential construction firms, especially builders who do not self-accomplish most actual on-site work, to arrange to get better worksite health and hazard data collected, analyzed, and reported to them in a way that encourages them to develop a continuing improvement process around workplace safety. Other researchers have also noted that these types of organizational barriers to better safety can be overcome if decision makers can be informed about the influence of the better methods on the work environment, work performance, and profits (Rose et al., 2011). Another approach would be to integrate attention to workplace safety and the work environment into existing decision support tools.

7. Barriers to better translation of research to practice in fields other than occupational safety: The largest proportion of existing papers we identified were concerned with how to reduce the gap between research and practice have been published for and about the health care field (e.g. Glasgow and Emmons, Dunnapfel et al., 2013; Bero et al., 1998). Health care researchers have expressed concern because studies in a variety of health care areas suggested that evidence-based, best practice healthcare interventions were implemented only about 50% of the time. In health care, the barriers that have been determined to slow or impede the translation of research to practice in health care included "historical, political, social, economic, scientific, cultural and organization factors" (Glasgow and Emmons, 2007). Much like typical residential construction firms, the health care providers were facing many of the same types of barriers to better translation of research to practice (e.g. historical, cultural and organizational, economic). Unlike typical residential

construction firms, health care providers had typically been eager to learn about and adopt better evidence-based practices. In addition, the use of best safety practices "about 50% of the time" would likely represent important progress for the residential construction industry.

8. Barriers to better partnerships between the construction industry and academics: One study reviewed some of the literature on problems with applied research in construction that focused on the relationship between academia and industry as it affected the translation of safety research to practice (McCoy et al., 2012). This paper also included an examination of nine case studies "targeting various topics within the field of construction industry safety" and defined as "small scaled-NIOSH funded projects, targeting specific NORA goals and intended to result in future research opportunities." The case studies included individual interviews of personnel associated with the projects. McCoy and coauthors at Virginia Polytechnic Institute and State University identified barriers in the case studies that previous research had argued posed obstacles to effective partnerships between academia and industry. Those attributable to academia included:

1) "differences in culture and incentives relative to industry",
2) academics "are disillusioned by industry",
3) academics "have unrealistic demands",
4) academics "are unwilling to research outside initiated projects", and
5) academics "ineffectively communicate research findings".

Barriers that posed obstacles attributable to industry included:

1) "industry often turns to consultants given differences in values",
2) "industry requires quick outcomes to gain a competitive edge",
3) "industry is reluctant to commit to long term R&D given short-term shareholder expectations", and
4) "industry often changes its expectations relatively quickly".

According to the authors, both academia and industry also represented organizations that "are linked to events where the surrounding environments are changing at a dynamic rate" (McCoy et al., 2012). The conclusions of the paper included the posing and testing of a model for translational research that addressed some of the barriers identified in academic research applied to industry adoption of safety in construction. This model, entitled "research to practice to research" (r2p2r) is iterative or repeats again and again. It identifies deficiencies at each of six proposed stages in its r2p2r model: translation, implementation,

evaluation, reformulation, investigation, and verification. McCoy et al. have clearly devoted research efforts to identifying barriers to the translation of research to practice in the construction industry. Aside from better partnerships between academics and industry, it is unclear to this reviewer what McCoy et al. believe should change to improve the translation of safety research to practice.

Discussion of barriers

There were very few papers that focused on barriers to better translation of safety research to practice. Instead, most of the available literature concerned itself with barriers to better safety in residential construction or factors believed to contribute to the industry's high rates of injury. A number of barriers were identified from the studies reviewed in this section. Some of the barriers were typical of those that plague many industries (e.g. cost, productivity and quality issues; cultural and organization factors). Some of the barriers were particularly problematic or exacerbated in the residential construction sector (e.g. many small businesses with special vulnerabilities due to short term contracting; control issues such as the power differential between the builder and the subcontracted firms). A better understanding of and appreciation for the various barriers may be useful for determining what is likely to work and for suggesting directions about how to improve and optimize r2p translation methods that show promise.

TABLE 2. Barriers that hinder the adoption of innovations		
Study citation	Barriers	Notes
Kramer DM, Bigelow PL, Carlan N, Wells RP, Garritano E, Vi P, Plawinski M. Searching for needles in a haystack: identifying innovations to prevent MSDs in the construction sector. Appl Ergon. 2010 Jul;41(4):577-84.	The traditional culture of the construction sector and worksites devalues new thinking Cost of innovations Any productivity or quality advantages of safety are not sold well Innovations with strong advantages often seem too complex to adopt The ease of adoption or compatibility of many innovations are not sold well If other local construction firms aren't already doing it, why should we? Lack of awareness of safety as a problem System barriers Cultural barriers Lack of a competitive environment Lack of awareness and knowledge of the innovation	
Roelofs C, Sprague-Martinez L, Brunette M, Azaroff L. A qualitative investigation of Hispanic construction worker perspectives on factors impacting worksite safety and risk. Environ Health. 2011 Sep 30;10:84.	Supervisor pressure to work fast Workers' necessity for work and fear of retaliation if they speak up about unsafe conditions Lack of training Language and cultural differences	
Entzel P, Albers J, Welch L.. Best practices for preventing musculoskeletal disorders in masonry: stakeholder perspectives. Appl Ergon. 2007 Sep;38(5):557-66.	Cost Availability Safety Effects on productivity Impact on trade jurisdiction Worker knowledge and training Jobsite conditions Limited ability to influence building design, material specifications, materials production and site management	
Albers J. Personal Communication. December 3rd, 2012 phone call to Jim Albers, US NIOSH for suggestions for barriers for the subcontractor version of the needs assessment questionnaire	Are you/your firm expected to comply with safety and health regulations on the worksites you work on? Do you have the informational resources you feel you need to comply with worksite safety and health regs? Do you have the material resources you feel you need to comply with worksite safety and health regs? Are you being paid enough to comply with safety and health regulations? Are you getting assistance from your home builder site manager so you	

	can comply with safety and health regs	
Gillen M, Gittleman JL. Path forward: emerging issues and challenges. J Safety Res. 2010 Jun;41(3):301-6.	A preponderance of small employers, Short term contracting and temporary employment, Multi-employer worksites, Multi-cultural workforce, and Episodic exposure to risks	
Hung Y, Smith-Jackson T, Winchester W. Use of attitude congruence to identify safety interventions for small residential builders. Construction Management & Economics. 2011;29(2): 113-130.	Smaller builders differ from larger construction firms: …. shorter periods of employment, frequent changes in jobsites, high worker turnover, and a higher number of workers with sporadic work patterns	
Esmaeili, B. and Hallowell, M. Diffusion of Safety Innovations in the Construction Industry. J. Constr. Eng. Manage. 2012;138(8), 955–963.	Reverse bandwagon: if everyone else isn't doing it …	
McCoy AP, Saunders L, Kleiner B, Blismas N. Application of Safety Project Interview Data to a Cyclical Research Model of Translation. International Journal of Construction Education and Research. 2012;8(4):260-280.	Those attributable to academia included: 1) "differences in culture and incentives relative to industry", 2) academics "are disillusioned by industry", 3) academics "have unrealistic demands", 4) academics "are unwilling to research outside initiated projects", and 5) academics "ineffectively communicate research findings". Barriers that posed obstacles attributable to industry included: 1) "industry often turns to consultants given differences in values", 2) "industry requires quick outcomes to gain a competitive edge", 3) "industry is reluctant to commit to long term R&D given short-term shareholder expectations", and 4) "industry often changes its expectations relatively quickly". Both academia and industry also represent organizations that "are linked to events where the surrounding environments are changing at a dynamic rate"	

3. What works best to diffuse safety innovations and to get them adopted in construction?

There were few published papers or other studies that focused on investigating how to diffuse innovations to the residential construction industry and workforce. We defined "diffusion of innovations", for the purposes of this report, as efforts made to disseminate information and then accomplish the adoption of safer innovations among multiple companies or large individual employee groups across multiple worksites as measured by self-reports of adoption or indirectly by evidence of reduced health and hazard outcomes or other outcomes. All of the studies reviewed below appeared to be imperfect (i.e. the methodology of intervention and/or the intervention evaluation conducted was less than optimal according to recognized criteria) (Robson et al., 2001).

Effect of regulation-based efforts on safety and health outcomes:

We located five studies that investigated the impact of legislated rules and regulations on the construction industry generally (Martinez-Aires et al., 2010; Beal, 2007; Lipscomb et al., 2003; Suruda et al., 2002; Derr et al., 2001). One such study of regulations separated out the effect of regulations on part of the residential construction sector (Derr et al., 2001). In general, the study abstracts affirmed that regulation-based efforts were effective at reducing injuries (see Table 3 for extracts). However, all the evidence demonstrated only associations between injury reductions and regulation; no direct causal linkage could be proven. Furthermore, the critique from the principal review article available suggested that the type and level evidence was poor (Van der Molen et al., 2012).

Effect of the 1989 OSHA excavation and trenching standard (Suruda et al. , 2002): A comparison of the fatal injuries from trench cave-ins in the construction industry in 47 US states between 1984-1989 (the five years prior to the enactment of the standard) and the 1990-1995 period (the five years after the standard came into effect) showed a two-fold decline in fatal injuries. For a critique of this study by Van der Molen et al., 2012, see page 25 below.

Effect of the 1995 OSHA fall protection standard (Derr et al., 2001): A comparison of injury data from federal reporting systems showed a statistically significant downward trend in fatal falls during the decade 1990-1999 for the construction industry generally overall and for a number of sub-sectors including residential building construction (i.e. observed versus

expected ratio=0.42, 95% confidence interval 0.34– 0.50). For a critique of this study by Van der Molen et al., 2012, see immediately below.

Effect of the 1991 Washington State vertical fall arrest standard (Lipscomb et al. 2003): A comparison of falls among a cohort of union carpenters who worked for the State of Washington in the general construction industry between 1989 and 1998 showed a significant decrease in the rate of falls from height, with the greatest decrease occurring between 3 and 3 ½ years after the standard came into effect. There were also significant reductions in mean paid lost days per event and in mean cost per fall after adjusting for age and temporal trends for costs among non-fall injuries. Van der Molen (2012) critiqued this study after including it in a meta-analysis with the other six regulatory studies observing that:

> "The seven studies were judged to be sufficiently homogeneous to be combined in a meta- analysis because the mechanism of the intervention (regulation) was assumed to have a similar effect for both fatal and non-fatal injuries. However, the changes in both level and slope were statistically heterogeneous (I2 = 71% and 56%, respectively). Most heterogeneity was caused by two studies (Aires 2010 - Austria; Derr 2001;) that had different results but we could not explain why they were different. Most of the included studies had rather short time series and thus these were fairly small studies, which could explain the variation in the results. The meta-analyses of the change in level and in slope showed a small but significant effect, indicating an increase in injuries immediately after the intervention (effect size 0.79; 95% CI 0.00 to 1.58) and in increase in injuries over time after the intervention (effect size 0.23; 95% CI 0.03 to 0.43). (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 under- lying downwards trend of injuries and no intervention effect." (Van der Mollen, 2012).

For additional criticism of this study by Van der Molen et al., 2012, see page 27 below. Lipscomb and coauthors responded to many of these same criticisms in an article published in 2009, after the first version of the Cochrane Review by Van der Molen was published (Van der Molen et al., 2007).

> "The Washington State Fall Standard followed a record number of twenty-two fall deaths in Washington in 1988. Considerable publicity followed these events and the promulgation of the standard, but preceded the date the standard became effective in 1991.Given the nature of the data available and this background, the use of

> autoregressive integrated moving average (ARIMA) models was less than ideal; the pre-intervention trend would have been established in a period of time in which injury rates might very well have been influenced by the publicity surrounding events that led to the intervention. Poisson regression was chosen as the multivariate analytical tool to allow assessment of injury rate ratios before and after the intervention through progressive lagging of time windows to assess potential latent effects. The models were adjusted for known risk factors for falls among this cohort (age, gender, time in the union). Based on the decreasing overall injury rates in the construction trade, the magnitude of decline of non-fall injuries among this cohort of workers was also controlled for in the analyses. The expectation that the Washington standard would not be effective immediately was clear, and the emphasis of the lagged analyses was exploration of latency. Similar use of Poisson regression has been reported in evaluating changes in injury rates over time following an intervention. As in the assessment of dose response, the issue of importance was felt to be the pattern, or lack thereof, rather than the level of statistical significance. The most substantial decline in fall rates was seen between 3 and 3.5 years after the standard went into effect. The interpretation by Lehtola et al., (i.e. a summary of the Van der Molen et al., 2007 results that was published in a peer review journal with another coauthor as lead author) was a lack of any sustained intervention effect based on a lack of a significant initial downward change in slope or level. In this interpretation neither the circumstances leading to enactment of the legislation or reasonable latency are considered. Knowledge of when interventions designed to influence complex work practices become effective and when they lapse is essential to understanding and improving worker safety. In a workplace injury intervention effectiveness study, where worker reporting (self-report, report to workers' compensation, etc.) captures the outcome of interest, basing a determination of success or failure upon an initial change in level also fails to recognize potential effects of an intervention on reporting." (Lipscomb et al., 2009).

Resolving the differences between these two points of view is difficult. The evaluation in the Lipscomb et al, 2003 paper was, of course, not perfect in every respect. As an evaluation that took place in the real world, there were special circumstances under which it was conducted and situational variables that may have influenced the outcomes. Van der Molen and coauthors have critically reviewed the Lipscomb et al., 2003 paper (as well as other studies).

Whether any or all of the criticisms are valid is one issue. Another consideration is whether the study's problems constitute major flaws or tolerable imperfections. For additional discussion of issues such as the appropriateness of combining the Lipscomb et al., 2003 results with others into a meta-analysis to determine their validity see Lipscomb's critique of systematic reviews and meta-analyses on page 37 below.

Effect of 1989 and 1992 European Union directives on the construction industry (Martinez-Aires et al., 2010): Ten of fifteen countries experienced a more than 10% lower workplace accident rate after the directives went into force; three varied less than 10%; and only two had significantly worse rates. The authors cautioned there was no evidence of the specific success of the directives themselves, in terms of national incidence rates, because of other uncontrolled factors and events occurring during the evaluation period. For a critique of this study by Van der Molen et al., 2012, see page 27 below. (note: this paper was split up by Van der Molen et al., 2012 into three parts – Aires Austria, Aires Belgium, and Aires Germany, 2010)

Effect of instituting construction design management regulations in the United Kingdom (Beal, 2007): The Construction Design Management (CDM) regulations were introduced in the United Kingdom in 1995 in response to a European Union directive to reduce deaths and injuries on construction sites by changing design and management procedures. Beal, 2007 was skeptical that the regulations had a positive impact. The author noted that, for the first seven years of the CDM Regulations, the average site death rate remained the same as the year before the regulations came into force and average deaths per 100,000 workers showed only a 4% reduction. From 2002 onwards, the situation improved, with a 15% reduction in average deaths and a 27% reduction in deaths per 100,000 workers. The Van der Molen review (2012) combined the Beal, 2007 results with six other studies of regulatory interventions, and concluded that none "showed a significant initial or sustained intervention effect in terms of a significant downwards change in level or slope" in the rate of fatal or nonfatal injuries.

Critique of the regulation-based efforts (van der Molen et al., 2012): This review and meta-analysis of construction safety interventions critiqued the regulation studies as follows:

> "Seven studies evaluated regulation (Aires 2010-Austria; Aires 20100-Belgium; Aires 2010-Germany; Beal 2007; Derr 2001; Lipscomb 2003; Suruda 2002). There was a downwards trend in injuries over time before the regulation was introduced

> as indicated by the negative values for the pre-intervention slopes… However, none showed a significant initial or sustained intervention effect in terms of a significant downwards change in level or slope. On the contrary, three studies showed a significant increase in level and three studies showed a significant increase in slope after the intervention. This effect was similar for both fatal and non- fatal injuries. The seven studies were judged to be sufficiently homogeneous to be combined in a meta-analysis because the mechanism of the intervention (regulation) was assumed to have a similar effect for both fatal and non-fatal injuries. However, the changes in both level and slope were statistically heterogeneous (I2 = 71% and 56%, respectively). Most heterogeneity was caused by two studies (Aires 2010 Austria; Derr 2001;) that had different results but we could not explain why they were different. Most of the included studies had rather short time series and thus these were fairly small studies, which could explain the variation in the results. The meta-analyses of the change in level and in slope showed a small but significant effect, indicating an increase in injuries immediately after the intervention (effect size 0.79; 95% CI 0.00 to 1.58) and in increase in injuries over time after the intervention (effect size 0.23; 95% CI 0.03 to 0.43).” (Van der Molen et al., 2012)

There is general agreement that the adoption of new regulation or even better enforcement of existing governmental regulation are both unlikely, in the near term, for the construction industry (see Recommendations section below) but particular “elements” of regulation may both be practical to accomplish and have relevance for reducing injuries.

Effect of “faux or pseudo regulation” through worksite hazard inspections alone or coupled with information dissemination and training among volunteer firms

Effect of worksite inspections coupled with information dissemination and training with OSHA (HomeSafe) among 65 Colorado companies (Gilkey et al., 2003): This study compared job-site safety audit scores before and after 2.5 years of an intervention among of a cohort of Denver-area residential construction workers working for 41 companies. The intervention was a voluntary, comprehensive program that included:

1) a 3 hr safety training and program orientation class,
2) a pocket-sized booklet guide to ten safe work practices for home builders and
3) an 87 item yes or no audit tool that evaluated work practices and environmental conditions, as well as

4) access to optional OSHA-approved ten hour construction courses tailored to the particular needs of residential construction employees. Participating companies also received:

5) focused inspections from OSHA on the ten booklet practices (thus limiting citations for non-serious violations) and were eligible for maximum penalty reductions if cited. Participants were also

6) eligible for worker compensation premium reductions of 5-10%.

The program was run by the local home builders association. Companies, including those with fewer than ten employees, submitted OSHA 200 logs, first reports of injury, and worker compensation loss runs to the local home builders association (which, in turn, forwarded it to the HomeSafe research staff). Results showed that audit scores significantly improved from before to after the intervention for the 41 companies and that the after measures for the 41 companies were significantly better than for the control companies. The Van der Molen et al., 2012 critique did not include Gilkey et al., 2003 in its analysis, apparently because it lacked a control group.

Effect of information dissemination and training with OSHA inspections (HomeSafe) among 97 Colorado companies (Darragh et al., 2004): This was a second HomeSafe study much like the one described above. Data from 97 participating companies were included (identified by the Denver Home Builders Association's list of companies audited two years previously and from prior contacts with Colorado State University investigators). The intervention was a comprehensive program that included all six elements described in GIlkey et al., 2003 (immediately above) and was conducted through the local home builders association and collected data the same way. The results showed that injury incidence rates declined significantly following HomeSafe; however, this effect was not statistically significant once temporal variation was controlled. The Van der Molen et al., 2012 critique did not include Darragh et al., in its analysis because it lacked a control group.

Effect of a region-wide safety inspection contest in Finland (Laitinen et al., 2010): Beginning in 1997, trained safety inspectors conducted unannounced evaluation visits to construction worksites in southern Finland that volunteered to participate. The personnel at the best performing companies and sites received monetary rewards at annually-held public seminars. Even though participation was voluntary, more than 70% of the total number of construction sites in the target area participated in the contest. In their analysis, the authors claimed that an estimated 4,000 accidents and three fatalities were prevented each year, while accident risks

in other parts of the country during the same period showed no improvement. The Van der Molen et al. critical review noted that "The study did not show an initial or sustained reduction in injuries from a safety campaign consisting of a contest and inspections with effect sizes of 0.47 (95% CI -0.04 to 0.98) and 0.46 (95%CI 0.36 to 0.56), respectively" (Van der Molen et al., 2012).

Effect of safety walk-arounds at a large nonresidential construction multi-employer worksite in Denmark (Mikkelsen et al., 2010): This was another non-residential construction study of a large transportation facility construction project. The safety audits covered physical safety standards and safe or unsafe acts where tunneling and construction of underground stations and emergency shafts took place that covered 15 different safety indicators at 15 sites over a two year period from January 1, 2000 to December 31, 2001 (approximately 3.5 million person-hours of work). The audits were customized, depending on the specific site and stage of construction, and focused on the most significant construction industry injury risks, as expressed in injury statistics, such as guard rails and coverings, scaffolding, ladders, housekeeping, and personal protection equipment. The influence of the safety walk-arounds (safety inspection hazard audits) was assessed retrospectively and the results showed they both predicted and prevented injuries. Mikkelsen et al., 2010 was published too late to be included in the Van der Molen et al., 2012 review article.

Effect of an inspection program during an Italian earthquake relief effort (Miscetti et al., 2008): After an earthquake reconstruction effort was begun, the annual incidence of workplace injuries decreased compared to rates prior to the quake. This article was available only in Italian. A portion of the English abstract reads:

> "Construction notifications showed building sites increased in number from the 200 sites/year before the earthquake to almost 1,400 per year at maximum reconstruction activity. Inspections and surveillance also increased to over 350 inspections/year in 250 sites/year. About 600 firms were monitored and sanctions increased. Sanctions mainly referred to high-level work, scaffolding, protection against falls from heights, and DPI (Personal Protective Equipments). Accidents increased from 150/year before the earthquake to about 300/year. The annual incidence, a rough indicator of prevention, dropped, indicating good quality prevention strategies were in force." (Miscetti et al., 2008)

The Van der Molen critique concluded:

> "(Miscetti 2008) showed no significant initial or sustained intervention effect of safety inspections combined with sanctions for violations on non-fatal injuries with effect sizes of 0.07 (95%CI -2.83 to 2.97) and 0.63 (95%CI -0.35 to 1.61), respectively … The intention of the study was to show that in spite of increased construction volume there would not be an increase in injury rate, actually a so-called noninferiority or equivalence study. Even though there were no significant changes in level and in slope, the CI values were very wide. Therefore the study does not provide evidence that rates before and after the increase of inspections were equivalent" (Van der Molen et al., 2012).

Effect of a pilot, two year comprehensive worksite inspection and training occupational health program in Great Britain (Tyers et al., 2007): The federal Health and Safety Executive in Great Britain designed a pilot occupational health program specifically to meet the needs of employers and workers in the construction industry. The voluntary program began operation in October 2004 and provided services until June 2006. The occupational health and safety services program was extensive and included:

1) marketing of the program to the construction industry, as well as
2) site visits,
3) risk assessments,
4) document reviews,
5) training of staff and management, and
6) health surveillance by nurses and case management of people on sick leave by OHS professionals.

A comprehensive 105 page final evaluation report is available online (Tyers et al., 2007). The goals of the pilot program included:

1) reaching and providing services to 50% of the construction employers in the area (1,190 firms),
2) providing in-depth services to 25% (595 firms), and
3) reaching 5,031 workers with visits and health screenings.

The evaluation compared injury rates and other outcomes among companies in the Leicestershire area (intervention group) with the Avon area (control group) before and after the 21 month long program. Outcome data were derived from self-reports obtained from

employers' questionnaires. One of the major findings was that small employers or sole proprietors in construction were less likely to have procedures in place for managing occupational health (e.g. especially recent health and safety training - 58% among small employers and sole proprietor operations compared to large employers at near 100% and conducting formal risk assessments at 23% compared to 56% for large employers).
The Van der Molen et al., 2012 review concluded:

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

Effect of worksite inspections coupled with a safety campaign at a large nonresidential construction multiemployer worksite in Denmark (Spangenberg et al., 2002): This study conducted a multi-faceted safety campaign at a large non-residential construction transportation construction project. Worksite inspections were part of the intervention. The campaign was designed to promote positive attitudes toward safety and to improve the behavioral aspects of safety at work. The campaign included banners at worksites, informational materials for employees, and public posting of campaign results at locations where employees could access them. Annual monetary awards were given to employees at the worksite determined to be the safest. Informational campaigns were conducted to draw attention to hazards and prevention around specific injury circumstances on a monthly basis. Results showed that comparisons between baseline and follow-up data collected after the campaign demonstrated a 25% reduction of the number of injuries resulting from accidents across all participating worksites. The Van der Molen critique affirmed that this study reduced injuries (Van der Molen et al., 2012).

Effect of safety training or information dissemination campaigns:

Effect of participatory ergonomics among 5 companies in Denmark (van der Molen et al., 2005): In this randomized control trial, a six step intervention was conducted with five small bricklaying companies (N=65 subjects) while five other companies (N=53 subjects) served as controls. The adoption and use of four ergonomic innovations by bricklayers and bricklayers' assistants was assessed from worksite observations and questionnaires at baseline and after

6 months. The innovations included adjusting work height when picking up bricks and mortar, adjusting work height for bricklaying at a wall side, mechanizing brick transport, and mechanizing mortar transport. The results showed the intervention did not lead to greater use of the four ergonomic innovations for bricklaying or the transport of materials by company employees. The authors speculated the lack of effect could have been explained by the lack of compliance with aspects of the intervention by most of the companies, some inadequacy of the intervention, and/or methodological limitations in the evaluation such as a lack of statistical power.

Effect of training among 70 Latino day laborers in New Jersey (Williams et al., 2010): Pre and post self-report measures exploring exposures, personal protective equipment use, attitudes, work practices, and work- related injuries were obtained from 70 immigrant day laborers in association with a a one day (minimum of six hour) Spanish language health and safety training class. The classes were led by trained worker trainers and were designed to engage participants in a series of tasks requiring teamwork and active problem-solving focused on applying safe practices to situations they encountered at their worksites. Results showed statistically significant increases in reported use of certain types of personal protective equipment (hard hats, work boots with steel toes, safety harnesses, and visible safety vests), and increases in the frequency of self-protective work practices such as trying to find out more about job hazards on one's own. There was also a nonsignificant decrease in self-reported injuries (receiving an injury at work serious enough that you had to stop working for the rest of the day) post-training based on small numbers. Sixty-six percent of workers surveyed post-training reported that they shared information from their safety workbook with friends and co-workers. The Van der Molen et al., 2012 review did not include this study because it was a before and after study with no control group.

Effect of recruiting and training employee opinion leaders to diffuse an innovation to thirteen companies (Kramer et al, 2009): This case study attempted to disseminate information to individuals at thirteen companies about a safer, more efficient work practice (a hydraulic ladder lift that aided with loading and unloading of ladders off van vehicle roofs) through employee opinion leaders (van operators) who were trained to inform workmates not employed by their companies but who worked on the same site as them about the practice. The trained van operators also gave presentations at prearranged health and safety meetings (where the results showed that attendees indicated that they thought the hydraulic ladders sounded like a good idea). Overall, the authors claimed the information dissemination effort reached at least

32 companies and potentially several thousand employees. The Van der Molen et al., 2012 review does not mention the Kramer et al., 2009 paper as having been considered for inclusion or as excluded.

Effect of a training program on injury rates at a major railway construction project in Italy (Bena et al, 2009): In this study, researchers evaluated injuries before and after 2,795 workers were involved in a safety training program at multiple construction sites for a high-speed railway line. An interrupted time series analysis found no statistically significant differences in injury rates. The Van der Mollen review noted "One study (Bena 2009) showed no significant initial or sustained intervention effect of a training programme on non-fatal injuries with effect sizes of 0.10 (95% CI -1.74 to 1.94) and -0.43 (95% CI -0.96 to 0.10), respectively" (Van der Molen et al., 2012).

Other types of programs including drug-free workplace programs

Effect of instituting drug-free workplace programs in 1996 in Washington State (Wickizer et al., 2004): Worker compensation claims from 1994 through 2000 and work hours reported by employers were used to assess the effect of a drug-free workplace program instituted in 1996 among 261 intervention companies compared to 20,500 control/nonintervention companies. The companies were involved in the fields of construction, manufacturing, and service industries. Among other finding, the study found a reduction in overall injury rates and in the incidence rate of more serious injuries involving four or more days of lost work time in the construction industry. The intervention effect was also strongest for the construction industry. The intervention involved the workers' compensation insurance providers in the state who offered a five percent discount in workers' compensation premiums for up to three years to private employers who enrolled in the program. As detailed in Wickizer et al., 2004, the program required employers to:

> "develop a comprehensive formal written substance abuse policy outlining prohibitions and sanctions for drug and alcohol abuse, procedures for drug testing, use of employee assistance programs (EAP) for referral to treatment, and provisions to protect worker confidentiality. Second, the employer had to require and pay for preemployment, postaccident, and posttreatment drug testing (random drug testing was optional). Third, the employer had to select an EAP from an approved list of EAPs and had to agree to provide treatment for employees through that EAP. Employees violating the substance abuse policy could not be terminated if they agreed to receive treatment, abide by procedures for follow-up care, and have no subsequent violations. Fourth, the employer had to ensure that

> employees received an annual educational program on substance abuse. Finally, the employer had to ensure that all supervisors and managers received a minimum of two hours training regarding substance abuse, treatment referral, and drug testing." (Wickizer et al., 2004).

Van der Molen (2012) critiqued this study observing that:

> "(Wickizer 2004) showed a significant initial intervention effect of a drug-free workplace programme with a non-fatal injury rate difference of -7.59 per 100 person-years between the intervention and control group; the study had a downwards trend of injuries over time (Table 2). A sustained effect of the intervention was observed with an injury rate difference of -1.97 per100 person-years per year between the intervention and control group. This yielded effect sizes of -6.78 (95% CI -10.01 to -3.55) and -1.76 (95% CI -3.11 to -0.41) for initial effect and sustained effect, respectively. For the intervention group alone, an initial effect of a drug-free workplace programme was found with a reduction in non-fatal injuries of -4.62 per 100 person-years; no sustained intervention effect was found. In conclusion, low-quality evidence exists for the effectiveness of a drug-free workplace programme to prevent non-fatal injuries."

Available review articles and critiques:

Four critical reviews of interventions in the construction industry were available (Van der Molen et al., 2007; 2012; Esmaeili and Hallowell, 2012; Rinder et al., 2008).

The Cochrane Injuries Group (Van der Molen et al., 2012; 2007): This organization first published a review in 2007 of studies published up to June 2006 (Van der Molen et al., 2007). In 2012 the review was republished with some editing and with additional studies included (those published through 2010). The updated report made no change to the conclusions of the original review (Van der Molen et al., 2012). The plain language study abstract from the 2012 paper noted:

> "… Thirteen studies were identified. … In these studies, there is no evidence that introducing regulation alone is effective in preventing non-fatal and fatal injuries in construction workers. There is no evidence that regionally oriented interventions such as a safety campaign, training, inspections or the introduction of occupational health services are effective in reducing non-fatal injuries in construction workers. There is low-quality evidence that a multifaceted safety campaign and a

multifaceted drug-free workplace programme at the company level are effective in reducing non- fatal injuries. Introducing regulation alone is not effective in reducing non-fatal and fatal injuries in construction workers. Additional strategies are needed to increase the compliance of employers and workers to the safety measures that are prescribed by regulation. Continuing company-oriented interventions among management and construction workers, such as a targeted safety campaign or a drug-free workplace programme, seem to have an effect in reducing injuries in the longer term." (note: the safety campaign referred to in the last line was Spangenberg et al., 2002 which included worksite inspections). (Van der Molen et al., 2012).

Review of the extent of diffusion of typical administrative safety programs among large general contracting firms (Esmaeili and Hallowell, 2012): The authors drew a sample of 211 construction contractors from a list of companies that were members of an industry organization (Associated General Contractors) in the Western US (i.e. CA, WA, OR, WY, CO, MN, ID, AZ). The sample focused on what the study called "vertical" contractors that specialized in commercial and office buildings, residential buildings, industrial facilities and manufacturing plants. Twenty-seven percent, or 58 of the 211 contractors contacted, agreed to participate in the study's interviews. The individuals interviewed were most often owners or presidents of the firms (48%), senior project managers (28%) or safety managers (24%). The firms were generally fairly large with 44% having annual revenues of less than $10 million, 25% with $10-100, and 31% over $100 million. The interviewers asked whether and when the firms had adopted each of twelve safety program strategies. The results showed that, of the respondents:

91% reported frequent worksite inspections,
90% had safety and health orientations for new employees,
88% claimed upper management support for safety program strategies,
86% had record keeping and analysis,
84% used job hazard analysis,
84% used emergency response planning,
78% reported employee involvement and evaluation,
74% had safety and health committees,
69% had substance abuse programs,
64% had subcontractor selection and management programs, and
62% reported having a safety manager on-site.

The authors concluded that “the construction industry has now reached saturation with respect to traditional injury prevention strategies and new safety innovations are needed” (Esmaeili and Hallowell, 2012).

The Esmaeili and Hallowell study has evident problems with its methods. First, the study set out to use 211 firms to represent the entire US construction industry. This number falls far short of the sample size such a claim would require. Second, seventy-three percent or 153 of the 211 subjects in this paper’s sample declined to respond,. Third, of those who did respond, nearly half of the interviewees were owners or presidents of the firms (48%). Firm owners or presidents are less than ideal respondents to interrogate about what safety and injury prevention strategies are in place and working well in their firms than safety officers or line personnel. Fourth, previous research in the construction industry is at odds with this study’s findings that traditional injury prevention strategies have “reached saturation” in this industry (CPWR, 2013; Moore et al., 2013; Gillen, 2010; NAS, 2009; NIOSH, 2008).

Systematic review of interventions to prevent musculoskeletal disorders in construction (Rinder et al., 2008): This systematic review and critical appraisal identified eight intervention studies relevant to reducing musculoskeletal disorders and work demands as well as studies that increased human capabilities, comfort, or ease of use. All eight studies these authors reviewed were limited by their focus on relatively small intervention groups:

- 44 workers - Luijsterburg et al., 2005
- 34 workers - Ludwig and Borstad, 2003
- 36 workers – Holmstrom and Moritz, 1992
- 30 workers - Holmstrom and Ahlborg, 2005
- 22 workers - Mirka et al., 2003
- 12 workers - Vink et al., 2002
- 10 workers - Van der Molen et al., 2004
- 10 workers - Hess et al., 2004

The studies focused on individuals rather than on a group of firms, which would have been more relevant for assessing the effectiveness of moving research to practice. Two studies addressed adjusting work height (Vink et al., 2002; Luijsterburg et al., 2005), one

addressed mechanization of transporting tools or materials (Hess et al., 2004), and one study addressed both interventions (Van der Molen et al., 2004). Another study evaluated three tools or labor aids (Mirka et al., 2003). Two studies focused on the value of exercise (Ludewig and Borstad, 2003 for stretching and strengthening and Holmstrom and Ahlberg, 2005 for daily warm up exercises). Another study covered the use of belts for support during work by individuals with lower back pain (Holmstrom and Moritz, 1992). Unfortunately, the only conclusion that the authors of this review reached at the end of their review and explication of these eight studies was that existing research was lacking and better research was needed.

Critiques of systematic reviews and meta-analyses (Lipscomb et al., 2009): In 2009, Lipscomb and coauthors published an extensive and detailed critique of systematic reviews and meta-analyses of workplace injury interventions that made specific reference to the Van der Molen et al., 2007 review of construction intervention studies (Lipscomb et al., 2009). The larger argument these authors made was that "the methods used to establish evidence for public health practice including occupational safety must be appropriate to the task and must consider the relevant context." Lipscomb and coauthors strongly objected to the methods used in the Van der Molen meta analyses including:

1) focusing on "controlled studies" to the exclusion of other study types. They maintained that controlled studies are often difficult to conduct and may not even be possible to conduct in functioning workplaces where situations may preclude carefully isolated control groups. They argued that systematic reviews that consider only controlled studies could benefit by also considering diverse observational methodologies.

2) the pooling of data from multiple studies into a combined measure of effect for a meta analysis. They argued that this approach risked the loss of essential contextual detail in individual studies and may mask evidence of effectiveness,

3) the methods used to assess the slope of outcomes such as injury rates also risked loss of evidence. They argued that, for example, the requirements for successful interventions to demonstrate a significant initial downward change in level after the intervention begins were flawed because of the known tendencies of workplace interventions to initially produce improved reported of injuries or other "latent effects on rates" prior to exerting sustained effects over longer periods of time,

5) unrealistic expectations that workplace interventions can be evaluated over relatively short time periods (e.g. in the initial months or year after they are initiated). Lipscomb and coauthors maintained that instead, research experience shows that interventions can "typically require substantial changes in complex work environments" and "would need to be in place for several years to gain a clear understanding of effectiveness" and "very large samples would be needed to detect meaningful changes" in outcomes fatal and nonfatal injuries (Lipscomb et al., 2009).

One fundamental problem that has placed occupational health intervention evaluation studies at a disadvantage in systematic reviews has been the lack of funding for the kinds of large, multi-year, multiple-site studies that are actually needed to fairly conduct, evaluate, and compare intervention effectiveness (Robson et al., 2001). Lipscomb's observations have been echoed elsewhere. Researchers in health care economics (Anderson, 2009), diet and chronic disease (Truswell, 2005), and public injury control (Curnow, 2005) have raised similar types of objections about Cochrane reviews of interventions because the Cochrane reviews tended to devalue the larger context within which studies took place, placed all observational studies outside the bounds of research with relevance, and because the practice of combining studies into a meta-analysis could void the significance and types of evidence that the individual studies brought to bear on important questions.

Discussion of interventions to reduce injury in the construction industry:

The types of interventions that have been conducted in the construction industry have included:

1) regulation and enforcement,
2) faux or pseudo regulation and enforcement with hazard inspections and corrections,
3) training and informational campaigns, and
4) other intervention types such as drug free workplace programs.

There is controversy about whether studies of various types of interventions in the construction industry have demonstrated actual injury reductions. The study results and critiques of studies presented in this section point to the uncertainty and controversy over whether any but a few construction industry interventions have clearly reduced injuries (i.e. Spangenberg et al., 2002; Wickizer et al. 2004).

The Cochrane review by Van der Molen et al., 2012 sorted through the highest quality studies and determined that just two studies accomplished injury reductions. Wickizer et al., 2004 demonstrated that there was both an initial and sustained reduction in injuries among a subset of construction firms when drug-free workplaces were mandated statewide in Washington State in 1996. One could reasonably argue that this was actually a demonstration of the effectiveness of a type of regulation coupled with enforcement.

The second study was a pseudo-regulation approach that coupled worksite inspections with a comprehensive, employer-based, safety campaign at a large multi-employer worksite in Denmark (Spangenberg et al., 2002). The intervention was designed to promote positive attitudes toward safety and improve safety behavior.

So we do know that mandatory regulations can reduce injuries industry-wide and that pseudo-regulation, in the form of interventions that promote worksite inspections and hazard awareness and corrections, can reduce injuries across entire multiemployer worksites.

As noted elsewhere, “high quality, adequately powered trials of optimized interventions are required to evaluate effects on objective outcomes (Free et al., 2013). Few, if any optimal interventions with adequately controlled or powered, long term evaluation trials with sufficiently large numbers of participants (like those in studies of chronic diseases) have ever been funded and conducted in residential construction or in the construction industry generally. In fact, such studies are unusual in the occupational health and safety literature in general. Any of the real or imagined failures to demonstrate intervention effectiveness in construction industry settings may be attributable to failures to achieve one or all of these factors (i.e. high quality, adequately powered trials of optimized interventions). The existing studies may not have accomplished their interventions competently or optimally. They may not have designed and executed their intervention evaluation components competently or optimally or they may have faced other barriers they were unable to surmount (e.g. sample size too small, lack of a carefully isolated control group, less than ideal choice of outcome measures, lack of verification of outcomes, etc. – see Robson et al., 2001).

Nonetheless, there appears to be high quality evidence that workplace hazard inspections coupled with information campaigns encouraging hazard awareness and corrections have proven successful in at least one study in the construction industry in general (Spangenberg et al., 2002).

TABLE 3. Dissemination and diffusion studies		
Study citation	**Intervention, evaluation methods, design, subjects**	**Results**
Effect of regulation-based efforts on the industry		
Suruda A, Whitaker B, Bloswick D, Philips P, Sesek R. Impact of the OSHA trench and excavation standard on fatal injury in the construction industry. J Occup Environ Med. 2002 Oct;44(10):902-5.	In 1989 the US Occupational Safety & Health Administration revised the excavation and trenching standard. We examined fatal injuries from trench cave-in in the construction industry for five year periods before and after the revision in the 47 US states for which data were available for both periods. We examined OSHA investigation reports for 1984 to 1995 in a manner similar to the previous study.4 Fatality reports containing a description of the incident were available from April 1984 onward. For the period 1984 to 1989, the OSHA data were available for 47 U.S. states and excluded California, Michigan, and Washington State. For the period 1990 to 1995, we restricted the analysis to the same 47 states. We chose the observation period to provide approximately five years of data both.	There was a 2-fold decline in the rate of fatal injury after revision of the standard, which substantially exceeded the decline in other causes of fatal injury in the construction industry during the same period. The decline was somewhat greater in large business firms but was evident in construction firms of all size classes. The fatality rate from trench cave-in in union construction workers was approximately half that of nonunion workers, but we were unable to determine whether this was best explained by union status, employment of union workers at larger construction firms, or both. This study provides evidence for the effectiveness of OSHA regulation in preventing fatal work injury.
Derr J, Forst L, Chen HY, Conroy L. Fatal falls in the US construction industry, 1990 to 1999. J Occup Environ Med. 2001 Oct;43(10):853-60.	Interrupted time series design using injury data from construction firms covered by data in OSHA IMI system. Observational study of the effect of the 1995 OSHA fall protection standard.	A statistically significant downward trend in fatal falls was evident in all construction and within several construction categories during the decade. Although the study failed to show a statistically significant intervention effect from the new OSHA regulations, it may have lacked the power to do so.
Lipscomb HJ, Li L, Dement J. Work-related falls among union carpenters in Washington State before and after the Vertical Fall Arrest Standard. Am J Ind Med. 2003 Aug;44(2):157-65.	The study evaluated changes in the rate of falls from elevations and measures of severity among a large cohort of union carpenters after the fall standard change in Washington State, taking into account the temporal trends in their overall injury rates. Using data from the Carpenters Trusts of Western Washington, the United Brotherhood of Carpenters and Joiners, and the Washington State Department of Labor and Industries (L&I) we identified a cohort of union carpenters who worked in the State of	There was a significant decrease in the rate of falls from height after the standard went into effect, even after adjusting for the overall decrease in work-related injuries among this cohort. Much of the decrease was immediate, likely representing the publicity surrounding fatal falls and subsequent promulgation of the standard. The greatest decrease was seen between 3 and 3½ years after the standard went into effect. There was a significant reduction in mean paid lost days per event after the standard change and there was a

	Washington between 1989 and 1998, their hours of union work each month, and their workers' compensation claims. The compensation claims data included the date of injury, American National Standards Institute (ANSI) codes describing the events in terms of body part injured, the nature of the injury, the type of event causing the injury, the amount of lost work time associated with each injury, and the costs associated with lost time, medical care, and permanent impairment. The records of workers' compensation claims filed by these individuals included medical only claims as well as those, which resulted in lost work time. Detailed information about the data sources and the merging of these records on an individual basis without the use of personal identifiers has been previously reported [Lipscomb et al., 1997; Lipscomb et al., 2000].	significant reduction in mean cost per fall when adjusting for age and the temporal trend for costs among non-fall injuries.

Martínez Aires MD, Rubio Gámez MC, Gibb A. Prevention through design: The effect of European Directives on construction workplace accidents. Safety Science 2010;48(2), 248-258.	This paper first analyzes policies regarding accident prevention in the European Union, as initially stipulated in the European Framework Directive 89/391/EEC, and more specifically in Directive 92/57/EEC, on the implementation of minimum safety and health requirements at temporary or mobile construction sites, concentrating on prevention through design. The second section of the paper analyzes the incidence rate of workplace accidents in the construction sector in each country from the year when these regulations came into force until the present time. Based on the evolution of these accident rates, the paper postulates the extent to which European policies have contributed to accident prevention in construction.	11 of the 15 countries considered have seen a fall in their accident rate since the EU directive was implemented nationally, with and average improvement of 28%, ranging from 66% to 3.4%. Greece and Belgium shows the best results with a decreasing incident rate of 65%, 7% and 42% respectively. Finland's figures are within 1.5% and Denmark, Ireland, and Sweden are the countries that have higher accident rates in 2005 than when their national legislation went into force. According to the results obtained, 10 countries experienced a more than 10% lower workplace accident rate after the Directives' safety and health provisions went into force, three varied less than 10% and only two had significantly worse rates, although there are some unresolved anomalies with these data. Despite the fact that these regulations are not the only factor to be considered, results show that, since the legislation came into force, the tendency in the European countries is positive and the incidence rate has decreased. However, there is no evidence of the specific success of the TMCS directive itself in terms of national incidence rates because other factors such as ''custom and practice", variation of the productivity, and others important events have also occurred. Countries, such as Luxembourg, Ireland, and Sweden, where the accident rate was higher at the end of the time period studied, reflect the need for a more in-depth study of national statistics, the adaptation of the EU provisions, enforcement policy, and implementation in different countries.
Beal AN. CDM regulations: 12 years of pain but little gain. Proceedings of the ICE - Civil Engineering 2007;160:82–8.	The Construction (Design Management) (CDM) Regulations 19941 were introduced in the UK in 1995 in response to an EU Directive2 to reduce deaths and injuries on construction sites by changing design and management procedures. Although the Regulations have been in force for just over 12 years, surprisingly little has been published assessing how they have operated and what their effects have been in practice.	Thus, for the first seven years of the CDM Regulations, the average site death rate remained the same as the year before they came into force and average deaths per 100 000 workers showed only a 4% reduction. From 2002 onwards, the situation improved, with a 15% reduction in average deaths and a 27% reduction in deaths per 100 000 workers. Detailed analysis of the accident records

	This paper considers how the requirements of the Regulations have been translated into reality, what effects they have had on the work of designers and contractors, and what effects they have had on construction safety. The CDM Regulations were launched in 1995 with high hopes that they would improve construction efficiency and quality and bring about a major reduction in construction accidents. In practice, some parts of the Regulations (such as the health and safety file produced at the end of a project) have proved to be useful, but the benefits from other parts are harder to identify. There is a need for a comprehensive survey and analysis of the working of the Regulations in practice, identifying the parts which have worked well and those which have not.	would be necessary to establish the reasons for this improvement. However, the change did not occur until seven years after the CDM Regulations came into force, so the possibility must be considered that some other factor was responsible. Between 1989 and 1995 (the last years before the Regulations came into force) the site death rate fell from 154 to 83, a reduction of 46%. However, in the first seven years of the CDM Regulations, annual deaths varied between 65 and 105 with an average of 83, the same as the year before the Regulations were introduced. Reported major injuries actually increased during this period. Since 2002 there has been a fall in site deaths but this is probably attributable to changes in site working practices rather than the CDM Regulations.
<u>effect of information dissemination and training coupled with OSHA inspections on 65-97 Colorado companies (HomeSafe)</u>		
Gilkey DP, Hautaluoma JE, Ahmed TP, Keefe TJ, Herron RE, Bigelow PL. Construction work practices and conditions improved after 2-years' participation in the HomeSafe pilot program. AIHAJ 2003 May-Jun;64(3):346-51.	As in Darragh et al., 2004 but after 2.5 years of HomeSafe with 65 Denver area companies involved in single family dwelling construction who volunteered for the program. Auditors approached the first available worker to initiate contact. Laborers were the overwhelming majority of contacts in all three groups (92% or more). 15% of workers were in electrical trades, 11% framing and 11% excavation.	Quasi-experimental cohort design hazard audit based on direct observation. Repeated measures design with a control group. 20-30 minute audit forms were administered on-site and unannounced at 41 retest sites, 25 previously unaudited intervention sites and 41 control sites. Results showed significantly higher (safer) audit scores for both previously audited (76) and unaudited (74) groups compared to controls (67) for firms within the HomeSafe program for at least two years). The Home Builders Association was the primary resource for additional information and they developed a material for their members entitled "Comprehensive Safety and Health Program for Residential Builders."
Darragh AR, Stallones L, Bigelow PL, Keefe TJ. Effectiveness of the HomeSafe Pilot Program in reducing injury rates among residential construction workers, 1994-1998. Am J Ind	Data from 97 participating companies were included (identified by the Denver Home Builders Association's list of companies audited two years previously and from prior contacts with Colorado State University	Data from three pre-HomeSafe years were compared to the two HomeSafe years. Injury incidence rates declined significantly following HomeSafe; however, this effect was not statistically

Med. 2004 Feb;45(2):210-7.	investigators). The program consisted of 1) a 3 hr safety training and program orientation class, 2) a pocket-sized booklet guide to 10 safe work practices for home builders and 3) an 87 item yes or no audit tool that evaluated work practices and environmental conditions, as well as 4) access to optional OSHA approved 10 hr construction courses tailored to the particular needs of residential construction employees. Participating companies also received focused inspections from OSHA on the 10 booklet practices (thus limiting cites for non-serious violations) and were eligible for maximum penalty reductions if cited. Also eligible for reduced worker comp premiums of 5-10%. The program was run by the local home builders association. Companies, including companies with fewer than 10 employees, submitted OSHA 200 logs, first reports of injury, worker comp loss runs to the HBA (which, in turn, forwarded it to the HomeSafe research staff).	significant once temporal variation was controlled.

effect of a safety campaign on a large, nonresidential, multi-employer worksite in Sweden and Denmark		
Spangenberg S, Mikkelsen KL, Kines P, Dyreborg J, Baarts C. The construction of the Øresund Link between Denmark and Sweden: the effect of a multi-faceted safety campaign. Safety Science 2002;40(5), 457-465.	Interrupted time series design using injury data. The purpose of the present study was to evaluate the effect of a safety campaign implemented midway during the construction of the railway and road link across the Sound,Øresund,between Denmark and Sweden. The safety campaign was multi-faceted and aimed both at promoting positive attitudes towards safety and at the behavioural aspects of safety at work.	The effect of the campaign was a 25% reduction of the number of injuries resulting from accidents, which did not completely fulfill the objective set by the site owner. This effect became only just statistically significant when heterogeneity of type of work before and after the campaign was taken into account. The modest effect of the safety campaign might be explained by the fact that the site, like any construction site, was a temporary workplace, where several contractors' had short-term project assignments. Apparently, the contractors working routines were not sufficiently affected by the safety campaign. Other factors, that might affect a safety campaign at a construction site, are discussed.
effect of a safety campaign during earthquake reconstruction in Italy		
Miscetti G, Bodo P. Prevention of building site accidents in Umbria during reconstruction after an earthquake the experience of one Local Health Unit [Esperienza i prevenzione di un Servizio ASL nei cantieri della ricostruzione post–sismica in Umbria]. Medicina del Lavoro 2008;99(2):136–44.	Building site related accidents are so frequent and are associated with such serious consequences that they constitute a major "health emergency" in Italy where dangerous work conditions in the construction industry often derive from excessive financial, organisational and time pressures. After the 1997 earthquake in Umbria an extensive re-building programme led to a concentration of innumerable construction firms, sub-tendering practices and the use of poorly skilled workforces who were often employed in the black economy. At the same time, SPSAL (Prevention Service for Occupational Settings) activity needed to be intensified in Perugia Health Unit No 2 in the District of Assisi, which had been devastated by the earthquake. Discussion and Conclusions: To monitor construction site development, related accidents and injuries, and surveillance activity, data were collected from building site notifications on the basis of Article 11, Law 494/96, outcomes of inspections, including sanctions, and INAIL (National Insurances) certificates of work-related injuries.	Construction notifications showed building sites increased in number from the 200 sites/year before the earthquake to almost 1400 per year at maximum reconstruction activity. Inspections and surveillance also increased to over 350 inspections/year in 250 sites/year. About 600 firms were monitored and sanctions increased. Sanctions mainly referred to high-level work, scaffolding, protection against falls from heights, and DPI.(Personal Protective Equipments). Accidents increased from 150/year before the earthquake to about 300/year. The annual incidence, a rough indicator of prevention, dropped, indicating good quality prevention strategies were in force. The drop in the annual incidence index would not have been evident without concomitant monitoring of notifications and certificates of work-related injuries. These two databases are invaluable tools when investigating changes in the reference standard of the construction industry and assessing the efficacy of implemented prevention programmes.

effect of a safety walk-arounds on a large, nonresidential multi-employer worksite in Denmark		
Mikkelsen KL, Spangenberg S, Kines P. Safety walkarounds predict injury risk and reduce injury rates in the construction industry. Am J Ind Med. 2010 Jun;53(6):601-7.	Data from the construction of the Copenhagen Metro were analyzed to determine the method's ability to predict injury risk related to joint responsibilities and individual worker responsibilities. The present study is a follow-up investigation of employees with the main contractor, COMET, during construction of the first stage of the Copenhagen Metro. The study covers the 2-year period from January 1, 2000 to December 31, 2001 (approximately 3.5 million man-hours), where tunneling and construction of underground stations and emergency shafts took place. Injury data and the safety observation registrations from 15 Metro sites—7 underground stations, 7 emergency shafts, and 1 cross tunnel— formed the basis of the present study.	A statistically significant association between the risk level as measured by the Safe Workplace methodology and injury risk was found. The relative risk of injury increased with the number of safety indicators violated and was elevated for safety indicators reflecting both individual and joint safety responsibility. The observed injury risk was not elevated in the post-safety walk-around period for safety indicators of individual responsibility, but the joint responsibility indicators retained an elevated injury risk level. The data support the hypothesis that safety walk-arounds both predict and prevent injuries. Safety indicators of individual responsibility are more likely to be corrected than those of joint responsibility.
effect of a safety inspection contest at over 1000 construction sites of over 20 companies in Finland		
Laitinen H, Paivarinta K. A new-generation safety contest in the construction industry - a long-term evaluation of a real-life intervention. Safety Science 2010;48:680-6.	A new-generation safety campaign has been taking place in southern Finland since 1997. The Finnish Construction Employer's Association together with trade unions, safety inspectorates, and other institutions have been organizing a safety contest based on the standardized TR-observation method. Safety inspectors conduct evaluation visits without previous notice to the sites, and best performing companies and sites are rewarded at annually held public seminars. Even though participation is voluntary, more than 70% of the total number of construction sites in the target area have participated in the contest, and the results have been successful.	Deficiencies in protection against falling have decreased by 63%, in order and tidiness by 69%, and in working habits by 51%. The effectiveness is also evident in the accident figures. An estimated 4000 accidents and three fatalities are prevented each year, while other parts of the country during the same period show no improvement in accident risk. A key success factor may be the adoption among firms of a new, standardised safety monitoring method which has been used effectively by senior management teams. The method employs a combination of penalties and incentives in order to set and enforce new safety targets. Another success factor is the close co-operation between the construction industry, labour organisations and safety authorities.

effect of participatory ergonomics program with employers at 5 companies in Denmark		
van der Molen HF, Sluiter JK, Hulshof CT, Vink P, van Duivenbooden C, Holman R, Frings-Dresen MH. Implementation of participatory ergonomics intervention in construction companies. Scand J Work Environ Health. 2005 Jun;31(3):191-204.	The effectiveness of the implementation of participatory ergonomics intervention to reduce physical work demands in construction work was studied. In a cluster randomized controlled trial, 10 bricklaying companies were randomly assigned either to an intervention group (N=5) or a control group (N=5). The intervention strategy used a consultant-guided six- step approach in which company stakeholders participated. Bricklayers and bricklayers' assistants in the intervention group (N=65) and the control group (N=53) were followed for 6 months, and their use of four ergonomic measures (adjusting work height when picking up bricks and mortar, adjusting work height for bricklaying at a wall side, mechanizing brick transport, and mechanizing mortar transport) was compared. The use of the ergonomic measures was assessed from worksite observations and questionnaires at baseline and after 6 months. The workers' and employers' behavioral change phases were determined by questionnaires and interviews, respectively. Performance indicators were assessed for the intervention from the researchers' observations during the implementation process and through questionnaires completed by the workers.	The strategy had no statistically significant effect on the use of any of the four ergonomic measures, at either the cluster or the individual level. None of the companies in the intervention group passed through all six steps of the intervention. Process outcomes suggest that the ability to use ergonomic measures increased. In bricklaying, self-efficacy and skills to adapt the work height on the scaffolding improved significantly. The intervention did not lead to greater use of ergonomic measures in bricklaying or the transport of materials. Performance indicators of intervention and the corresponding behavioral change phases of stakeholders can help to detect essential elements of such intervention. The lack of an increase in the use of ergonomic measures could be explained by (i) the lack of compliance, (ii) the intervention, and (iii) methodological limitations. First, compliance with the intervention was low. The performance indicators at the company and worker level did not show high scores. The economic recession during the intervention caused some companies to concentrate entirely on their core business and stop discussing and trying out ergonomic measures. In addition, the intended participation of different stakeholders and workers was not achieved within the companies. Only one company completed the preparation step. Two companies installed no steering groups, one company simply discussed the ergonomic measures and, in one company, only one bricklaying team had planned to follow the participatory ergonomics strategy. None of the companies completed the "ability to use ergonomic measures"of ergonomic measures. Steering groups were planned as a means of implementing ergonomic measures among all the workers in the companies. Second, the intervention itself may have contributed. It was hypothesized that, in most

		companies, information strategies did not suffice to increase the use of ergonomic measures at the worksites. A systematic review of this subject (9) suggested that a participatory ergonomics strategy and direct worker involvement could be effective. However, most studies were uncontrolled and the published type of studies tended to report optimistic results.
effect of training among 70 Latino day laborers in New Jersey		
Williams Q Jr, Ochsner M, Marshall E, Kimmel L, Martino C. The impact of a peer-led participatory health and safety training program for Latino day laborers in construction. J Safety Res. 2010 Jun;41(3):253-61.	To recruit workers, project staff repeatedly visited corners where construction laborers congregated in six Northern and Central New Jersey communities (Lakewood, Matawan, Red Bank, Dover, Orange, and New Brunswick). Baseline and follow-up surveys (22% response rate 2-4 months later) were collected from 70 New Jersey Latino day laborers in construction exploring exposures, PPE use, attitudes, work practices and work prior to their participation in a one day (minimum of six hour) Spanish language health and safety training class. The classes, led by trained worker trainers, engaged participants in a series of tasks requiring teamwork and active problem solving focused on applying safe practices to situations they encounter at their worksites.	Statistically significant differences in the use of certain types of PPE (hard hats, work boots with steel toes, safety harnesses, and visible safety vests), and in the frequency of self-protective work practices (e.g., trying to find out more about job hazards on your own). There was also a suggestive decrease in self-reported injuries (receiving an injury at work serious enough that you had to stop working for the rest of the day) post-training based on small numbers. Sixty-six percent of workers surveyed post-training reported sharing information from their safety workbook with friends and co-workers.
effect of recruiting and training employee opinion leaders to diffuse ladder lifts via communications with employees in 13 companies		
Kramer D, Bigelow P, Vi P, Garritano E, Carlan N, Wells R. Spreading good ideas: a case study of the adoption of an innovation in the construction sector. Appl Ergon. 2009 Sep;40(5):826-32.	The intervention was a hydraulic ladder lift that aided with loading and unloading of ladders off van roofs. Thirteen companies, with five to 900 employees, were involved. The van operators informed workmates not employed by their companies but who worked on the same site as them about the intervention. The opinion leaders informed decision makers within their	While the research was designed to evaluate the role of opinion leaders as disseminators of knowledge, it became apparent that they were not the only ones who could be disseminators of the innovation. All the workplace parties could and were involved in KT. In this case, because the workplace parties were involved throughout the process, the

	companies which led to commitments to purchase similar units. They also gave presentations at prearranged health and safety meetings, where attendees indicated that they thought the intervention sounded like a good idea. Soliciting the names of opinion leaders was done at two labour management meetings and four trade-specific committee meetings (electrical, pipe-trades, sprinkler and refrigerator), with the idea that leaders could be the springboard for innovation within the industry. They were asked: What company sets the trends in your sector? Who would you consider calling for help? Who is the ''best'' company in your sector? Which is the most ''respected'' company? Which company is the trend-setter? If an individual company was identified as an opinion leader more than three times, they were selected to be part of the study. Initially 33 companies were contacted. Thirteen agreed to participate. Added to these were two companies who were already using the ladder lift, and three employers who did not accept the innovation, but gave information on their decision-making process.	KT also took place throughout the process. The KT was not simply the focus of the research but also the result of the research. In this form of applied research, much like participatory action research, KT is an integral component of the research, and not just a final stage of the research. As a result of this applied research at least 13 companies were initially introduced to an ergonomic intervention. The participants in the research also reached beyond their own 13 companies to at least 32 more companies and each of the thousands of employees of the original 13 companies had the potential to inform several thousand more employees. This study shows that the potential for workplace change can be exponential.
effect of recruiting and training employees		
Bena A, Berchialla P, Coffano ME, Debernardi ML, Icardi LG. Effectiveness of the training program for workers at construction sites of the high-speed railway line between Torino and Novara: impact on injury rates. American Journal of Industrial Medicine 2009;52(12):965–72.	The aim of this study was to assess the impact of the training program on injury rates at a major railway construction project. The population consisted of 2,795 workers involved in a safety training program at the construction sites of the high-speed railway line Torino – Novara. Two types of analyses were carried out in order to assess the effectiveness of the training program in reducing the number of injuries: (i) a pre – post analysis, which took into account the fact that workers were enrolled at different times and the training intervention did not occur at the same time for all subjects; (ii) an interrupted time-series model, which corrected for the time trend and considered the autocorrelation between individual observations.	Twenty-nine percent of workers who spent at least 1 day at the construction sites attended at least one training module. Pre – post analysis: At the end of the training program, the incidence of occupational injuries had fallen by 16% after the basic training module and by 25% following the specific modules. Time-series model: Training led to a 6% reduction in injury rates, which was not statistically significant.

	Because injury risk varies by type of work, the training program consisted of a basic module for all workers, and four specific modules addressing the different roles and jobs, structured according to the main risks involved in each activity. Each module consisted of two parts, each lasting 2 hr. At the end of the second part, the worker had to pass a learning test. Depending on their specific job, each worker was invited to attend several modules, starting from the basic module and then going on to complete the specific modules for the activity to be performed at the construction site. Usually, workers were required to pass the basic module test before being able to attend the specific modules.	
Tyers C, Sinclair A, Lucy D, Cowling M, Gordon-Dseagu V, Rick J. Constructing better health, final evaluation report. Health and Safety Executive 2007; Research Report 565:1–227.	The CBH pilot offered a specifically designed occupational health intervention targeted at the construction industry in Leicestershire from October 2004 to June 2006. It was an attempt for policymakers to work closely with the construction industry and the success of the initiative will be judged differently from these two perspectives. The main aim of the CBH pilot was to raise awareness of occupational health issues within the construction industry as well as to test out a model of delivery so that learning points could be used in the design of any national scheme. In addition, secondary aims were: to help tackle cases of ill-health identified amongst workers, to help employers improve systems dealing with health to promote good risk assessments processes that address health issues and, ultimately, to reduce the incidence of ill-health and associated absence within the pilot area. The CBH pilot was jointly run by two specialist providers. Anyone working in the construction industry within Leicestershire was eligible for their support. The actual services on offer were: 1. site visits where occupational health issues were discussed and employer needs determined either for other aspects of the CBH service or for referral onto other providers, 2. risk assessments conducted by qualified staff on	Evaluation Survey: In total, data on 27 different outcomes was analysed in the survey data. The greatest difference between CBH users and non-users/the out-of-area control group was that they appeared to have better health and safety policies, deliver more training, to keep better records and to better inform subcontractors, and that they had maintained good practice in these areas over time. Therefore CBH appears to have encouraged the continuation of good practice rather than, so far, to have influenced employers to introduce new measures or systems. CBH users were more likely to report having experienced accidents and ill-health and to report higher incidence levels on these measures. Given that CBH users also have better recording and reporting procedures, once conclusions could be that this, at least in part, reflects their greater awareness of the types of accidents and ill-health experienced by their staff. However, of course they could also actually experience more accidents/ill-health and/or have become engaged with CBH to help reduced these levels. CBH users also exhibited attitudinal differences and became less positive over time about the extent to which the construction industry prioritizes risks, how much they know about health and safety, and whether they have enough time to

	construction sites, 3. document reviews to ensure that employers are operating the most effective health and safety management systems and policies to counter any employee health risks, 4. the provision of training in the form of 'toolbox talks' designed specifically by CBH staff to cover a range of occupational health issues and information for workers, and two- day management training interventions tailored to individual employer needs, 5. the use of a mobile health testing unit staffed by a qualified occupational health nurse or technician to deliver health surveillance and voluntary health checks, 6. case management by trained occupational health professionals for those on sick leave, or identified as in need of support through health testing.	deal with health and safety issues properly. These changes would suggest that their engagement with CBH has affected their attitudes towards occupational health issues. Users may now have better information with which to assess their own performance and that of the industry. Overall, therefore, there was no hard evidence that CBH had reduced accident, ill-health or absence rates at this point in time, although such changes could materialise in the future. Health outcomes are very difficult to measures and can take significant periods of time to emerge sufficiently to be measured. The fact that CBH users are more likely to continue to keep good practice procedures in place over time, however, could suggest that they are more likely to experience positive outcomes in the longer term. Marketing: As a new initiative working with a hard-to-reach sector, CBH tested a range of marketing and promotional activities. By the end of the pilot, 40 per cent of employers in the pilot area had heard about the service. Getting the messages and approach right has taken time, but there are a number of learning points that have emerged. These included: 1. the need for continued and repeated contacts with employers to generate interest in the pilot, particularly in the first year of operation 2. the difficulties inherent in reaching the smallest contractors, although those who subcontract to larger companies can be reached via these main contractors 3. the time required to use larger employers as a means of cascading messages and, within each employer, to get to the point of actual service delivery were both significant, 4. the proven effectiveness of telemarketing in reaching employers with more than five employees 5. the lack of interest in web-based resources or a telephone helpline. Employers in this sector respond better to proactive approaches by service providers and face-to-face contact.

effect of instituting drug-free workplace programs in 1996 in Washington state		
Wickizer TM, Kopjar B, Franklin G, Joesch J. Do drug-free workplace programs prevent occupational injuries? Evidence from Washington State. Health Serv Res. 2004 Feb;39(1):91-110.	Washington state worker comp data, employer work hours data. Drug free workplace programming initiated in 1996 including testing and treatment.	Drug free programs were associated ($p < .05$) with a statistically significant decrease in injury rates for construction and in the incidence rate of more serious injuries involving four or more days of lost work time.
review article for papers published prior to 2010		
van der Molen HF, Lehtola MM, Lappalainen J, Hoonakker PLT, Hsiao H, Haslam R, Hale AR, Frings-Dresen MHW, Verbeek JH. Interventions to prevent injuries in construction workers. Cochrane Database of Systematic Reviews 2012, Issue 12. Art. No.: CD006251. (note: the 2012 review covers only the same seven studies included in the 2007 versions and reports the same conclusions as in 2007 version - van der Molen HF, Lehtola MM, Lappalainen J, Hoonakker PL, Hsiao H, Haslam R, Hale AR, Verbeek J. Interventions for preventing injuries in the construction industry. Cochrane Database Syst Rev. 2007 Oct 17;(4):CD006251).	Review of injury reducing interventions. Three of the five studies evaluated the effectiveness of regulation (Derr et al., 2001; Libscomb et al., 2003; Suruda et al., 2002), one presented an evaluation of a drug-free workplace program (Wickizer et al., 2004) and one evaluated a multifaceted safety campaign for a Danish highway and rail construction project (Spangenberg et al., 2002).	There is moderate evidence that regulation alone is not effective in preventing non-fatal and fatal injuries in the construction industry. There is limited evidence that a safety campaign and a drug-free workplace program are effective in reducing non-fatal injuries in the construction industry. Authors' conclusions: The vast majority of technical, human and organizational interventions that are recommended by standard texts of safety, consultants and safety courses have not been adequately evaluated. There is no evidence that introducing regulations for reducing fatal and nonfatal injuries are effective as such. There is neither evidence that regionally oriented safety campaigns, training, inspections nor the introduction of occupational health services are effective at reducing non-fatal injuries in construction companies. There is low quality evidence that company-oriented safety interventions such as a multifaceted safety campaign and a multifaceted drug workplace program can reduce non-fatal injuries among construction workers. Additional strategies are needed to increase the compliance of employers and workers to the safety measures that are prescribed by regulation. Continuing company-oriented interventions among management and construction workers, such as a targeted safety campaign or a drug-free workplace program, seem to have an effect in reducing injuries in the longer term.

4. What works best to diffuse safety innovations to get them adopted in other industries?

The National Academy of Sciences' report on the NIOSH construction industry program specifically recommended "Leveraging promising approaches from related high-risk sectors such as agriculture and mining into construction" (NAS, 2009, p. 13). In this section, we explored other industries to see whether they have answered the question "what works to move research to practice?" We focused on: 1) industries overall, 2) production agriculture, and 3) the small business sector.

We were interested in determining whether there was evidence from high quality studies that various types of interventions had been able, with rigorous intervention evaluation, to demonstrate that interventions can and have worked to reduce injuries or hazards. We considered improvements in these health and hazard indicators to be proxies for the accomplishment of moving research to practice. For firms to comply with regulations for example, they would need to adopt new safety innovations or new work methods or management methods, etc.

Effects of regulation-based interventions across all industries:

We begin this section by addressing an issue raised by Van der Molen et al., 2012 who claimed "there is no evidence that regulation alone is effective in preventing fatal and nonfatal injuries in construction workers" (Van der Molen et al., 2012, plain language abstract). There is controversy about the overall effectiveness of occupational safety regulations and enforcement at reducing rates and numbers of injuries and injury severity. What evidence is there that governmental regulation actually reduces injury in industries generally?

Effects of governmental inspections on manufacturing industries (Haviland et al., 2012; 2011): Recent studies have demonstrated that federal OSHA inspections can reduce injuries in manufacturing establishments by up to 20% over the two years following the inspections under certain conditions. The most consistent findings have been when: 1) inspections also result in monetary penalties, and 2) the firms inspected have more than 20 but fewer than 250 employees (Haviland et al., 2012; 2011; Gray and Mendeloff, 2005; Gray and Scholz, 1993).

Effects of randomized governmental safety inspections on all types of industries (Levine et al., 2012): This study took advantage of a "natural field experiment" by comparing 409 randomly

inspected establishments in California with 409 matched-control establishments that were eligible, but not chosen, for inspection. The authors reported that "Compared with controls, randomly inspected employers experienced a 9.4% decline in injury rates … and a 26% reduction in injury cost … and found "no evidence that these improvements came at the expense of employment, sales, credit ratings, or firm survival."

Effects of regulatory enforcement and consultation visits on worker compensation claims on all types of industries in Washington state (Foley et al., 2012): This study merged ten years worth of Washington state workers' compensation records of claims and costs with records of Washington state employers having either an inspection or voluntary consultation. Workplaces were limited to those that were stable over time and had at least ten or more full-time employees. The results showed that

> "Enforcement activities are associated with a significant reduction in (claims incidence rates) and costs. Similar results may also be attributable to consultations. Inspections were associated with a 4% decline in time-loss claims rates relative to uninspected workplaces. The effect strengthens when (musculoskeletal disease) claims are excluded. Citations for non-compliance are associated with a 20% decline in (musculoskeletal disease) claims incidence rates relative to uninspected workplaces. There is also some evidence for a reduction in (musculoskeletal disease) claims rates beginning in the second year following inspection. Enforcement and consultation activity is associated with substantial decreases in claims costs."

The authors concluded that their results showed that:

> "Enforcement activities make a significant contribution to reducing (claims incidence rates) and costs. Similar results following consultations may also exist. Inspections with citations are more effective than those without. Claims rates for non-(musculoskeletal disease) injuries, related to hazards covered by specific standards, are more affected in the year following the visit, while those for (musculoskeletal diseases) take longer to begin falling."

Effects of targeted worksite inspections on manufacturing industries in Canada (Hogg-Johnson et al., 2012): Governmental safety and health agencies in Canada targeted high hazard manufacturing firms for a prevention system consisting of consultations or formal inspections. Over a four year period, 63% of those targeted for consultations were served and 56% of those targeted for inspections. The results showed that "Consultation and enforcement programmes as implemented were not sufficient to reduce work injury outcomes over 21 month follow-up.

Lack of benefit could be due to non-specific firm selection methods, limited firm participation in interventions, low intervention intensity or insensitivity of available outcomes."

Discussion of the effects of regulation-based interventions across all industries:

There is a large amount of literature of this type and only a few of the more recent studies have been selected for inclusion here. Although not always, many recent studies appear to confirm that there is strong evidence that regulation (i.e. identifying work hazards with inspections) and enforcement (i.e. insuring that any work hazards are corrected) is effective in preventing fatal and nonfatal injuries among workers in manufacturing industries and industries in general. Accomplishing change in the workplace through regulation and enforcement is the method for moving research to practice for which there is the strongest, most consistent evidence.

What has been demonstrated to work in production agriculture?:

In the US, production agriculture is an industry with many similarities to residential construction. An overwhelming proportion of the production agriculture operations in the US are small, with fewer than ten (and often fewer than five) employees. Many are sole proprietor firms, where the farmer is the owner-manager and sole paid full-time employee. The situation of these family farms with regard to occupational safety and health in some ways resembles that of small residential construction businesses including the many sole proprietor firms that work as subcontractors in residential construction. In the US, most small business agricultural operations have been exempted from enforcement of OSHA regulations, by annual US legislative mandates, in part due to the political power of the farm lobby and, in part, due to the logistical difficulty of inspecting large numbers of small operations. This corresponds, to some degree, to the situation in the residential construction industry where the large numbers of small firms receive the least safety and health regulation attention.

The pre-eminent review and meta analysis of occupational safety interventions in production agriculture (Rautiainen et al., 2009): Rautiainen and coauthors published a Cochrane Review and meta-analysis of interventions for preventing injury in production agriculture in 2009 that covered intervention papers published from as early as 1966 through June 2006. The review identified five randomized controlled trials and three interrupted time series studies that met the criteria for study quality. The eight studies included:

1) two papers on regulation and enforcement (Springfeldt, 1993 on roll over protection – ROPS- in Sweden and Roberts et al., 2003 on a pesticide ban in Sri Lanka – both interrupted time series);

2) four papers on faux or pseudo regulation that included a worksite inspection component (Rasmussen et al., 2003; Gadomski et al., 2006; Rautiainen et al., 2004 – all randomized controlled trials);

3) two papers on training and informational campaigns (Lee et al., 2004 conducted an information dissemination campaign among FFA along with a randomized controlled trial of the results; and Pekkarinen et al., 1994 –Pekkarinen coupled medical health examinations with information dissemination along with randomized controlled trial to evaluate results); and

4) one other intervention, an interrupted time series study of the effect of worker compensation insurance discounts on injury claims (Rautiainen et al., 2005).

Of the eight studies, the review's authors concluded that only one, Sweden's regulations to prevent tractor rollovers, demonstrated an association with a significant initial and progressive decrease in fatal injuries (Springfeldt et al.,1993). The review also stated in its abstract:

> "The selected studies provided no evidence that educational interventions are effective in decreasing injury rates among agricultural workers. Financial incentives could reduce injury rates. Legislation to ban pesticides could be effective. Legislation expanding the use of safety devices (ROPS) on new tractors was associated with a decrease in fatal injuries."

In the text that follows, we describe the studies reviewed by Rautiainen et al., 2009 and some others.

Effects of regulation in agriculture

Effects of regulation in agriculture – Nordic country tractor rollover regulations (Springfeldt et al., 1998; Thelin, 1998; Springfeldt, 1993): In the US, tractor rollovers are the largest single cause of fatal injury in production agriculture and have held this distinction for decades. Sweden began addressing this same problem with a regulation that went into effect in 1959 requiring that all new tractors must include crash protection features that prevented rollover injury and death (Springfeldt et al., 1998; Thelin, 1998; Springfeldt, 1993). In 1965, another regulation went into effect mandating that all older tractors needed to be modified to include these same crash protection features or be retired from service. The regulations were supported by educational and information dissemination efforts and were strengthened in 1970 and 1983. By 1990, the numbers and rates of tractor rollover fatalities had essentially been reduced to zero. Denmark, Norway, and Finland all adopted a very similar approach with similar results (Springfeldt et al., 1998; Thelin, 1998; Springfeldt, 1993). On the other hand,

the 2009 Cochrane review agreed with, yet qualified, the idea that this series of tractor regulatory measures in Sweden was consistently effective at reducing both fatal and nonfatal injuries. They noted:

> "The Swedish study on ROPS (Springfeldt 1993a) is frequently cited as strong evidence of the effectiveness of ROPS (Reynolds 2000). The effect on the time series of injury rates appears clear as legislation has been implemented in several cases, the percentage of tractors with ROPS has increased and the number of injuries and fatalities has decreased. However the changes in the level and trend of the injury rate and the rate of fatalities following four specific legislative measures were contradictory with some increasing and some decreasing. One explanation could be that there is no interruptive effect of legislation but only a gradual effect. By the end of the study period nearly 100% of tractors had ROPS. It is interesting to note that the fatalities reduced to near zero quite early, much before the ROPS percentage reached full compliance. The Springfeldt 1993a study provides annual proportions of tractors equipped with ROPS. This proportion shows a gradual steady increase, which indicates that the enforcement of the legislation may not have been immediate, but gradual over time. Another limitation of the study is that there were only two time points before the first ROPS legislation came into force in 1959 making it difficult to evaluate the data. Yet this initial legislation may have been the most important, having resulted in the steady increase in the percentage of tractors with ROPS (simultaneously decreasing injury rates), particularly in the early years of the observation period. (Rautiainen et al., 2009)."

Effects of regulation in agriculture – a legislated ban on the pesticide Endosulfan (Roberts et al., 2003): This study assessed the results of banning a pesticide known to be associated with both occupational and intentional pesticide poisonings in Sri Lanka, an industrially-developing country. According to the Cochrane review, the study failed to demonstrate evidence of effectiveness although it did lead to some injury reduction:

> "… there was evidence that an Endosulfan ban had a progressive effect of reducing injuries (poisoning deaths). This study had an increasing injury rate over time as indicated by the positive pre-intervention slope …. The immediate effect was also significantly positive, meaning that the number of injuries still increased right after the intervention (effect size 2.20, 95% CI 0.97 to 3.43). However, there was a significant progressive effect of reducing the number of injuries (effect size - 2.15, 95% CI -2.64 to -1.66)."

Effects of faux or pseudo-regulation in agriculture

Effect of faux or pseudo regulation in agriculture: Iowa Safe Farm training coupled with OSHA-type inspections (Rautiainen et al., 2004): This study described the results of the Iowa Certified Safe Farm program which used:

1) worksite inspections coupled with
2) annual health screenings and informational meetings,
3) other farmers participating in informational meetings, and
4) which paid money each year to a large number of participating farms in Keokuk county in Iowa.

There was little injury reducing effect. According to the Cochrane review, the meta-analysis (where this study was combined with two others) showed no evidence for an effect on injury rates (Routiainen et al., 2009).

Effects of faux or pseudo regulation in agriculture (Rasmussen et al., 2003): This study was conducted over four years on 393 farm operations in Denmark with a pre and post evaluation and a control group. The intervention combined

1) worksite inspections with
2) a safety course,
3) group discussion and a presentation by a seriously injured farmer, and
4) written reports of the farm safety checks and the provision of material to those not able to participate in the course.

This randomized controlled trial showed no evidence for an effect on injures according to a meta-analysis in the Cochrane review (where this study was combined with other studies) (Routiainen et al., 2009). A later review by Breslin, 2010 took a different view and affirmed the value of Rasmussen et al., 2003 (see Section 3.4.3.3.2. below). So there is evidence for and against injury reducing effects from two different reviews.

Effects of training and informational campaigns in agriculture

Effect of a safety training and information dissemination campaign in agriculture (Lee et al., 2004): Lee et al., 2004 conducted a randomized controlled trial with 3,081 farm youths and 81 advisors of a national organization where the intervention for the treatment group combined a number of elements of both training and a public informational campaign including:

1) interactive training,
2) contact with a community health nurse,

3) presentations at national conventions,
4) phone contacts,
5) involvement of local agribusinesses,
6) instruction guides,
7) "Treasure chest", quarterly mailings, free Personal Protective Equipment (PPE), and
8) training travel reimbursement and money for community nurse involvement.

The results showed there was no evidence for injury reduction.

Effect of a safety training and information dissemination campaign in agriculture (Gadomski et al., 2006): This study was conducted on 931 New York state farms and consisted of a farm safety visit by a lay educator and the provision of booklets and booster materials but also did not show a significant effect according to the Rautiainen et al., 2009 review.

Effects of interventions incorporating financial incentives in agriculture:

Effect of financial incentives to invest in safer, more profitable ways to produce in agriculture (Lundgvist, 1999): Between 1990-1995, Sweden conducted an intervention in its production agriculture sector based on financial incentives to reduce injury. As part of a larger nation-wide, all industry program, over 2,000 production agriculture firm managers were provided with grants to invest in innovations intended to improve working conditions. In addition to federal grants to the production agriculture firms totaling $23 million, participating farm managers contributed $64 million of their own to the program over the six year period. One evaluation of the effectiveness of the intervention focused on twenty dairy farms considered to be better than average operations with post-hoc questionnaires administered to the farm managers. Results included self-reported improvements in rates of work injuries after the program compared to before the intervention. Another post hoc, no control group evaluation surveyed all 164 dairy, beef and pork operations in a single county that had participated in the grant program. Some 84% of the questionnaires were returned. Of these, 24% reported reductions in musculoskeletal disorders, 19% reported reductions in respiratory disorders, 16% reported reductions in injury risks, and 6% reported less time on sick leave (Lundqvist, 1999). The 2009 Cochrane review of interventions in agriculture excluded the Lundqvist paper, probably because was not one of the study types meeting the criteria for consideration (i.e. an interrupted time series, a randomized controlled trial, or a prospective cohort study with a concurrent control group).

Effects of a worker compensation premium discount program in Finland (Routiainen et al., 2005): This study used an interrupted time series design to assess the effects of incentives (i.e. how insurance discounts affected injury claims). The results were also poor with the Cochrane review noting:

> "there was evidence that incentives have an immediate injury-reducing effect. This study based solely on incentives (insurance premium discount program) had a significant immediate effect decreasing the number of injuries (effect size -2.68, 95% CI -3.80 to -1.56). After the intervention, there was no further decrease - no significant progressive effect (effect size -0.22, 95% CI -0.47 to 0.03)."

Effect of an information campaign with financial incentives in Wisconsin agriculture (Chapman et al., 2013): This study used an interrupted time series design with a control group to evaluate an information dissemination intervention that encouraged adoption of three work methods considered to be safer and more profitable than traditional methods. The campaign ran for seven years and targeted 4,300 Wisconsin dairy farmers. The results showed that the intervention was strongly associated with significant increases in self-reported adoption of all three work methods. The study did not examine injury rates.

Discussion of what has been demonstrated to work in production agriculture:

There were commonalities among the Cochrane review findings for construction and agriculture interventions along with a few differences. As in construction, the Cochrane review standards for the evidence of intervention effectiveness in agriculture were too high for many existing studies to be included in the review, excluding all but eight studies in agriculture and all but thirteen studies in construction. Of these, just one study in agriculture was able to be shown effective (Springfeldt, 1993 on tractor rollover protection regulations in Sweden); and just two studies in construction (i.e.Wickizer et al., 2004 on a statewide, mandated, multifaceted drug-free workplace program including mandatory testing and, Spangenberg, 2002 on a multifaceted company safety campaign coupled with worksite inspections). The interventions that were judged to be effective injury reducers in both construction and agriculture both shared regulation or faux regulation in their approaches. Worksite inspections were involved in two (i.e. Spangenberg et al., 2002 in construction and Springfeldt in agriculture with the tractor rollover regulations that included equipment inspections).

A recently published commentary paper about the barriers and the reasons for the gap in translating research to practice in farm safety may provide some useful insights along with

some possible solutions for residential construction (Fiske and Earle-Richardson, 2013). In production agriculture, the barriers these authors saw were how to: 1) encourage demand by the owners of the firms for effective risk-reducing innovations and 2) how to get proven farm safety innovations into commercial production so they were readily available to farm business owners who wanted to acquire and adopt them. The study authors noted that 1) the lack of effective enforcement and 2) the low monetary penalties in production agriculture for infractions tended to reduce farm business owner demand that the small markets for innovations due to the small numbers of agricultural producers tended to discourage commercialization of proven safety practices and technology. Fiske and Earle-Richardson suggested seven ideas as ways to improve the translation of research to practice in agriculture:

"1) Target key groups within the industry with the best potential for success …
2) Look for opportunities to utilize products with applications in both agriculture and other industries…
3) Develop innovations that have other benefits that offset cost.
4) Focus on low investment innovations …
5) Create an intermediary government-supported role where prototypes are created, evaluated and sold (below cost if needed).
6) Work with insurers to develop incentive systems that incorporate proven safety innovations.
7) Explore the potential of international markets, manufacturers and funding agencies."

These recommendations, developed explicitly to improve the translation of research to practice in production agriculture, may also have relevance for the residential construction industry. For example, the ideas about how the power of focusing on the market-driven attractiveness of innovations that yield benefits to firm managers (aside from greater safety) may be relevant to the firm managers who control residential construction worksites (see Recommendations section below).

What has been demonstrated to work in small business interventions?

Reviews of occupational safety and health interventions in small businesses:

Review of interventions in small business (Breslin et al., (2010): A review of the effectiveness of occupational safety interventions among small businesses (i.e. less than 100 employees) identified five high quality studies and concluded that safety audits coupled with training (Torp,

2008; Rasmussen et al., 2003) or safety audits accompanied by engineering controls (Lazovich et al., 2002) as well as engineering controls alone (Crouch et al., 1999) and training alone (Wells et al., 1997) all "showed a limited amount of evidence of improving safety outcomes" (Breslin et al., 2010). All five of these studies are reviewed individually below.

Review of interventions in small businesses (Hasle and Limborg, 2006): The authors focused on small businesses with less than 50 employees, but the scope of their review was larger and very inclusive. The review included both intervention studies and observational studies such as papers on the characteristics of small enterprises, their internal occupational safety and health activities, and the how the risks were different for them than for a medium or large business. However, no intervention studies were described in detail, thus detracting from the value of the review for this manuscript. The authors noted:

> "The most effective preventive approaches seem to be simple and low cost solutions, disseminated through personal contact. It is important to develop future intervention strategies which study the complete intervention system: from the intermediaries through dissemination methods to the resulting preventive activities of the small enterprises."

Effects of governmental regulations and enforcement among small businesses:

No studies were identified about regulatory enforcement effects on reducing injury in small businesses.

Effects of faux or pseudo regulation among small businesses:

Effects of worksite inspections along with safety training on farms in Denmark (Rasmussen et al., 2003): As noted previously in the agriculture section above, the Rasmussen study was conducted over four years on 393 farm operations in Denmark with a pre and post evaluation sample and a control group. The intervention combined:

1) worksite inspections with:
2) a safety course,
3) a group discussion and a presentation by a seriously injured farmer, and
4) written reports of the farm safety checks and the provision of material to those not able to participate in the course.

The authors noted their results in the abstract as follows:

> "Pre- and post measurements showed a substantial reduction in injury rates in the intervention group in comparison with a slight reduction in the control group. In a

> multivariate regression analysis the intervention effect was estimated to be a 30% injury-rate reduction of all injuries, while there was a 42% reduction for medically treated injuries only. Although none of these effects are statistically significant with the present sample size, their magnitude and direction support an intervention effect. The measures of safety behavior revealed significant improvements, and this finding supports the conclusion that the intervention effect was positive, since they concern some of the mediating factors on the pathway from intervention to improved injury rates."

The review of small business occupational safety and health interventions by Breslin, 2010 affirmed the value of Rasmussen et al., 2003 by stating that "The high quality study (Rasmussen et al., 2003) showed a positive effect on behavioral measures. However, the study showed no effect on health-related outcomes." (Breslin et al., 2010).

Effects of a worksite inspection and training program among small California businesses (Wells et al., 1997): Legislation in California mandated that employers implement a program of worksite inspections and hazard corrections along with improvements in injury investigation and employee training and communication. An evaluation based on a sample of case study data from eight small businesses (out of a sampling frame of 151) conducted two months before and one year after the intervention was conducted and showed that the intervention was associated with fewer illnesses and improved employee perceptions of access to protective devices.

Effect of a worksite inspection program coupled with worker and employer training and other worksite assistance in small Minnesota woodworking businesses (Lazovich et al., 2002): This study randomly assigned 24 small woodworking businesses (5-25 employees) to an intervention group and another 24 as controls that received only written recommendations for controlling workplace dust hazards. The intervention group received:

1) a one hour worker training session designed to modify work practices associated with high dust production and an employer training visit to model facilities (accompanied by two employees),
2) technical assistance consisting of individualized industrial hygiene measurements of dust production at each firm for parts their dust collection system along with
3) more detailed written recommendations customized for each firm for improving their engineering and administrative controls.

In a pre and post evaluation with control group study design, the post intervention assessment showed that employees reported behavioral changes and increases in knowledge and awareness of dust producing work activities and that median dust concentrations were reduced by 10% compared to baseline measures.

Effects of training and information dissemination campaigns among small businesses:

Effects of a two year lay manager training program for small enterprise managers in Norway (Torp, 2008): This before and after controlled trial included 226 managers of motor vehicle repair firms in Norway. The intervention consisted of four day-long seminars over two years for firm managers across seven regions in Norway. Self-report questionnaire responses from the managers (n=116) demonstrated that those who participated in the seminar reported significantly greater improvements in their health and safety management systems (as measured by sixteen items) compared to their own baseline and compared to the control group of another 116 managers. A separate set of questionnaires administered to employees demonstrated a significant increase in satisfaction with the physical work environment in the intervention group.

Effects of other types of interventions among small businesses

Effects of accountants as occupational health and safety intermediaries in Denmark (Hasle et al., 2010): There have long been problems reaching small businesses with health and safety information. As a result, there has been special interest in using intermediaries outside the traditional occupational safety and health system (e.g. dealers and suppliers, customers, insurers, industry associations, local civic organizations, etc.) as a way to gain access to and the interest of small businesses. In this study, the researchers invited state-authorized accountants to an occupational safety and health seminar about occupational safety and health concerns for small businesses. Of 2,500 recruited, 164 participated in one or more of the three rounds of training sessions over the two years (one hour of classroom training plus two hours of practical exercises for some trainees), and 74 completed the evaluation questionnaire. The training was quite basic and focused on: 1) how to check whether a company was in compliance with occupational health and safety regulations, 2) how the process of regulation worked, what documentation was required, and 3) an introduction to workplace hazard assessment. In their abstract, the authors noted:

> “Most of the accountants had actually given health and safety advice and for most of them it was a positive experience. However, they also faced constraints due to the

> relatively minor role health and safety played in their agendas with their clients and their own limited knowledge about health and safety even after taking part in the training seminars. This study concludes that it is possible for accountants to act as health and safety intermediaries, but that institutional support for the training activities is important to secure a broader application of this approach."

In their discussion, the study authors further described their results and the implications:

> "… The majority of the accountants did use the information provided at the training seminars to communicate with their small enterprise clients about health and safety. Some of them only used it to pass on the information, but most of them took a more advisory approach, explaining the legal requirements and the written information, asking about compliance by the client and checking whether the client followed up on the advice. However, the majority of the respondents did not follow up on the advice given. This might be due to lack of opportunity because they rarely have meetings with their small enterprise clients – usually only once a year. The accountants generally experienced a positive response but also felt somewhat constrained by their limited knowledge about health and safety. That result indicates that although short seminars worked as an introduction, it is important to follow up with more in-depth training. It is still an open question as to how much training accountants would be willing to undertake. There is also the risk of a reduction in interest as the time passes after the training seminars, but approximately one quarter of the respondents to Survey A had prior experience of discussing health and safety. This suggests that the subject spontaneously comes up in the accountant–client relationship, which would help keep it on the agenda."

Effect of safety coaching of owner/managers in Denmark (Kines et al., 2013): This study was an attempt to determine whether an integrated safety management system could be implemented in small businesses in the metal working industry (10–19 employees). Integrated safety management was defined as having two essential parts: 1) a behavior-based participatory problem-solving process with both management support and worker involvement, and 2) a workplace culture change process. Together, these two parts were designed to produce visible and focused safety activities and tangible outcomes which spread throughout the firm, and in turn lead to greater senses of trust, mutual obligation and reciprocity which in turn lead to increased motivation to continue the problem solving process. Sixty-four firms were contacted and sixteen agreed to participate. After random assignment, the study authors

attempted to implement this program among six firms with eight firms serving as controls (and two dropouts). The evaluation was a before and after with control group research design and included administration of a safety inspection (using the tool developed by Laitinen et al., 2010 for the construction industry) and an employee safety perception and injury reporting questionnaire. This paper's authors reported in their abstract:

> "Safety coaching of owners/managers result in the identification of 48 safety tasks, 85% of which are solved at follow-up. Owner/manager led constructive dialogue meetings with workers result in the prioritization of 29 tasks, 79% of which are accomplished at follow-up. Intervention enterprises have significant increases on six of eight safety-perception-survey factors, while comparisons increase on only one factor. Both intervention and comparison enterprises demonstrate significant increases in their safety observation scores. Interview data validate and supplement these results, providing some evidence for behavior change and the initiation of safety culture change. Given that over 95% of enterprises in most countries have less than 20 employees, there is great potential for adapting this integrated approach to other industries."

The researchers also cited Lipscomb et al., 2009 when they noted that "Conditions could not practically be tightly controlled, and flexibility was required in delivery and follow-up assessments to accommodate the demands of the workplaces" (Kines et al., 2013).

Discussion of how small business interventions are relevant to research to practice in residential construction:

Once again, worksite inspections to identify hazards coupled with follow-up efforts to correct hazards appear to be supported by findings of injury reductions (i.e. Rasmussen et al., 2003; Lazovich et al., 2002; Wells et al., 1997). These findings supported the idea that hazard inspection and correction may be a viable direction for improving research to practice in residential construction.

The results of two other types of interventions accomplished among small businesses may also demonstrate encouraging directions for residential construction research to practice. The study of accountant education to provide them with basic information about safety and health hazards, rules, costs, and the implications of noncompliance illustrated a way to quickly and concisely bring occupational safety issues from "off the radar" to manager attention by using the firm's accountant as an intermediary. Getting health and hazard control onto the radar of

managers is a particular problem for the middle and smaller-sized firms that predominate in the residential construction sector.

Finally, the Kines et al., 2013 study provides an example of how a carefully considered socio-cultural approach with employee and manager cooperation and involvement (i.e. the safety management approach) can lead to a process of continuing improvement for safety in very small firms. This study may be able to provide a model for small residential construction firms. The Kines et al. study included hazard inspections that used the audit tool developed by Laitinen et al., 2010 for construction worksites.

5. What works best to diffuse non-occupational safety innovations and get them adopted in construction?

Effects of worksite health promotion studies in construction

Effects of worksite health promotion studies among construction employees in Denmark (Gram et al., 2012; Groeneveld et al., 2010): Although recreational physical activity has been shown to improve physical fitness and muscle strength and endurance, several studies have shown that occupational physical activity sometimes does not (Gram et al., 2012). There are a few studies of worksite health promotion interventions among construction firms including one that focused on the clinical effectiveness of exercise or stretching on cardiovascular or muscle performance indicators (Gram et al., 2012). A small study among three workplaces at three companies in Denmark undertook a randomized controlled trial of individualized, short duration exercise programs (20 m) three times per week over a twelve week period. Of 154 recruited, 52 did not respond and 34 declined to participate. 67 were randomized into treatment and control groups. Average attendance in the treatment group was 68% overall. The results showed a clinically relevant increase in estimated maximal oxygen uptake but not in muscle strength (Gram et al., 2012). Another study focused on reducing body weight among overweight construction workers with a six month long individual counseling program using motivational interviewing techniques delivered face to face and by telephone. For the 191 randomized into the intervention group (compared to 181 in the control group) for which there were all three measures (start, six months later and 12 months later), body weight significantly decreased at six and twelve months (Groeneveld et al., 2010). The relevance of these two papers for research to practice is probably limited to showing that individual training interventions and motivational interviewing interventions can yield changes in employee behavior coupled with objective, quantitative measurements to document their effectiveness.

Effects in studies in residential construction of adopting more profitable production practices

Observational studies of the adoption of new products and other innovations by residential construction companies (Koebel, 2008; Ganguly et al., 2010; McCoy et al., 2010): Research teams associated with Professor CT Koebel at Virginia Polytechnic Institute and State University have published a number of studies on the diffusion and adoption of new products and practices in the residential construction industry. A study published in 2008 with Koebel as sole author was based on two surveys: one of small and another of large firms. The first survey was administered in 2004 to a random sample of 1,200 individuals who were members

of the National Association of Home Builders (i.e. residential construction firms – typically builders in charge of projects but who were not self-accomplishing many tasks). A total of 196 responses (16% response rate) were received that were predominantly from individuals associated with small homebuilding firms (i.e. 75% built less than 50 units per year, 66% built less than 25 units per year). The second survey was sent to approximately 1,700 individual members of the National Association of Home Builders employed by the 400 largest builders in the US and a total of 84 responses were received (5% response rate). In the abstract, Koebel reported these results:

> "Small builders receptive to innovation are likely to be led by a technology champion and to build custom homes for a relatively affluent and informed clientele. These firms provide a likely audience for technology innovations that require more upfront investment, as with some green building products, but can be marketed as highly innovative to home- buyers interested in higher performance in energy efficiency, sustainability or durability. In order to impact a larger portion of the housing market, large production builders should be the target for innovations that contribute to affordability in entry-level homes or to energy efficiency, sustainability and durability in higher priced houses.
>
> Takeaway for practice: Planners aiming to encourage innovation in homebuilding should craft strategies that recognize the opportunities, the structure of the industry, and the factors influencing innovation adoption. Local builders with owners who champion innovation are good targets for demonstration programs that involve custom homes. Larger production builders will want strategies that can be replicated in multiple market areas, and are likely to avoid localities whose codes and regulations would require them to change their production models" (Koebel, 2008).

Ganguly et al., 2010 and McCoy et al., 2010 (both with CT Koebel as coauthor) made use of data they collected through the National Association of Homebuilders via its "Annual Building Practices Survey" that began in 1996 and included findings over ten years up to 2005. Usable questionnaires each year varied from 1,821 to 2,777 and totaled 20,670 for the ten year period (likely with the same low response rates as in Koebel, 2008 above – 16%). Ganguly et al., 2010 investigated adoption and usage of innovative wall-cavity insulation materials by residential homebuilders in the US with 5,757 usable question responses to assess trial adoption, intermediate adoption, and complete adoption. The research results indicated that "though a higher proportion of large firms are more likely to adopt innovative insulation material, they continue using established products while slowly increasing their use of the

innovative material over time. However, when smaller homebuilders adopt an innovative insulation material, it replaces the existing product from their material usage portfolio at a faster rate" (Ganguly et al., 2010).

McCoy et al., 2010 studied thirteen highly innovative products (e.g. innovative methods for floor sheathing, wall headers, below grade exterior walls, etc.) and supplemented the ten years of survey data from the National Association of Home Builders with case studies of the development process. The authors focused on the influences of new product commercialization processes in an attempt to learn more about why there is often so much market resistance to new products and practices that contain substantial technological value and deserve rapid adoption. The authors were specifically interested in a process they called "concurrent commercialization" (as a product development and commercialization strategy that may be able to improve adoption success among residential construction firms, especially when coupled with management best practice recommendations). The authors referred to an earlier paper (McCoy et al., 2009),that reviewed adoption literature in residential construction (Koebel, 2003; Dubois and Gaddis, 2002; Ball, 1999; Toole, 1998; Blackley and Shepard, 1996). In that paper, McCoy and coauthors (2009) identified and described six properties of a new product or new practice innovation that represented key decision points for residential construction firm managers who were potential adopters (modeled after the list of innovation characteristics that helped or hindered adoption described in Rogers, 2003).

"1) consistency of installation (based on supply chain, organizational and environmental risk literature) refers to site and project variability;
2) product lifecycle (based on technical and legal risk literature) includes durability, serviceability, maintainability, reliability and disposability;
3) diffusion within/across builder firms (based on organizational and environmental risk literature) includes knowledge transfer between builders, i.e. small, independent builders;
4) market awareness (based on financial and market risk literature) requires knowledge of end-user preferences or influence within the building process;
5) customizability (based on organizational and environmental risk literature) is the complexity of a product or process; and
6) breadth of code compliance (based on operational and legal risk literature) examines the extent of local and regional regulation."

The findings of the McCoy et al., 2010 study supported the importance of the six properties that make an innovation more or less likely to be easily and quickly adopted by a large proportion of the residential construction industry. Furthermore, the findings supported the beneficial influence of the process approach they called "concurrent commercialization" to develop an innovative product or practice for the market of residential construction firms. The conventional commercialization process for a new product or practice for residential construction moves through a top down, linear process where one firm develops the product and markets it with the help of another firm and then distributes it through another firm that may in turn rely on a local product supplier firm and then often involves yet another even more local firm to install the product before it becomes available to the end user firm. The idea of concurrent commercialization is instead that all these firms at each step of the process learn as they go and may have ideas about how to improve the product that get listened to and incorporated. The concurrent commercialization process builds on problems and insights discovered at each step of the commercialization process that are then used to refine and reconfigure the product as it is commercialized. There is feedback from each step in the commercialization chain of firms. As the authors state: concurrent commercialization, "drawing on concurrent engineering, expands the definition of the market to include all supply-chain participants, not just the installers and advocates the establishment of a complete supply chain, possible only if every member of the chain foresees net benefits to joining. In strengthening the commercialization process, the product might experience better probability of success." This paper has immediate practical relevance for residential construction occupational health and safety research to practice innovations by suggesting that there needs to be involvement, active participation, and feedback to reconfigure and redesign the innovative safety tool, practice, or product (as well as give and take about what's promoted and how) that includes a wide range of actors and stakeholders in the process that includes, especially the end users themselves (i.e. the employees) (McCoy et al., 2010).

Literature reviews and case studies of research to practice sources in the construction industry (Gambatese and Hallowell, 2011a; 2011b): In the first study, Gambatese and his coauthor sought to "determine and evaluate the factors that influenced the initiation, development, implement and successful diffusion of technical innovations in the construction industry based on the experiences of successful construction innovation generating organizations." The authors reported their finding in their abstract as follows:

> "Some technical innovations diffuse rapidly throughout the construction industry while others take a long time or are never integrated into everyday practice. Understanding

> the initiation, development, implementation and outcomes of successful technical innovations within the construction industry provides guidance for the improvement of the innovation process. To further this understanding, innovation generating organizations (IGOs) in the construction industry were surveyed and the data were statistically analysed. Two sources were used to identify newly developed products, technologies and management strategies: the Construction Innovation Forum's NOVA Award website and the Emerging Construction Technologies (ECT) website. A total of 233 innovative products were identified from the two websites. The results showed that there are many statistically significant motivating factors for investment in the initial development of successful technical innovation, barriers and enablers to efficient diffusion and innovation outcomes on construction projects. Additionally, successful development, implementation and diffusion of an innovative product required an average of 38 months, 4700 worker hours and $836,000."

A second study by Gambatese and Hallowell (2011b) conducted an evaluation of ten case studies. The findings, as reported in the paper's abstract, are as follows:

> "Innovation is vital to successful, long-term company performance in the construction industry. Understanding the innovation process, how innovation can be enhanced and how it can be measured are key steps to managing and enhancing innovation. The factors that affect innovation on a project were identified, as well as how these factors can be used to measure the level of innovation on a project, and the practices and processes that encourage and facilitate innovative changes. Case studies of construction projects in the United States revealed three necessary components of innovation: idea generation, opportunity and diffusion. A variety of practices are used to optimize each component including support and commitment from the owner/client and firm upper management, workforce and project team integration and diversity. Applying the practices
>
> identified in the research leads to enhanced innovation through better communication among project team members, integration of the design and construction disciplines, more efficient designs, development of unique ways of completing work and sharing of the lessons learned. The end result of innovation will be projects that successfully meet and exceed cost, quality, schedule and safety goals" (Gambatese and Hallowell, 2011).

Discussion of how non-occupational interventions are relevant to research to practice in residential construction:

Individualized attention and programming led to greater success in interventions seeking to improve employee aerobic capacity and in those to reduce employee body weight (Gram et al., 2012; Groeneveld et al., 2010). On the other hand, neither of these types of personalized interventions appeared to have much relevance to advancing residential construction research to practice. There were important findings available from existing research on technical innovations in the residential construction industry including: 1) how to diffuse information about innovations, 2) how to modify innovations in development (i.e. concurrent commercialization), and 3) how to configure innovations to encourage maximal adoption (Koebel, 2008; Gangulay et al., 2010; McCoy et al., 2010). The proposed set of six characteristics that categorized technical innovations most likely to be adopted successfully are also likely to have important relevance for improving the likelihood of successful adoption of safety innovations (McCoy et al., 2009). Researchers interested in getting a product or process that yields better safety more widely adopted might be advised to be patient, to get some feedback from a pilot group, and to be prepared to make some changes in their intervention plans and perhaps even in the product or process being promoted itself (McCoy et al., 2010). Finally, the studies of how to encourage adoption of more profitable construction practices made clear that success often comes to those with the biggest eyes and ears – those that recognize that there needs to be give and take about what's promoted and how - that includes a wide range of actors and stakeholders in the process that includes, especially, the end users themselves (i.e. the employees) (McCoy et al., 2010).

6. What can observational studies about construction injuries and innovations add to understanding adoption?

Observational studies are those that study work injury problems but do not mount an intervention to prevent them. Observational studies have long been valued for their ability to identify: 1) trends in injury occurrence, 2) pertinent injury circumstance information, and 3) risk factors for injuries that can help target research to practice efforts. Observational studies relevant to two types of residential construction injuries are presented in this section: roof falls and nail gun injuries. Observational studies relevant to other injury types in residential construction are available and should be investigated to help guide research to practice efforts.

Studies of Falls

Observational studies of risk factors associated with falls from roofs among US construction workers (Dong et al., 2013): This study collected and sorted data from a variety of sources in an attempt to construct a representative record of work-related fatalities among US construction workers associated with falls including falls from roofs over an eighteen year period (1992-2009). The study also gathered detailed information about the fatally injured individuals and their employers, the fatal injury, and the injury circumstances associated with each fall. The greatest detail was available for the seven most recent years (2003-2009). The major findings with relevance for research to practice were that “roof fatalities accounted for one-third of fatal falls in construction in 1992–2009. A disproportionately high percentage (67%) of deaths from roof falls occurred in small construction establishments (1–10 employees). Roofers, ironworkers, workers employed with roofing contractors, or working at residential construction sites, had a higher risk of roof fatalities. A higher rate of roof fatalities was also found among younger (<20 years) and older (>44 years) workers, Hispanics, and immigrant workers.” The study authors concluded that “roof fatalities corresponded with economic cycles and differed among construction subgroups and worksites” and that “prevention strategies should target high-risk worker groups and small establishments.” They also suggested that future research should focus on ”the influence of different types of PFAS (personal fall arrest systems) on productivity and safety during residential roofing construction” (among other recommendations they made) in part because negative effects on productivity and worker comfort have been cited as reasons for its lack of use by both employers and employees. The authors also drew attention to the Hierarchy of Fall Hazard Control Methods that has been adopted in the United Kingdom, Australia, and British Columbia, Canada as a useful tool when planning work at heights.

Observations of self-reported fall risk perceptions, fall prevention knowledge and behavior, and fall injuries among apprentice carpenters and suggestions for how to improve current training (Kaskutas et al., 2010; 2010): The first study (2011 SJWEH paper) administered a questionnaire to 1,037 apprentice carpenters between 2005-2006 at a training center in St. Louis, Missouri to identify individual and organizational factors associated with falls from heights. The cross sectional study achieved a 98.9% response rate and found that "51% knew someone who had fallen from a height at work and 16% had personally fallen in the past year, with ladders accounting for most of the falls. Despite participation in school-based and on-the-job training, fall-prevention knowledge was poor. Ladders were perceived as low risk and ladder training was rare. Apprentices reported high levels of unsafe, fall-related behaviors on their work crews. Apprentices in residential construction were more likely to fall than those in commercial construction, as were apprentices working on crews with fewer senior carpenters to provide mentorship, and those reporting more unsafe behaviors among fellow workers." The authors concluded: "Despite participation in a formal apprenticeship program, many apprentices work at heights without adequate preparation and subsequently experience falls. Apprenticeship programs can improve the timing and content of fall-prevention training. This study suggests that organizational changes in building practices, mentorship, and safety practices are also necessary to decrease worker falls from heights."

The second study (2011 JSR paper) was also conducted in the St. Louis training center and in the surrounding community and combined a worksite audit at 197 residential construction worksites with focus groups involving 36 apprentices and results from the same questionnaire to 1,025 apprentices described in the study immediately above. The purpose of the study was to improve the fall prevention instruction at the training center (and a team of carpenter instructors and researchers revised the fall prevention training to fill the gaps that were identified). The results showed that:

> "Most apprentice carpenters performed work tasks at heights prior to training and fall protection techniques were not commonly used at residential construction sites. Priorities of the revised school-based training included safe ladder habits, truss setting, scaffold use, guarding floor openings, and using personal fall arrest systems. New apprentices were targeted to ensure training prior to exposure at the workplace. We used adult learning principles to emphasize hands-on experiences. A framed portion of a residential construction site was fabricated to practice fall protection behaviors in a realistic setting. The revised curriculum has been delivered consistently and apprentice feedback has been very favorable. … Integration of needs assessment results was

invaluable in revising the school-based carpenters apprentice fall prevention curriculum. Working closely with the instructors to tailor learning experiences has provided preliminary positive results. Impact on Industry: The fall safety of the residential construction industry continues to lag behind commercial construction and industrial settings. The National Occupational Research Agenda includes a Strategic Goal to strengthen and extend the reach of quality training and education in the construction industry via mechanisms such as construction safety and health training needs assessments. This study demonstrates how a structured process can be used to identify and remedy gaps and improve training effectiveness. We encourage others to take steps to assess and increase the impact of training efforts directed at all residential construction professionals; including both union and non union workers. The implications are even greater in the non-union sector where most U.S. residential work is done."

Studies of nail guns

Observational studies of risk factors associated with nail gun injuries among US construction workers (Lipscomb et al., 2011; 2010): The 2010 Lipscomb study administered questionnaires to 464 apprentice carpenters at a training program center in St. Louis, Missouri in 2008 which asked them to report any nail gun injuries they experienced in the last year along with how many hours they worked and how many of those hours involved nail gun use and what triggering mechanism the nail guns they used had (safer sequential triggers that required the nose of the device to be depressed into the surface prior to firing or automatic triggers that fire whenever the trigger is depressed). Again the authors claimed response rates above 95%. The 2008 data was combined with data from similar questionnaires from 2005-2007. The results showed that: "Injury rates declined 55% from baseline measures in 2005 with early training and increased use of tools with sequential actuation. Injury rates declined among users of tools with both actuation systems, but the rates of injury were consistently twice as high among those using tools with contact trip triggers." The authors concluded that "Nail gun injuries can be reduced markedly through early training and use of tools with sequential actuation. These successful efforts need to be diffused broadly, including to the non-union sector."

The 2011 Lipscomb study collected data from personnel at 217 points of sale or rental of framing nail guns in North Carolina, West Virginia and southwestern Pennsylvania, Missouri, and southern Illinois based on a list of suppliers obtained using the Internet and Yellow Pages. The outlets included those selling to builders (such as lumber yards, building supply and tool

outlets) as well as those selling to consumers (such as big box home improvement stores, and hardware stores). The results showed that "Sales personnel had little understanding of risks associated with use of framing nail guns. Individuals who had used the tool and those working in construction outlets were more likely to be knowledgeable; even so, less than half understood differences in trigger/actuation systems." The authors concluded: "Consumers, including contractors purchasing for workers, cannot count on receiving accurate information from sales personnel regarding risks associated with use of these tools. The attitudes and limited knowledge of some sales personnel regarding these potentially deadly tools likely contributes to a culture accepting of injury. The findings demonstrate how influences on the culture of construction are not limited to workers, employers, or the places construction gets done."

Discussion of how observational studies in residential construction may be relevant to better translation of research to practice in residential construction:

Observational studies have provided evidence about the prevalence of workplace hazards, the injuries associated with them, and likely directions for injury prevention and hazard reduction. More widespread adoption of measures inspired by observational studies appear to be able to help prevent residential construction roof fall injuries and nail gun injuries through research to practice interventions.

7. What can economic analysis of intervention studies add to understanding adoption?

Different interventions have different costs of delivery per employee and in terms of costs per desired result (Tengs et al., 2006): There is merit to evaluating interventions in terms of what they cost to deliver as well as in terms of their yield compared to other interventions. With this information, funding agencies and businesses can judge what type or what mix of types of interventions they can pursue within their budget limits to best optimize injury reduction. For example, a survey of 587 life-saving interventions of all types including occupational safety and health interventions suggested that there is a wide range in terms of costs per year of life saved (Tengs et al., 2006). The median costs per year of life saved for injury-reducing interventions were $48,000 versus $42,000 for all types of interventions. The range was from $10 billion dollars per year of life saved to those that saved more than they cost (e.g. from saving in medical care, lost time, etc. due to reduced rates of injury). Ten of the studies were evaluations of construction safety standards (most often comparisons between 1971 or 1972 and 1988 or 1989 versions of standards such as concrete construction standard, underground construction standard, safety standard for trenches, safety standard to prevent cave-ins, etc.). The range of costs was from saving more than they cost (<$0) up to $400,000.

Review of economic evaluations of occupational safety and health interventions in single companies (Tompa et al., 2009): The authors carried out a systematic review of occupational safety and health interventions with economic analyses that had a workplace component. 72 studies were identified for the period 1990-2008 and the 34 considered to be of medium and high quality were included in an evidence synthesis. None of the studies took place in the construction industry. Most or all of the studies were centered on a single employer or company so there was little to learn about moving research to practice across larger groups such as regions or groups of companies. Although the authors noted how evaluation quality could be improved, they also decided that there was relatively strong evidence supporting the economic merits of: 1) ergonomic interventions in manufacturing and warehouse work, and 2) “system-level” disability management interventions in a number of industries.

Review of economic evaluations of workplace-based return to work interventions (Franche et al., 2005): Disability management programs intervene after an employee has been injured on the job in an attempt to speed the return to work process and control other costs associated with the injury. These programs are typically provided by a stakeholder with a strong financial

interest in the outcome such as the employer (most often) or by the firm's health care provider, or by another intermediary such as the worker compensation insurer. Studies were identified that were published between 1990 and 2003 and ten were considered high quality and included in the review. A number of the ten studies included multiple workplaces in multiple industries and so may be able to provide useful ideas for diffusing innovations and increasing research to practice translations. Workplace-based disability management programming typically includes five components: 1) early contact with the worker by the workplace after the injury, 2) work accommodation offers to modify the job, 3) contact between the health care provider and the workplace so the care provider can better understand the job demands, 4) ergonomic work site visits to identify and solve problematic physical job demands, and 5) an individual is assigned to be the return to work coordinator. The study's authors concluded:

> "There was strong evidence that work disability duration is significantly reduced by work accommodation offers and contact between healthcare provider and workplace; and moderate evidence that it is reduced by interventions which include early contact with worker by workplace, ergonomic work site visits, and presence of a RTW coordinator. For these five intervention components, there was moderate evidence that they reduce costs associated with work disability duration. Evidence for sustainability of these effects was insufficient or limited."

Discussion of economic analysis literature on intervention studies as it relates to research to practice in residential construction:

There seem to be a few useful insights here. Certainly cost is a consideration in most managers' minds when they are considering adopting a new program or innovation. Cost was cited as an important barrier to adoption and to research to practice in earlier in this review (e.g. 3.2.3.4). Another difficulty is that interventions are not often subjected to careful economic analysis of both their costs and their benefits. There appears to be merit in paying attention to who experiences the costs of injury and so has a direct interest in interventions designed to help prevent and control injuries at work. For small firms and sole proprietor firms engaged in residential construction, the costs of injury typically fall on the employer/firm owner, the employee, and the worker compensation insurer.

What we know and don't know about improving the translation of research to practice in residential construction

1. We don't know very much at all about translating research to practice in residential construction or general construction.

There are almost no studies available about what works best for translating research to practice in construction. Most of the studies reviewed here have been about whether interventions have been shown to reduce injuries. This suggests strongly that more studies about translating research to practice in residential construction need to be done.

2. We know that most published studies don't meet rigorous quality standards for evaluation (and that the few that meet the standard mostly don't produce significant initial and continuing injury reductions).

We know that most studies reporting interventions of all major types (i.e. regulation, pseudo-regulation, training and informational campaigns, other types of interventions) intended to translate research into practice in construction or in agriculture or in the small business sector are not consistently associated with significant reductions in injury when their study evaluation results are subjected to rigorous standards in reviews that have high quality standards for intervention evaluation. In fact, most study reports of all types of interventions in construction, production agriculture or the small business sector do not meet minimum standards for intervention evaluation quality and so are impossible to fairly review (i.e. lack of controls, etc.). This suggests that improving the quality of intervention evaluation is an important objective to pursue whenever residential construction interventions are conducted.

3. We know future research should be higher quality.

We know that it makes sense to encourage future intervention and intervention evaluation studies to adopt minimum Cochrane review criteria in their evaluation design (for randomized controlled trials, interrupted time series, or before and after controlled trials) in order to improve the methodological quality of future studies and to increase the likelihood that those studies that conduct interventions and intervention evaluations will be included in future literature reviews with high quality criteria and will receive a fair trial.

4. We don't really know, fundamentally, why most construction, production agriculture or small business sector intervention studies fail critical review.

We do not appear to know whether the study failures to survive critical review are due to fundamental flaws in the intervention approaches or to other causes that render them unworthy of future consideration such as a less than optimal intervention accomplishment, a less than optimal intervention evaluation approach or accomplishment, or other factors or combinations of factors.

5. We know regulation with safety inspections and corrections works in construction.

When rigorous evaluation standards are applied, we know that, in construction, mandatory regulations can reduce injuries industry-wide across an entire state (although the study demonstrating this followed a mandate for drug free workplaces – Wickizer et al., 2004). We also know that, in construction, pseudo regulation in the form of worksite inspections coupled with a comprehensive, employer-based safety information effort that was imposed across a large, multi-employer worksite can reduce injuries (Sprangenberg et al., 2002).

6. We know future efforts will likely need to partner with industry.

We know that looking to the residential construction industry itself (along with its industry associations such as the national and regional Associations of Homebuilders) for leadership on translation of occupational safety and health research to practice is one of the few "growth areas" available in view of static or shrinking roles for government-led or academic research-led occupational safety efforts. We don't know which if any of the most promising existing strategies will work best or how they'll need to be modified given the current situation where strong federal governmental regulation and enforcement (the strategy with the best evidence for working best and most quickly and reliably in high hazard industries in the past) appears to be simply not an option for at least the next decade.

7. We "kind of" know that industry-led interventions can work.

We know that, although there is only modest evidence in construction (from a study of safety inspection competitions in Finland in Laitinen et al., 2010), there is modest evidence from other industries that supports the pursuit of industry-led interventions and government partnerships for reducing injuries (Rasmussen et al., 2003). Especially when financial incentives can be incorporated, there are good reasons to continue to explore this type of intervention.

8. We know there is a large information gap that could be explored and exploited for greater translation of research to practice and greater safety.

We suspect that residential construction, like most other industries, is one where top managers, middle managers, supervisors, and employees in many if not most firms may be unable to recognize or characterize: 1) their own firm's work-related injury and disease rates, how they compare with industry averages, or what costs they bring to the firm, 2) the ranking of various types of existing workplace hazards in terms of which are responsible for the most frequent severe injuries/ largest costs, or which are most easily and cheaply preventable, or 3) the potential benefits from adopting safety best practices in terms of advantages in profitability, work performance, or work quality. Managers of middle and smaller-sized residential construction firms are unlikely to have management information systems that collect and summarize occupation safety and health-relevant information in ways that managers can act on.

9. We know that making the business case for an innovation or intervention can make it easier to disseminate and increase the likelihood that firm managers decide to adopt it.

We know that researchers will want to be able to quickly scale-up any research to practice innovations or interventions that are popular and actually work to reduce injuries and/or hazards. It makes sense to encourage future research to practice studies to track and report separately both the costs of implementing their interventions and the costs of conducting their intervention evaluations. Calculating costs for different-sized firms and per employee are also likely to be useful. Pressures to justify costs are not likely to lessen in the coming decade and so future research to practice studies should be encouraged to make efforts to place dollar values on the benefits their interventions achieve. We know that it is important to make the business case if we want to get our interventions and innovations widely adopted. We know that managers of both large and small firms and managers of both residential construction builder firms and subcontractor firms are all interested in efforts to better depict and "sell" the economic implications of (and arguments for) adopting safety innovations (Kramer et al., 2010). This approach could be called disseminating information about "dollar bills laying on the sidewalk" or "money left on the table" depending on whether one prefers metaphors from economics or card games. Managers especially appear to want better information and better tools that can help them estimate the start up and continuing costs of an innovation as well as its return on investment. They want to be able to plan the implementation phase after they've decided to adopt a particular innovation and want the planning to be easy to scale exactly to their firm's particular characteristics (size, type of building product, typical schedule, etc.). This is not unreasonable. In fact, having good enough information of this type that allows a manager to develop budgets, assign resources and personnel time, and project likely outlays and future

returns is basic to the types of product information now available (often in online management decision support systems) for technical production innovation products in construction. Safety innovations need to catch up if they want serious consideration and want to be able to demonstrate the value of investing in one particular type of safety innovation rather than another or in a safety innovation rather than an innovation that improves profits and production in some other way.

10. We know that there is merit to reading and reviewing the previous literature carefully and building on those ideas for which there is good evidence. On the other hand, we probably don't know yet all the ideas that could work now to reduce injuries.

There is no reason to automatically close off or shut down concepts or strategies that otherwise give an indication of being reasonably promising ideas or approaches to the research to practice problem in residential construction. In part this is because there has been so little previous work done and evaluated on research to practice in any industry, let alone residential construction. Living in a dynamic setting where old rules about what works can change due to rapid societal, cultural, and technological change is another reason to stay open-minded about what can work and can result in industry-wide changes that improve the health and safety of large proportions of the workforce.

11. We know that residential construction is very different from all other industries, with its own special problems.

On the other hand, we also know that the safety problems in residential construction and the processes for solving them incrementally are not all that different from problems and solution-finding processes that have been applied to other industries. As has been the experience in other industries searching to improve safety and health research to practice, residential construction's problems are likely to yield to the application of hard work, the dedication of resources, an openness to innovative ideas, and an appreciation and understanding of what has worked in the past both in construction and in workplace safety efforts in related industries.

12. We know that previous studies describing projects that attempted to address the smallest businesses in residential construction can provide valuable information not available elsewhere.

We know that three interventions in construction warrant special attention (without regard for their failure to survive and succeed in the Cochrane Review of their effectiveness) for their attempts to deliver comprehensive programming to large numbers of both large and small firms

across a region. These three studies addressed the special needs of small business construction firms including small specialty trades firms and sole proprietor firms that are already known to be very hard to identify and serve effectively. The three interventions are the Denver "HomeSafe" intervention (Gilkey et al., 2003; Darragh et al., 2004), the "CBH" intervention in the United Kingdom (Tyers et al., 2007), and the industry-led, governmental regulatory agency-assisted, region-wide, safety inspection contest-based intervention effort in Finland (Laitinen et al., 2010).

13. We know that all interventions are not created equal.

Some interventions try to reach for the sky while others are much more modest. A failure to demonstrate a significant finding by a study that seeks to increase worksite inspections and hazard corrections so as to reduce injuries among dozens of firms is not unusual because a great deal is being attempted. On the other hand, a failure to demonstrate a significant finding by a study that seeks to increase worker knowledge and improve worker attitudes among a single firm with dozens of employees is less remarkable because much less is being attempted and the expectations are for results that can be more easily demonstrated (e.g. knowledge and attitudes at a single time versus injury rates averaged over long time periods). There are compelling reasons to reach higher with research to practice interventions that attempt to change practices among multiple firms across regions or industry-wide across the nation rather than pursuing "case studies" with a single example of a best practice application.

Recommendations

Assumptions about the near term situation in residential construction safety:

A policy analysis-based perspective on strategies to improve research to practice among small business residential construction contractors and subcontractors probably first needs to acknowledge a pre-existing set of situational and political factors.

First, there is a very low likelihood that substantially enhanced enforcement of existing federal or state occupational safety and health regulations will take place for the foreseeable future, or that there will be enactment of many or even any new regulations. Federal and state occupational and health regulatory agencies responsible for enforcement are, in fact, more likely to face budget pressures that may force them to cut back their efforts.

On the other hand, there may be some exceptions when particular aspects of construction work receive high profile treatment in the news, such as the recent attention given to crane collapses. While media attention can be valuable (e.g. see Schneider and Check, 2010) by educating the public and by drawing attention to the industry and to highly specific needs for safety and health improvements, it is unlikely that these periodic instances will result in an increase in overall levels of support for regulation and enforcement efforts. Here again, media-driven developments may instead detract from safety in the industry overall by resulting in a further bleeding of resources and personnel toward the subject of the periodic, immediate crisis and away from more comprehensive, systematic efforts.

Second, there can be no realistic expectations of important increases in the levels of funding for academic research about residential construction occupational safety and health for the foreseeable future. The next decade is more likely to see the field consolidate and to build on existing work. In fact, it may not be desirable that the limited available funding be redistributed to favor more large, well-designed, long term studies of high quality interventions in the residential construction industry. More progress may be achieved by “letting many flower bloom” with more funding for smaller, lower cost but well-designed studies that are accompanied by robust intervention evaluation opportunities.

Third, and on the other hand, there is no reason to believe that in light of expectations for no new regulation and new research funding, that research to practice efforts are bereft, entirely without resources, or lacking in concrete ideas or a number of directions to pursue. Nor is

better translation of research to practice in residential construction lacking in the potential to enact large improvements in residential construction industry workforce injury and disease. The current state of affairs may instead represent an opportunity.

What CPWR should be doing to reach more residential construction firms and to translate more research to practice:

The findings of this review suggest there are a number of viable strategies for translating research to practice more widely: There are a number of potentially promising directions for CPWR to consider when it prioritizes future research efforts and many are depicted in Table 4. The most evidence supports the clear value of hazard inspection and correction-based strategies although the approach can be conducted in various ways incorporating various features likely to make results more or less effective (e.g. unannounced inspections, routine follow-up to insure corrections, inspector training to a standard, incentives for managers based on recognition or on a financial incentive or argument). There are also new directions to explore where evaluation evidence is unclear or not available that coincide with new knowledge being developed in the industry such as: 1) building better safety into the residential construction industry's increasing use of electronic planning tools, 2) training employee opinion leaders to diffuse an innovation (Kramer et al., 2009), 3) training accountants in safety and health (Hasle et al., 2010), 4) taking a socio-cultural approach with employee and manager cooperation and involvement (i.e. the safety management approach) which can lead to a process of continuing improvement for safety in very small firms (Kines et al., 2013).and 5) taking steps to affect the industry's procurement practices and shift them toward greater safety (e.g. Lipscomb et al., 2011,2010).

CPWR needs to be aware of the trade-offs between "big science" and "little science": Ideally, with unlimited resources, researchers could conduct "big science" studies of residential construction efforts to improve translation of research to practice with groups of thousands of individuals followed carefully over time at the scale of the classic epidemiology conducted in the Framingham, Massachusetts studies of cardiovascular disease (de Solla Price et al., 1986). The promise is that a "big science" approach could investigate exactly what works, how, why and for whom (type of company). More realistically, funding agencies and research entities now need to consider and make decisions about how to balance the expenditure of scarce resources between needs to 1) get interventions communicated to and conducted among the largest audiences nationwide that they could reasonably benefit, and 2) evaluating whether and how well the interventions work (or work under certain conditions). The highest quality intervention

evaluation is very costly, routinely costing as much as the costs of conducting the interventions they are intended to evaluate. And, as noted earlier, Cochrane-type reviews typically require a high quality of intervention evaluation evidence for a study even to be considered. As a result, smart little science may trump big science. CPWR should seek to fund projects that are both highly efficient and highly circumspect in their evaluation designs and outcome selections. Projects that rely on data that is already collected and available or very easy to acquire are to be favored. Statistical power calculations for demonstrating injury reductions may require higher sample sizes than for demonstrating reductions in hazard audit scores. Projects with statistical power calculations that allow a great deal to be accomplished with smaller budgets should be given special consideration. For example, Spangenberg et al., 2002 conducted an intervention including workplace audits that required 4,250 worker years to achieve statistical significance for an effect size of a 20% reduction of injuries. On the other hand, Laitinen et al., 2010, conducted an intervention that focused on the outcome of getting workplace hazards identified and controlled with repeated inspections. They then projected likely injury reductions that would be expected to result.

Promote what can become "self-accomplishing" instead of relying on regulatory enforcement or academic research studies: Ideally, an entity like CPWR that wants to promote an aim like the rapid diffusion and adoption (nation-wide and industry-wide) of a raft of "next generation" safety innovations through better research to practice efforts might be best served by finding and advancing those projects and ideas that, once started, were nearly "self-accomplishing". These types of ideas and projects would only need CPWR support to get them started (e.g. identified, defined, piloted). CPWR would provide the spark and then the ideas/projects would spread and be picked up on their own momentum across the entire residential construction sector nationwide. The current model for what CPWR as a research to practice-promoting NIOSH-funded center does is to conduct or administer studies somewhere that require CPWR researchers to carefully nurture them among a few dozen participating firms or subjects for a few years and then publish a paper in a peer reviewed journal that carefully evaluates the results. CPWR and NIOSH then both hope someone follows up by reading the paper and builds on it. On the other hand, "self-accomplishing" interventions are those ideas or projects that take-off or "go viral" or otherwise somehow take hold and relatively quickly become self-sustaining because of their inherent characteristics. In retrospect, they are looked on as ideas whose time had come and they only really needed to be identified, defined, articulated and then set loose in the business world for them to succeed on their own. Examples of self-sustaining interventions might include those that have promoted hybrid seed corn (in the 1940s and 1950s)

and farmers' markets (Rogers, 2004). Each of these projects embodied features of production or marketing that proved to be valued highly enough for the innovation to build momentum and gather an increasing portion of the potential adopters sharing these values to adopt the better practice through market forces and consumer demand until they spread nationwide and industry-wide without the need for governmental regulation. On the other hand, other governmental and nongovernmental agencies did play a role in communicating the ideas throughout the production agriculture sectors for each of these examples (e.g. governmental Extension agents helped promote hybrid seed corn – see Rogers, 2004 and in establishing farmers markets – see Baker et al., 2009). Perhaps the best example of a self-accomplishing innovation in current residential construction is the idea of "green buildings" where an idea was identified and defined and then grew through consumer demand over the last ten years or so. Since then, scales have been developed to characterize the degree of "greenness". Special tools and work methods have been developed that take into account the needs for green building worker protection from injuries and disease (Rajendran et al., 2009). There is reason to believe that similar approaches may hold promise for future improvements in the safety and health-relevant conditions of work on residential construction sites.

Promote research to practice ideas and projects that both benefit the bottom line and clearly reduce injuries and hazards first, then work back toward ideas that improve safety where the bottom line is neutral or worse: CPWR is faced with a situation where it needs to recruit and gain cooperation from firms in an industry where there are governmental regulations but where governmental regulatory enforcement and penalties have long provided only a poor incentive for compliance. In the US, Occupational Safety and Health Administration inspections and penalties for infractions have been infrequent for most of the firms in the residential construction sector. Because there has been so little likelihood of being caught and penalized for failures to comply with regulations that stipulate safer ways to work (and because the situation is unlikely to change much in the near term), new approaches deserve consideration. Any new approach might benefit by enlisting both the residential construction builders and the smaller specialty trades contractors that builders contract with to do the work. One way to start a dialogue about safety that managers of these firms are likely to pay attention to is to begin by emphasizing changes that can be shown to improve both safety and profits. Managers who do recognize that there are safer, more profitable ways to work will be able to show cost savings plus better safety instead of one or the other. Once theses managers begin to pay attention to ways to save by making work safer, other innovations where the bottom line is neutral or worse could have a better chance of receiving serious consideration and succeeding. CPWR can facilitate these

developments by assembling (or, if unavailable, gathering) and making more widely available information on start up costs, continuing costs and return on investment for specific innovations when adopted by firms of varying operation sizes. This safer yet more profitable approach has worked in other industries to disseminate information and diffuse innovations. Useful publications are available that explore this approach (e.g. Kogi et al., 2003; Thurman et al., 1988).

Promote innovations through industry leaders and industry organizations on the national, regional, and local level: Future CPWR-sponsored efforts to increase translation of research to practice in residential construction could benefit by enlisting firm managers and their industry associations (developing partnerships). Ultimately it is the firm manager who controls the conditions on the worksite and who is the most crucial individual to enlist for any intervention to begin and to succeed.

TABLE 4. What published evidence shows we know about effective dissemination of information and adoption of innovations and recommendations to improve research to practice and to expand effective diffusion of innovations and intervention effectiveness	
Tier 1. What works best	Who it works best for and notes
1. 1. Governmental regulation and enforcement including widespread, regular, unannounced inspections of the entire worksite for hazards with strong enforcement and heavy penalties for repeated, knowing, and willful violations. Inspections conducted by well trained and experienced state or federal OSHA inspectors coupled with a series of required follow-up inspections to verify corrections. Regulation and enforcement supplemented by OSHA's extensive set of training, education, and informational materials and resources that firms can use to improve their compliance.	All firms of any size (although OSHA regulatory enforcement is not applied to small firms or sole proprietors).
Tier 2. What works but less well	
2.1. Faux or pseudo regulation consisting of information dissemination and training coupled with OSHA-type inspections among volunteer firms. This option is likely to work better to the degree that inspections are truly widespread, regular and unannounced; by the degree to which there are strong incentives to make hazard corrections after inspections have identified them, by the degree to which inspections are conducted by well trained and experienced inspectors, and by whether there are required follow-up inspections to verify corrections.	For firms that volunteer
Tier 3. What can work but often fails	
3.1. Voluntary hazard audits of some or all of the worksite conducted by managers or supervisors or some other "trained employee" of the worksite-controlling firm (typically the site's builder and general contractor) who provide a report with some specifications for any needed corrections but there are essentially no associated penalties for violations or for failures to correct. This service may or may not be coupled with traditional "toolbox training sessions" for employees or other safety education measures. (This option is essentially announced inspections without the penalties or the follow-up).	For firms that volunteer
3.2. Supplements or modest practices that can improve worksite safety and health	
Tier 4. Methods for which there is no available evidence about whether they work or too little to provide a fair test	
4.1. Better site safety and health planning and management with electronic planning tools, training employee opinion leaders to diffuse an innovation (Kramer et al., 2009), training accountants in safety and health (Hasle et al., 2010), or a socio-cultural approach with employee and manager cooperation and involvement (i.e. the safety management approach) can lead to a process of continuing improvement for safety in very small firms (Kines et al., 2013).	
4.2. Improved research foundation to improve translation of research to practice such as improved monitoring of exposures to tasks and hazards, exposure characteristics, and an improved exposure assessment model	

References

Ahluwalia G. Subcontracting and channels of distribution. Housing Economics 2003 (May):7-12.

Albers J. Personal communication. Jim Albers. NIOSH DART for suggestions for barriers for the subcontractor version of the needs assessment questionnaire. December 3rd 2012 and January 3rd, 2013.

Albers JT, Hudock SD. Biomechanical assessment of three rebar tying techniques. Int J Occup Saf Ergon. 2007;13(3):279-89.

Anderson R. Systematic reviews of economic evaluations: utility or futility? Health Economics 2009;19(3):350–364.

Arcury TA, Mills T, Marín AJ, Summers P, Quandt SA, Rushing J, Lang W, Grzywacz JG. Work safety climate and safety practices among immigrant Latino residential construction workers. Am J Ind Med. 2012 Aug;55(8):736-45..

Arditi D, Chotibhongs R. Issues in subcontracting practice J. Constr. Eng. Manage. 2005;131(8):866-876.

Baker D, Hamshaw K, Kolodinsky J. Who shops at the market? Using consumer surveys to grow farmers' markets: findings from a regional market in northwestern Vermont. Journal of Extension 2009;47(6):1-9.

Ball IR. Mathematical applications for conservation ecology: the dynamics of tree hollows and the design of nature reserves. (PhD Dissertation). Adelaide University, Adelaide. 19999

Barbeau E, Roelofs C, Youngstrom R, Sorensen G, Stoddard A, LaMontagne AD. Assessment of occupational safety and health programs in small businesses. Am J Ind Med. 2004 Apr;45(4):371-9.

Beal AN. CDM regulations: 12 years of pain but little gain. Proceedings of the ICE - Civil Engineering 2007;160:82–8.

Bena A, Berchialla P, Coffano ME, Debernardi ML, Icardi LG. Effectiveness of the training program for workers at construction sites of the high-speed railway line between Torino and Novara: impact on injury rates. American Journal of Industrial Medicine 2009;52(12):965–72.

Bero LA, Grilli R, Grimshaw JM, Harvey E, Oxman AD, Thomson MA. Closing the gap between research and practice: an overview of systematic reviews of interventions to promote the implementation of research findings. The Cochrane Effective Practice and Organization of Care Review Group. BMJ. 1998 Aug 15;317(7156):465-8. Review.

Blackley DM, Shepard EM. The diffusion of innovation in home building. Journal of Housing Economics 1996;5(4):303-22.

Boatman L, Chaplan D, Teran S. Creating the Climate for Making Ergonomic Changes. CPWR Report, December 2011.

Brunette M, Gagliardi M. Implementing a safety training intervention among Hispanic construction workers: a labor union – academia paratnership. (undated, unpublished manuscript). c/o M Brunette. University of Massachusetts- Lowell Work Environment Department.

Carroll CE. Corporate Reputation and the Multi-Disciplinary Field of Communication. The Handbook of Communication and Corporate Reputation. 2013. pp.1-10.

Champoux D, Brun J Occupational health and safety management in small size enterprises: an overview of the situation and avenues for intervention and research. Safety Science 2003:41(4):301–318.

Chapman LJ, Brunette CM, Karsh B, Taveira AD. A seven year intervention to increase adoption of safer dairy farming work practices. Journal of Agricultural Safety and Health (tentatively accepted subject to revisions) 2013.

Colleran PR. Re-examining first-line supervisor safety responsibilities. http://www.constructionsafetyconsultant.com/articles/first-line-supervisor%20safety-responsibilities.pdf

CPWR. The Construction Chart Book: The U.S. Construction Industry and Its Workers. Fifth Edition. Address correspondence to: Xiuwen (Sue) Dong, Dr.P.H., at CPWR – The Center for Construction Research and Training, 8484 Georgia Ave., Suite 1000, Silver Spring, MD 20910. ISBN: 978-0-9802115-1-1. April 2013.

Crouch KG, Gressel MG. The control of press cleaning solvent vapors in a small lithographic printing establishment. Appl Occup Environ Hyg. 1999;14:329–38.

Cunningham Thomas R, Ph.D. Personal communication. Assistant Program Coordinator, Small Business Assistance and Outreach, US DHHS, PHS, CDC, NIOSH. 4676 Columbia Parkway, C-10, Cincinnati, OH 45226 (513) 533-8325. TCunningham@cdc.gov. Accessed March 2013.

Cunningham TR, Galloway-Williams N, Geller ES. Protecting the planet and its people: how do interventions to promote environmental sustainability and occupational safety and health overlap? J Safety Res. 2010 Oct;41(5):407-16. Epub 2010 Sep 8.

Curnow WJ. The Cochrane Collaboration and bicycle helmets. Accident Analysis & Prevention 2005;37(3):569-573.

Curtis Breslin F, Kyle N, Bigelow P, Irvi, E, Morassaei S, MacEachen E, Amick BC. Effectiveness of health and safety in small enterprises: A systematic review of quantitative evaluations of interventions. Journal of occupational rehabilitation, 2010;20(2), 163-179

Dannapfel P, Peolsson A, Nilsen P. What supports physiotherapists' use of research in clinical practice? A qualitative study in Sweden. Implement Sci. 2013 Mar 14;8(1):31.

Darragh AR, Stallones L, Bigelow PL, Keefe TJ. Effectiveness of the HomeSafe Pilot Program in reducing injury rates among residential construction workers, 1994-1998. Am J Ind Med. 2004 Feb;45(2):210-7.

Derr J, Forst L, Chen HY, Conroy L. Fatal falls in the US construction industry, 1990 to 1999. J Occup Environ Med. 2001 Oct;43(10):853-60.

de Solla Price DJ. Little science, big science... and beyond. New York: Columbia University Press, 1986.
Dillman, Don A. 1999. Mail and Other Self-Administered Surveys in the 21st Century: The Beginning of a New Era. Revised version available in Gallup Research Journal.
Dong XS, Choi SD, Borchardt JG, Wang X, Largay JA. Fatal falls from roofs among U.S. construction workers. J Safety Res. 2013 Feb;44:17-24. doi: 10.1016/j.jsr.2012.08.024. Epub 2012 Dec 9.
Dubois A, Gadde LE. The construction industry as a loosely coupled system: implications for productivity and innovation. Construction Management and Economics 2002;20:621-31.
Entzel P, Albers J, Welch L. Best practices for preventing musculoskeletal disorders in masonry: stakeholder perspectives. Appl Ergon. 2007 Sep;38(5):557-66. Epub 2006 Nov 13.
ERD. Economic Research Division, Federal Reserve Bank of St Louis, FRED Graph Observation. Federal Reserve Economic Data. Accessed 09/01/2011. http://research.stlouisfed.org/fred2
Esmaeili, B. and Hallowell, M. Diffusion of Safety Innovations in the Construction Industry. J. Constr. Eng. Manage. 2012;138(8), 955–963.doi: 10.1061/(ASCE)CO.1943-7862.0000499
Fiske T, Earle-Richardson G. Farm safety research to practice: the long road from the laboratory to the farm. Journal of Agromedicine 2013;18:1:11-17.
FL, 2012. FIndLaw. OSHA Focuses on Safety in the Residential Construction Industry< http://knowledgebase.findlaw.com/kb/2012/Feb/503205.html> Published: 2012-04-16.
Foley M, Fan AJ, Rauser E, et al. The impact of regulatory enforcement and consultation visits on workers' compensation claims incidence rates and costs, 1999–2008. Am J Ind Med 2012. doi: 10.1002/ajim.22084. (Epub ahead of print).
Franche RL, Cullen K, Clarke J, Irvin E, Sinclair S, Frank J. Workplace-based return-to-work interventions: a systematic review of the quantitative literature. Journal of occupational rehabilitation, 2005;15(4), 607-631.
Free C, Phillips G, Galli L, Watson L, Felix L, et al. (2013) The Effectiveness of Mobile-Health Technology-Based Health Behaviour Change or Disease Management Interventions for Health Care Consumers: A Systematic Review. PLoS Med 10(1): e1001362. doi:10.1371/journal.pmed.1001362.
Gadomski A, Ackerman S, Burdick P, Jenkins P. Efficacy ofthe North American guidelines for children's agricultural tasks in reducing childhood agricultural injuries. American Journal of Public Health 2006;96(4):722–7.
Gambatese, J.A. and Hallowell, M. Enabling and measuring innovation in the construction industry. Construction Management and Economics, Taylor & Francis, Routledge, 2011;29(6), 553-567.
Gambatese, J.A. and Hallowell, M. Factors that influence the development and diffusion of technical innovations in the construction industry. Construction Management and Economics, Taylor & Francis, Routledge, 2011;29(5), 507-517.
Gangolells M, Casals M, Forcada N, Roca X, Fuertes A. Mitigating construction safety risks using prevention through design. J Safety Res. 2010 Apr;41(2):107-22. Epub 2010 Apr 2.
Ganguly I, Koebel CT, Cantrell RA. A categorical modeling approach to analyzing new product adoption and usage in the context of the building-materials industry. Technological Forecasting and Social Change, 2010;77(4):662-677.

Gilkey DP, Hautaluoma JE, Ahmed TP, Keefe TJ, Herron RE, Bigelow PL. Construction work practices and conditions improved after 2-years' participation in the HomeSafe pilot program. AIHA J (Fairfax, Va). 2003 May-Jun;64(3):346-51.
Gillen M. The NIOSH Construction Program: research to practice, impact, and developing a National Construction Agenda. J Safety Res. 2010 Jun;41(3):289-99. Epub 2010 May 14.
Gillen M, Gittleman JL. Path forward: emerging issues and challenges. J Safety Res. 2010 Jun;41(3):301-6. Epub 2010 May 15.
Gittleman JL, Gardner PC, Haile E, Sampson JM, Cigularov KP, Ermann ED, Stafford P, Chen PY. [Case Study] CityCenter and Cosmopolitan Construction Projects, Las Vegas, Nevada: lessons learned from the use of multiple sources and mixed methods in a safety needs assessment. J Safety Res. 2010 Jun;41(3):263-81. Epub 2010 May 22.
Glasgow RE, Emmons KM. How can we increase translation of research into practice? Types of evidence needed. Annu. Rev. Public Health 2007;28:413-433.
Goldenhar LM, Moran SK, Colligan M. Health and safety training in a sample of open-shop construction companies. Journal of Safety Research 2001;32(2):237-252.
Gram B, Holtermann A, Søgaard K, Sjøgaard G. Effect of individualized worksite exercise training on aerobic capacity and muscle strength among construction workers--a randomized controlled intervention study. Scandinavian J Work Environ Health. 2012;Sep;38(5):467-75. doi: 10.5271/sjweh.3260.
Gram B, Holtermann A, Bültmann U, Sjøgaard G, Søgaard K. Does an exercise intervention improving aerobic capacity among construction workers also improve musculoskeletal pain, work ability, productivity, perceived physical exertion, and sick leave? a randomized controlled trial. J Occup Environ Med. 2012 Oct 30. [Epub ahead of print]
Gray WB, Mendeloff J. 2005. The declining effects of OSHA inspections in manufacturing, 1979–1998. Ind Labor Relat Rev 58:571–586.

Gray WB, Scholz J. 1993. Does regulatory enforcement work?: A panel analysis of OSHA enforcement. Law Soc Rev 27:177–213.

Groeneveld IF, van Wier MF, Proper KI, Bosmans JE, van Mechelen W, van der Beek AJ. Cost-effectiveness and cost-benefit of a lifestyle intervention for workers in the construction industry at risk for cardiovascular disease. J Occup Environ Med. 2011 Jun; 53(6):610-7.

Groeneveld IF, Proper KI, van der Beek AJ, Hildebrandt VH, van Mechelen W. Short and long term effects of a lifestyle intervention for construction workers at risk for cardiovascular disease: a randomized controlled trial. BMC Public Health. 2011 Oct 31; 11:836. Epub 2011 Oct 31.

Groeneveld IF, Proper KI, van der Beek AJ, van Mechelen W.Sustained body weight reduction by an individual-based lifestyle intervention for workers in the construction industry at risk for cardiovascular disease: results of a randomized controlled trial. Prev Med. 2010 Sep-Oct;51(3-4):240-6. doi: 10.1016/j.ypmed.2010.07.021. Epub 2010 Aug 6.

Hale AR, Guldenmund FW, van Loenhout PLCH, Oh JIH. Evaluating safety management and culture interventions to improve safety: Effective intervention strategies. Safety Science, 2010;48:1026–1035.

Hasle P, Bager B, Granerud L. (2010). Small enterprises–Accountants as occupational health and safety intermediaries. Safety Science 2010;48(3):404-409.

Haviland AM, Mai R, Gray WB, Xia J, Mendeloff J. Are there unusually effective occupational safety and health inspectors and inspection practices?. Santa Monica, CA: RAND Corporation, 2012. http://www.rand.org/pubs/working_papers/WR914..

Haviland, Amelia, Rachel Burns, Wayne B. Gray, Teague Ruder, and John Mendeloff, “A New Estimate of the Impact of OSHA Interventions on Manufacturing Injury Rates,1998-2005,” American Journal of Industrial Medicine 2012 Nov;55(11):964-75. doi: 10.1002/ajim.22062. Epub 2012 May 7.

Hess JA, Hecker S, Weinstein M, Lunger M.A participatory ergonomics intervention to reduce risk factors for low-back disorders in concrete laborers. Appl Ergon. 2004 Sep;35(5):427-41.

Hinze J, Gambatese J. Factors that influence safety performance of specialty contractors. J. Constr. Eng. Man., 2003;129(2), 159–164.

Hogg-Johnson, S, Robson L, Cole DC, Amick BC, Tompa E, Smith PM, ... & Mustard C. A randomised controlled study to evaluate the effectiveness of targeted occupational health and safety consultation or inspection in Ontario manufacturing workplaces. Occupational and Environmental Medicine. 2012.

Holmström E, Ahlborg B. Morning warming-up exercise--effects on musculoskeletal fitness in construction workers. Appl Ergon. 2005 Jul;36(4):513-9. Epub 2005 Mar 31.

Holmström E, Moritz U.Effects of lumbar belts on trunk muscle strength and endurance: a follow-up study of construction workers. J Spinal Disord. 1992 Sep;5(3):260-6.

Hung YH, Winchester WW, Smith-Jackson TL, Kleiner BM, Babski-Reeves KL, Mills TH. Identifying fall-protection training needs for residential roofing subcontractors. Appl Ergon. 2012 Oct 22. pii: S0003-6870(12)00145-7

Hung Y, Smith-Jackson T, Winchester W. Use of attitude congruence to identify safety interventions for small residential builders. Construction Management & Economics. 2011;29(2): 113-130.

Hutchings DM, Christofferson JP. Management practices of residential construction companies producing 25 or fewer units annually. International Journal of Construction Education and Research 2004;9(2):34-44.

Ikpe E, Hammon F, Oloke D. Cost-benefit analysis for accident prevention in construction projects. J. Constr. Eng. Manage. 138(8), 991-998

Inyang N, Al-Hussein M, El-Rich M, Al-Jibouri S. Ergonomic analysis and the need for its integration for planning and assessing construction tasks. J. Constr. Eng. Manage. 2012;138(12):1370-1376.

Johanson U. Why the concept of human resource costing and accounting does not work: a lesson from seven Swedish cases. Personnel review, 1999;28(1/2):91-107.

Karttunen JP, Rautiainen RH. Occupational injury and disease incidence and risk factors in finnish agriculture based on 5-year insurance records. J Agromedicine. 2013;18(1):50-64. doi: 10.1080/1059924X.2012.742029.

Kaskutas V, Dale AM, Lipscomb H, Evanoff B. Fall prevention and safety communication training for foremen: Report of a pilot project designed to improve residential construction safety. J Safety Res. 2013 Feb;44:111-8. doi: 10.1016/j.jsr.2012.08.020. Epub 2012 Nov 20.

Kaskutas V, Dale AM, Lipscomb H, Gaal J, Fuchs M, Evanoff B; Carpenters' joint apprenticeship program instructor team. changes in fall prevention training for apprentice carpenters based on a comprehensive needs assessment. J Safety Res. 2010 Jun;41(3):221-7.

Kines P, Andersen LP, Spangenberg S, Mikkelsen KL, Dyreborg J, Zohar D. Improving construction site safety through leader-based verbal safety communication. J Safety Res. 2010 Oct;41(5):399-406. Epub 2010 Sep 4.

Koebel CT. Innovation in homebuilding and the future of housing. Journal of the American Planning Association 2008;74(1):45-58.

Koebel CT, Hudson E, Cavell M. The Diffusion of Innovation in the Residential Building Industry, Virginia Polytechnic Institute and State University, Blacksburg, VA. 2003.

Kogi K, Kawakami T, Itani T, Batino JM. Low-cost work improvements that can reduce the risk of musculoskeletal disorders. International Journal of Industrial Ergonomics, 2003;31(3):179-184.

Kramer DM, Bigelow PL, Carlan N, Wells RP, Garritano E, Vi P, Plawinski M. Searching for needles in a haystack: identifying innovations to prevent MSDs in the construction sector. Appl Ergon. 2010 Jul;41(4):577-84. Epub 2010 Feb 18.

Kramer D, Bigelow P, Vi P, Garritano E, Carlan N, Wells R. Spreading good ideas: a case study of the adoption of an innovation in the construction sector. Appl Ergon. 2009 Sep;40(5):826-32. Epub 2008 Nov 6.

Laitinen H, Paivarinta K. A new-generation safety contest in the construction industry - a long-term evaluation of a real-life intervention. Safety Science 2010;48:680-6.

Laitinen H, Marjamki M, Paivarinta K. The validity of the TR safety observation method on building construction. Accident Analysis and Prevention 1999;463–472.

Lazovich D, Parker DL, Brosseau LM, Milton FT, Dugan SK, Pan W, et al. Effectiveness of a worksite intervention to reduce an occupational exposure: the Minnesota wood dust study. Am J Public Health. 2002;92:1498–505.

Lee B, Lee BC, Westaby JD, Berg RL. Impact of a national rural youth health and safety initiative: results from a randomizedcontrolled trial. American Journal of Public Health 2004;94(10):1743–9.

Lehtola MM, van der Molen HF, Lappalainen J, Hoonakker PL, Hsiao H, Haslam RA, Hale AR, Verbeek JH.. The effectiveness of interventions for preventing injuries in the construction industry: a systematic review. Am J Prev Med. 2008 Jul;35(1):77-85. Epub 2008 May 14.

Levine DI, Toffel MW, Johnson MS. Randomized government safety inspections reduce worker injuries with no detectable job loss. Science 2012;336:907–11.

Lipscomb HJ, Nolan J, Patterson D, Sticca V, Myers DJ. Safety, incentives, and the reporting of work-related injuries among union carpenters: "You're pretty much screwed if you get hurt at work". Am J Ind Med. 2012 Oct 25. doi: 10.1002/ajim.22128. [Epub ahead of print]

Lipscomb HJ, Nolan J, Patterson D, Fullen M, Takacs BC, Pompeii LA. Buyer beware: Personnel selling nail guns know little about dangerous tools. American journal of industrial medicine,2011;54(8), 571-578.

Lipscomb HJ, Nolan J, Patterson D, Dement JM. Continued progress in the prevention of nail gun injuries among apprentice carpenters: what will it take to see wider spread injury reductions? J Safety Res. 2010 Jun;41(3):241-5. Epub 2010 Apr 18.

Lipscomb HJ, Nolan J, Patterson D. Perspectives of residential contractors on nail gun safety. New Solut. 2010;20(3):337-48.

Lipscomb HJ, Pompeii LA, Myers DJ, Schoenfisch AL, Dement JM. Systematic reviews of workplace injury interventions: what are we missing? (abstract only) Med Lav. 2009 Jul-Aug;100(4):247-57.

Lipscomb HJ, Li L, Dement J. Work-related falls among union carpenters in Washington State before and after the Vertical Fall Arrest Standard. Am J Ind Med. 2003 Aug;44(2):157-65.

Lin J, Mills A. Measuring the occupational health and safety performance of construction companies in Australia. Facilities, 2001;19(3/4), 131-139.

Liu, C, Arnett KP, Capella LM, Beatty RC. Web sites of the Fortune 500 companies: facing customers through home pages. Information & Management, 1997;31(6), 335-345.

Lobb B, Woods GR. In search of a representative sample of residential building work. Appl Ergon. 2012 Sep;43(5):868-75.

Ludewig PM, Borstad JD. Effects of a home exercise programme on shoulder pain and functional status in construction workers. Occup Environ Med. 2003 Nov;60(11):841-9.

Luijsterburg PA, Bongers PM, de Vroome EM. A new bricklayers' method for use in the construction industry. Scand J Work Environ Health. 2005 Oct;31(5):394-400.

Lum, M. Emerging models of moving research to practice. In 30th International Congress on Occupational Health (March 18-23, 2012). Icoh. 2012. http://icoh.confex.com/icoh/2012/webprogram/Paper7216.html

Lund J, Aarø LE. Accident prevention. Presentation of a model placing emphasis on human, structural and cultural factors. Safety Science, 2004;42:271–324.

Lundqvist P. Evaluation of the improvements in working conditions on farms funded by the Swedish Working Life Fund. Journal of Agricultural Safety and Health, 1996;2(4):191-196.

Madgwick P, Houdmont J, Randall R. Sun safety measures among construction workers in Britain. Occup Med (Lond). 2011 Sep;61(6):430-3. Epub 2011 Jul 13.

Manning C, Mullins dJ. Two nonconstruction employment series for specialty trade contractors. Monthly Labor Review 2006 (Oct):14-22.

Martínez Aires MD, Rubio Gámez MC, Gibb A. Prevention through design: The effect of European Directives on construction workplace accidents. Safety Science 2010;48(2), 248-258.

Martinez LS, Ndulue UJ, Brunette MJ. Lessons learned from the Proteccion en Contruccion (PenC) community research partnership. (undated, unpublished manuscript). c/o LS Martinez. Tufts University Community Health Program, Medford MA. <linda.martinez@tufts.edu>.

Mayhew C, Quinlan M. Subcontracting and occupational health and safety in the residential building industry. Industrial Relations Journal 2003;28(3):192-205.

McCoy AP, Saunders L, Kleiner B, Blismas N. Application of Safety Project Interview Data to a Cyclical Research Model of Translation. International Journal of Construction Education and Research. 2012;8(4):260-280.

McCoy AP, Badinelli R, Koebel CT, Thabet W. Concurrent commercialization and new-product adoption for construction products. European Journal of Innovation Management, 2010;13(2):222-243.

McCoy, AP, Badinelli RD, Thabet WT. Understanding the role of developer/builders in the concurrent commercialization of product innovation. European Journal of Innovation Management, 2009;12(1):000-000.

Melman S. Structure of the home building industry. National Association of Homebuilders. Special Studies. December 1, 2010. <housingeconomics.com>

Menzel, NN, Pramen PS. Social marketing to plan a fall prevention program for Latino construction workers. American journal of industrial medicine 2012;55:729-735.

Methner MM. Identification of potential hazards associated with new residential construction. Appl Occup Environ Hyg. 2000 Feb;15(2):189-92.

Methner MM, McKernan JL, Dennison JL. Task-based exposure assessment of hazards associated with new residential construction. Appl Occup Environ Hyg. 2000 Nov;15(11):811-9.

Mikkelsen KL, Spangenberg S, Kines P. Safety walkarounds predict injury risk and reduce injury rates in the construction industry. Am J Ind Med. 2010 Jun;53(6):601-7.

Mirka GA, Monroe M, Nay T, Lipscomb H, Kelaher D. Ergonomic interventions for the reduction of low back stress in framing carpenters in the home building industry. International journal of industrial ergonomics 2003;31(6), 397-409.

Miscetti G, Bodo P. Prevention of building site accidents in Umbria during reconstruction after an earthquake the experience of one Local Health Unit [Esperienza i prevenzione di un Servizio ASL nei cantieri della ricostruzione post–sismica in Umbria]. Medicina del Lavoro 2008;99(2):136–44.

Moore JT, Cigularov KP, Sampson JM, Rosecrance JC, Chen PY. Construction workers' reasons for not reporting work-related injuries: an exploratory study. Int J Occup Saf Ergon 2013; 19(1):97-105.

NAS. National Research Council and Institute of Medicine. Construction Research at NIOSH. Committee to Review the NIOSH Construction Research Program. Rpt. No. 8, Reviews of Research Programs of the National Institute for Occupational Safety and Health. Washington, D.C.: The National Academies Press. 2009.

NIOSH. A review of NIOSH construction research programs between 1996 and 2005 and related recommendations. Board on Infrastructure and the Constructed Environment. Committee to Review the NIOSH Construction Research Program, National Research Council. Chapter 2. NIOSH Construction Program Overview. Washington, DC: The National Academies Press, 2008.

NIOSH. Research to Practice at NIOSH. < http://www.cdc.gov/niosh/r2p/about.html> 2013.

NIOSH. NORA National Construction Agenda For Occupational Safety And Health Research And Practice In The U.S. Construction Sector. <http://www.cdc.gov/niosh/programs/const/goals.html> 10/20/08 Revision. 2008.

Moehrle T. Compensation of residential and nonresidential construction workers. Monthly Labor Review 2010 (April): 31-45.

Northrup HR. Arizona construction labor: A case study of union decline. Journal of Labor Research 1990;11(2):161-179.

Olsen K, Legg S, Hasle P. How to use programme theory to evaluate the effectiveness of schemes designed to improve the work environment in small businesses. Work: A Journal of Prevention, Assessment and Rehabilitation 2012;41:5999-6006.

Olson M. Big bills left on the sidewalk: why some nations are rich and others are poor. Journal of Economc Perspectives 1996; 10(2):3-29.

OSHA. Selected construction regulations (SCOR) for the home building industry (29 cfr 1926). § 1926.16 - Rules of construction. http://www.osha.gov/Publications/Homebuilders/Homebuilders.html. Accessed May 15th,2013.

Pekkarinen A, Anttonen H, Pramila S. Accident prevention in reindeer herding work. Arctic 1994;47(2):124–7.

Pedersen BH, Dyreborg J, Kines P, Mikkelsen KL, Hannerz H, Andersen DR, Spangenberg S. Protocol for a mixed-methods study on leader-based interventions in construction contractors' safety commitments. (abstract only) Inj Prev. 2010 Jun;16(3):e2.

Proceedings of a Meeting to Explore the Use of Ergonomics Interventions for the Mechanical and Electrical Trades, DHHS (NIOSH) Publication Number 2006-119, can be accessed at http://www.cdc.gov/niosh/docs/2006-119/.

Rabourn M. Organized labor in residential construction. Labor Studies Journal. 2008; 20(10):1-18.

Rajendran S, Gambatese JA, Behm MG. Impact of green building design and construction on worker safety and health. Journal of Construction Engineering and Management, 2009;135(10):1058-1066.

Rasmussen K, Carstensen O, Lauritsen JM, Glasscock DJ, Hansen ON, Jensen UF. Prevention of farm injuries in Denmark. Scand J Work Environ Health. 2003;29:288–96.

Rautiainen R, Lehtola MM, Day LM, Schonstein E, Suutarinen J, Salminen S, Verbeek JH. Interventions for preventing injuries in the agricultural industry. Cochrane Database of Systematic Reviews 2008, Issue 1. Art. No.: CD006398. DOI: 10.1002/14651858.CD006398.pub2.

Rautiainen RH, Ledolter J, Sprince NL, Donham KJ, Burmeister LF, Ohsfeldt R, Reynolds SJ, Phillips K, Zwerling C. Effects of premium discount on workers' compensation claims in agriculture in Finland. Am J Ind Med. 2005 Aug;48(2):100-9.

Rautiainen RH, Lange JL, Hodne CJ, Schneiders S, Donham KJ. Injuries in the Iowa Certified Safe Farm Study. J Agric Saf Health. 2004 Jan;10(1):51-63.

Rinder MM, Genaidy A, Salem S, Shell R, Karwowski W. Interventions in the construction industry: A systematic review and critical appraisal. Human Factors and Ergonomics in Manufacturing & Service Industries 2008;18(2), 212-229.

Roberts DM, Karunarathna A, Buckley NA, Manuweera G, Sheriff MH, Eddleston M. Influence of pesticide regulation on acute poisoning deaths in Sri Lanka. Bulletin of the worldHealth Organization 2003;81(11):789–98.

Robson LS, Clarke JA, Cullen K, Bielecky A, Severin C, Bigelow PL et al. The effectiveness of occupational health and safety management system interventions: A systematic review. Safety Science 2007;45:329–353. discussing safety issues.

Robson LS, Shannon HS, Goldenhar LM, Hale AR. Guide to evaluating the effectiveness of strategies for preventing work injuries: how to show whether a safety intervention really works. Cincinnati OH: US DHHS (NIOSH) Publication No. 2001-119. <http://www.cdc.gov/niosh/docs/2001-119/> 2001.

Roca-Servat, D. Justice for Roofers Toward a Comprehensive Union Organizing Campaign Involving Latino Construction Workers in Arizona. Labor Studies Journal 2010;35(3):343-363.

Roelofs C, Sprague-Martinez L, Brunette M, Azaroff L. A qualitative investigation of Hispanic construction worker perspectives on factors impacting worksite safety and risk. Environ Health. 2011 Sep 30;10:84.

Rogers, E.M. (2003), Diffusion of Innovations, The Free Press, New York, NY.

Rose, LM, Orrenius UE, Neumann WP. Work environment and the bottom line: survey of tools relating work environment to business results. Human Factors and Ergonomics in Manufacturing & Service Industries 2011;1-14.

Schneider S, Check P. Read all about it: the role of the media in improving construction safety and health. J Safety Res. 2010 Jun;41(3):283-7. Epub 2010 May 23.

Schoonover T, Bonauto D, Silverstein B, Adams D, Clark R. Prioritizing prevention opportunities in the Washington State construction industry, 2003-2007. J Safety Res. 2010 Jun;41(3):197-202. Epub 2010 Apr 14.

Sorensen JA, Jenkins PL, Emmelin M, Stenlund H, Weinehall L, Earle-Richardson GB, May JJ. The social marketing of safety behaviors: a quasi-randomized controlled trial of tractor retrofitting incentives.Am J Public Health. 2011 Apr;101(4):678-84. doi: 10.2105/AJPH.2010.200162. Epub 2011 Feb 17.

Spangenberg S, Mikkelsen KL, Kines P, Dyreborg J, Baarts C. The construction of the Øresund Link between Denmark and Sweden: the effect of a multi-faceted safety campaign. Safety Science 2002;40(5), 457-465.

Springfeldt B. Effects of occupational safety rules measures with special regard to injuries (Doctoral dissertation). Sweden: The Royal Institute of Technology, Department of Work Science. 1993.

Suruda A, Whitaker B, Bloswick D, Philips P, Sesek R. Impact of the OSHA trench and excavation standard on fatal injury in the construction industry. J Occup Environ Med. 2002 Oct;44(10):902-5.

Tengs, TO, Adams ME, Pliskin JS, Safran, DG, Siegel JE, Weinstein MC, Graham JD. Five hundred life saving interventions and their cost effectiveness. Risk analysis, 1995;15(3), 369-390.

Thelin A. Rollover fatalities—Nordic perspectives. J Agric Saf Health. 1998;4(3):157–160.

Thurman, JE, Louzine AE, Kogi K. Higher Productivity and a Better Place to Work: Practical Ideas for Owners and Managers of Small and Medium-Sized Industrial Enterprises: Action Ma. International Labour Organisation, 1988.

Toole TM. Uncertainty and home builders' adoption of technological innovations. Journal of Construction Engineering and Management, 1998;124(4):323-32.

Tompa E, Dolinschi R, de Oliveira C, Irvin E.. A systematic review of occupational health and safety interventions with economic analyses. Journal of Occupational and Environmental Medicine, 2009;51(9), 1004.

Torp S. How a health and safety management training program may improve the working environment in small- and medium- sized companies. J Occup Environ Med. 2008;50:263–71.

Truswell AS. Some problems with Cochrane reviews of diet and chronic disease. European Journal of Clinical Nutrition (2005) 59, Suppl 1, S150–S154. doi:10.1038/sj.ejcn.1602189

Tyers C, Sinclair A, Lucy D, Cowling M, Gordon-Dseagu V, Rick J. Constructing better health, final evaluation report. Health and Safety Executive 2007; Research Report 565:1–227.

van der Molen HF, Lehtola MM, Lappalainen J, Hoonakker PLT, Hsiao H, Haslam R, Hale AR, Frings-Dresen MHW, Verbeek JH. Interventions to prevent injuries in construction workers. Cochrane Database of Systematic Reviews

2012, Issue 12. Art. No.: CD006251. DOI: 10.1002/14651858.CD006251.pub3 *(p1 says edited no change to conclusions, p4 says all databases were searched up to June 2006)*.

van der Molen HF, Lehtola MM, Lappalainen J, Hoonakker PL, Hsiao H, Haslam R, Hale AR, Verbeek J. Interventions for preventing injuries in the construction industry. Cochrane Database Syst Rev. 2007 Oct 17;(4):CD006251.

van der Molen HF, Hoonakker PL, Lehtola MM, Hsiao H, Haslam RA, Hale AR, Verbeek JH. Writing a Cochrane systematic review on preventive interventions to improve safety: the case of the construction industry. (abstract only) Med Lav. 2009 Jul-Aug;100(4):258-67.

van der Molen HF, Sluiter JK, Hulshof CT, Vink P, van Duivenbooden C, Holman R, Frings-Dresen MH. Implementation of participatory ergonomics intervention in construction companies. Scand J Work Environ Health. 2005 Jun;31(3):191-204.

van der Molen HF, Grouwstra R, Kuijer PP, Sluiter JK, Frings-Dresen MH. Efficacy of adjusting working height and mechanizing of transport on physical work demands and local discomfort in construction work. Ergonomics. 2004 Jun 10;47(7):772-83.

Village J, Ostry A. Assessing attitudes, beliefs and readiness for musculoskeletal injury prevention in the construction industry. Appl Ergon. 2010 Oct;41(6):771-8. Epub 2010 Jan 27

Vink P, Miedema M, Koningsveld E, van der Molen H. Physical effects of new devices for bricklayers. Int J Occup Saf Ergon. 2002;8(1):71-82.

Wamuziri, S. (2013). Factors that influence safety culture in construction. Proceedings of the ICE - Management, Procurement and Law. 2013.

Wanberg J, Harper C, Hallowell MR, Rajendran S. Relationship between Construction Safety and Quality Performance. Journal of Construction Engineering and Management. epub 2013.

Weinstein MG, Hecker SF, Hess JA, Kincl L. A roadmap to diffuse ergonomic innovations in the construction industry: there is nothing so practical as a good theory. Int J Occup Environ Health. 2007 Jan-Mar;13(1):46-55.

Wells M, Stokols D, McMahan S, Clitheroe C. Evaluation of a worksite injury and illness prevention program: do the effects of the REACH OUT training program reach the employees? J Occup Health Psychol. 1997;2:25–34.

Wickizer TM, Kopjar B, Franklin G, Joesch J. Do drug-free workplace programs prevent occupational injuries? Evidence from Washington State. Health Serv Res. 2004 Feb;39(1):91-110.

Williams Q Jr, Ochsner M, Marshall E, Kimmel L, Martino C. The impact of a peer-led participatory health and safety training program for Latino day laborers in construction. J Safety Res. 2010 Jun;41(3):253-61.

Appendix 1. What construction industry innovations actually work to reduce injuries and hazard exposures? (Table 5):

Table 5, on the following pages, lists studies where the study objective was to determine whether specific innovations (e.g. different bricklaying methods, different styles of supervisor employee interactions, etc.) could be shown to reduce injury, disease, hazard exposure, or other health-related outcomes in small employee groups. These studies were determined to not be studies that translated research to practice (defined as efforts made to diffuse information and then actually get safer innovations adopted among multiple companies or among multiple individual employees in very large numbers and/or at multiple worksites as measured by self-reports of adoption or indirectly by evidence of reduced health and hazard outcomes or other outcomes (see Conventions used in writing the report at 2.2.2. above).

TABLE 5. Characteristics of selected intervention studies		
Study citation	Participants and design	Intervention outcomes and notes
Kines P, Andersen LP, Spangenberg S, Mikkelsen KL, Dyreborg J, Zohar D. Improving construction site safety through leader-based verbal safety communication. J Safety Res. 2010 Oct;41(5):399-406.	Two large and multinational enterprises were involved in the study. The companies' safety departments selected the construction sites and foremen/work gangs involved in the project. The study involved a total of seven foremen and their work gangs at four construction sites at three different geographic locations in Denmark during the period October 2006-October 2007. Foremen in two intervention groups are coached and given bi-weekly feedback about their daily verbal safety communications with their workers.	A pre- post intervention-control design with five construction work gangs. Baseline measurements in the two intervention and three control groups reveal that foremen speak with their workers several times a day. Workers perceive safety as part of their verbal communication with their foremen in only 6-16% of exchanges, and the levels of safety at the sites range from 70-87% (correct observations). Measurements from baseline to follow-up in the two intervention groups reveal that safety communication between foremen and workers increases significantly in one of the groups (factor 7.1 increase), and a significant yet smaller increase is found when the two intervention groups are combined (factor 4.6). Significant increases in the level of safety are seen in both intervention groups (7% and 12% increases, respectively), particularly in regards to 'access ways' and 'railings and coverings' (39% and 84% increases, respectively). Increases in safety climate are seen in only one of the intervention groups with respect to their 'attention to safety.' No significant trend changes are seen in the three control groups on any of the three measures.
Gram B, Holtermann A, Bültmann U, Sjøgaard G, Søgaard K. Does an exercise intervention improving aerobic capacity among construction workers also improve musculoskeletal pain, work ability, productivity, perceived physical exertion, and sick leave? a randomized controlled trial. J Occup Environ Med. 2012.	The study was a randomized controlled trial of male construction workers allocated to either an exercise or control group. The intervention lasted 12 weeks, and the exercise group trained 3 × 20 minutes a week. The participants completed health checks before and after the intervention period. Data from the first health check were used to tailor the exercise in the interventions. Study participants (N=35) and controls (N=32) were employees working in the construction industry. They were recruited from three workplaces and companies in Denmark.	At baseline, participants had maximal oxygen consumption (VO2max) of 2.9 [standard deviation (SD) 0.7L/min] and body mass index (BMI) of 28.3 (SD 4.7). Compared to representative data on employees in Denmark (N=78), this study population (N=67) had significantly lower relative aerobic capacity [difference in z--score --1.13 (SE 0.1), P<0.001] and higher BMI [difference in z--score 1.10 SE 0.2, P<0.001] at baseline. With respect to the intervention, group × time analyses showed a significant difference in estimated change in VO2max of 0.4 L/min for the exercise group and 0.0 L/min for the control group (P<0.001).

		Body mass and other general health measures remained unchanged. Training for 20 minutes, 3 times a week significantly increased VO2max with a clinically relevant magnitude regarding risk of cardiometabolic disorders. This study demonstrates a good effectiveness for integrat-- ing short exercise bouts into organizational routines among constructions workers.
Rinder MM, Genaidy A, Salem S, Shell R, Karwowski W. Interventions in the construction industry: A systematic review and critical appraisal. Human Factors and Ergonomics in Manufacturing & Service Industries 2008;18(2), 212-229.	A comprehensive search of seven electronic databases—Medline, PubMed, Ergonomics Abstracts, Health and Safety Science Abstracts, BIOSIS, Psychinfo, and NIOSHTIC 2—was performed to identify relevant articles. Further, the methodological quality of identified studies was assessed by the Epidemiological Appraisal Instrument (EAI). Eight intervention studies linking and introducing the following aspects of the construction industry were identified: an intervention with reduced MSD; decreasing work demands; or increasing human abilities, comfort, or ease of use among workers. The methodological quality of the studies ranged between marginal and average.	Two studies reported reducing MSD as a research outcome. Ludewig and Borstad (2003) reported significant reductions in pain and disability among the intervention group after a follow-up period of 8–12 weeks, during which the workers exercised stretching and strengthening movements. Luijsterburg et al. (2005) reported a 20% decrease in absences due to sickness among the intervention group after 10 months of follow-up, during which a device for raised bricklaying was used. Six studies (Hess et al., 2004; Holmstrom & Ahlborg, 2005; Holmstrom & Moritz, 1992; Mirka et al., 2003; Van der Molen et al., 2004; Vink et al., 2002;) reported decreasing work demands or improving human abilities as research outcomes. These six studies had measures including reduced trunk flexion, reduced spine compression, and increased trunk strength and endurance. Future studies should avoid the limitations of past studies, such as randomizing population selection and statistically accounting for all potential confounders.
Ludewig PM, Borstad JD. Effects of a home exercise programme on shoulder pain and functional status in construction workers. Occup Environ Med. 2003 Nov;60(11):841-9.	To evaluate a therapeutic exercise program intended to reduce pain and improve shoulder function, construction worker volunteers were screened by history and clinical examination to test for inclusion/exclusion criteria consistent with shoulder pain and impingement syndrome. Sixty seven male symptomatic workers (mean age 49) were randomized into a treatment intervention group (n = 34) and a control group (n = 33); asymptomatic subjects (n = 25) participated as an additional	The intervention group showed significantly greater improvements in the Shoulder Rating Questionnaire (SRQ) score and shoulder satisfaction score than the control groups. Average post-test SRQ scores for the exercise group remained below levels for asymptomatic workers. Intervention subjects also reported significantly greater reductions in pain and disability than controls. Results suggest a home exercise program can be effective in reducing symptoms and

	control group. Subjects in the intervention group were instructed in a standardized eight week home exercise program of five shoulder stretching and strengthening exercises. Subjects in the control groups received no intervention. Subjects returned after 8–12 weeks for follow up testing.	improving function in construction workers with shoulder pain.
Luijsterburg PA, Bongers PM, de Vroome EM. A new bricklayers' method for use in the construction industry. Scand J Work Environ Health. 2005 Oct;31(5):394-400.	The aim of this study was to investigate the effect of raised bricklaying on physical workload, reported musculoskeletal disorders, sickness absence, and job satisfaction. A controlled intervention study with a follow-up period of 10 months was performed among 202 bricklayers from 25 construction companies. Sixty bricklaying teams from 25 bricklaying firms participated in the study, the total study population consisting of 202 bricklayers. At the start of the study, 130 bricklayers were assigned to the control group and 72 to the intervention group. The companies in the intervention group were committed to the implementation of raised bricklaying. Raised bricklaying was used in the intervention group for more than half of the worktime during the follow-up period. The reasons that bricklaying firms gave for not adopting devices for raised bricklaying at all, or not all the time, included the following: (i) cost of the devices, (ii) contractor decisions on the materials used (eg, scaffolds, cranes), and (iii) too little communication between contractors and bricklaying firms concerning the desirability of raised bricklaying.	The introduction of devices for raised bricklaying decreased the physical load on the lower back and, to a less extent, on the shoulders and upper extremities. Although raised bricklaying had no effect on the number of lifts, decreases in trunk bending lowered the biomechanical moment. The results showed no decrease in reported musculoskeletal symptoms as a result of the adoption of raised bricklaying. Irrespective of the reason(s), the percentage of bricklayers in the intervention group reporting sickness absence was significantly lower than the same percentage in the control group. The results also showed that, in general, the bricklayers in this study were very satisfied with the use of devices for raised bricklaying. Conclusions Controlled intervention studies on ergonomic improvements are rare. This study shows that the introduction of an ergonomic improvement in the construction industry may reduce physical load and the incidence of sickness absence.

Hess JA, Hecker S, Weinstein M, Lunger M.A participatory ergonomics intervention to reduce risk factors for low-back disorders in concrete laborers. Appl Ergon. 2004 Sep;35(5):427-41.	This study was conducted during the construction of a $40-million four-story office and classroom building on a university campus. Laborers manually moving a hose delivering concrete to a placement site were evaluated. The hypothesis tested was that skid plates would prevent hose joints from catching on rebar matting, and the hose would slide more easily. This would decrease the need for repetitive bending and use of excessive force. Four laborers were evaluated wearing the Lumbar Motion Monitor (LMM), a tri-axial electrogoniometer that records position, velocity and acceleration. Workers were measured during three comparable concrete pours. Worker perceptions of the innovation utility and exertion were surveyed.	During initial use of skid plates, flexion increased significantly (po0:001) while velocity, acceleration and moments did not change. After implementing a worker modification, low back velocity, acceleration and moments were significantly reduced (p≤0:05). Reductions in these factors have been associated with decreased risk of belonging to an occupational group with LBDs. Use of secured skid plates during horizontal concrete hose movement may in part decrease the risk of LBD group membership among concrete laborers. Crew participation resulted in skid plates being a more effective intervention. The LMM is a promising tool for quantitative assessment in construction.
Holmström E, Ahlborg B. Morning warming-up exercise--effects on musculoskeletal fitness in construction workers. Appl Ergon. 2005 Jul;36(4):513-9. Epub 2005 Mar 31.	The aim of the present study was to evaluate the effects on muscle stretchability, joint flexibility, muscle strength and endurance in construction workers of a 3-month period of a 10-min morning warming-up exercise (MWU), performed at the building site every working day. Thirty construction workers participated in the program. Seventeen construction workers at other building sites served as controls. Muscle stretchability, joint flexibility, muscle strength and endurance were measured before and after the program. The MWU group consisted of 37 male construction workers from the same building site. They were informed about the study and accepted to participate.	Significant increase of thoracic and lower back mobility, increase of hamstring and thigh muscle stretchability were seen in the MWU group. A significant difference in back muscle endurance was found due to decreased endurance in the controls. Muscular strength was not influenced by the MWU. The results indicate that a short dose of morning warming-up exercise could be beneficial for increasing or maintaining joint and muscle flexibility and muscle endurance for workers exposed to manual material handling and strenuous working positions.

Holmström E, Moritz U. Effects of lumbar belts on trunk muscle strength and endurance: a follow-up study of construction workers. J Spinal Disord. 1992 Sep;5(3):260-6.	The effects on maximal isometric trunk muscle strength and endurance after wearing a soft heat-retaining belt or a weightlifter's belt were studies. The soft belt study group comprised 12 construction workers with healthy backs and the weightlifter's belt group comprised 24 construction workers with current or previous low back pain. The strength and endurance measurements were performed before the start of belt use, and after 1 and 2 months.	The soft belt group increased the trunk flexor strength by 13% ($p \leq 0.01$) after 2 months. The weightlifter's belt group increased the trunk flexor strength and endurance by 12% and 29%, respectively ($p \leq 0.001$). No significant decrease of trunk muscle strength and endurance was found at the end of the follow-up period.
van der Molen HF, Grouwstra R, Kuijer PP, Sluiter JK, Frings-Dresen MH. Efficacy of adjusting working height and mechanizing of transport on physical work demands and local discomfort in construction work. Ergonomics. 2004 Jun 10;47(7):772-83.	The efficacy of ergonomics measures to reduce physical work demands in a real working situation is often assumed, but seldom studied. In this study, the effect of adjusting working height and mechanization of transport on physical work demands and local discomfort of bricklayers' work was evaluated during a field experiment in the construction industry. In a within-subjects controlled experiment, 10 bricklayers and 10 bricklayers' assistants worked in two different conditions. Working height of bricks and mortar, and transport of materials were manipulated. The physical work demands were assessed through real time observations at the work site. Local discomfort of the lower back and of the shoulder region was measured by means of a visual analogue scale.	Working with a scaffolding console to adjust the working height of the storage of materials resulted in a significant reduction of the frequency and duration of trunk flexion (> 60 degrees) by 79% and 52% respectively, compared with bricks set out on the ground floor. Mechanization of transport of materials resulted in a significant reduction of the frequency and duration of trunk flexion (> 60 degrees) by 94% and 92% respectively, compared with the condition of manual handling. The frequency of handling objects (> 4 kg) reduced significantly by 86%. Local discomfort of the lower back was significantly less in the ergonomic conditions, while no significant difference was found for local discomfort of the shoulder between both conditions in bricklayers' assistants.

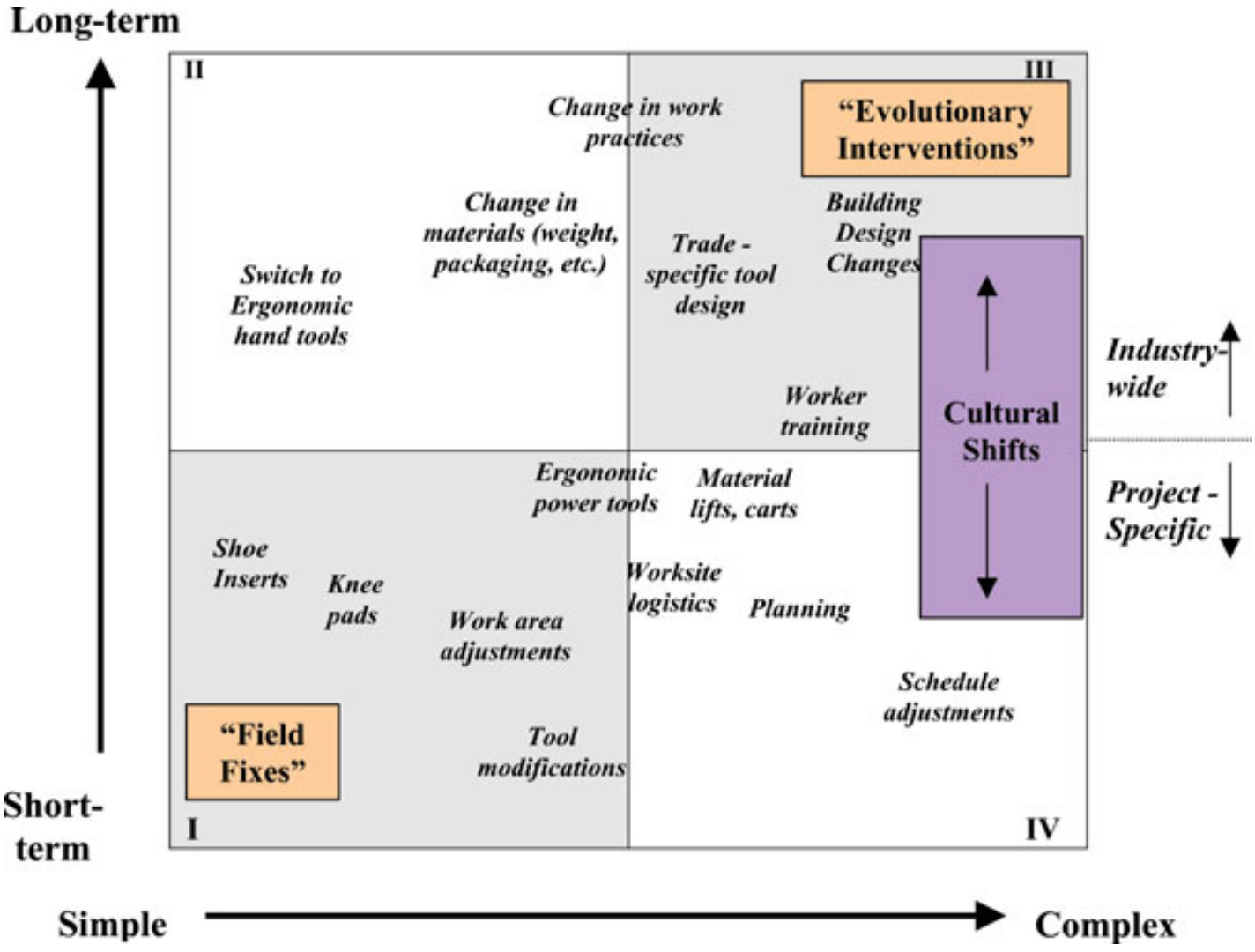
Vink P, Miedema M, Koningsveld E, van der Molen H. Physical effects of new devices for bricklayers. Int J Occup Saf Ergon. 2002;8(1):71-82.		
Mirka GA, Monroe M, Nay T, Lipscomb H, Kelaher D. Ergonomic interventions for the reduction of low back stress in framing carpenters in the home building industry. International journal of industrial ergonomics 2003;31(6), 397-409.	Framing carpenters in the residential sector of the construction industry have exposure to many of the documented risk factors for low back disorders. On-site exposure data were collected from a sample of residential framing carpentry subcontractors and these were summarized using the continuous assessment of back stress (CABS) methodology. A convenience sample of 15 workers from framing/carpentry subcontractors were continuously videotaped as they performed all of the framing tasks associated with the construction of a home. From these analyses those tasks placing the greatest stress on the low back were identified and prototype interventions were developed that reduced exposures to the specific risk factors. These prototypes were then evaluated in the field and their effects on the low back stress and productivity were quantified. The results of this analysis for three of these prototypes (a pneumatic wall lift, an extension handle for a pneumatic nail gun and a vertical lumber handling system) are presented in this paper.	The pneumatic wall lift reduced peak spine compression by 63% and had mixed effects on productivity depending on the characteristics of the wall being erected. The extension handle for the pneumatic nail gun had a marked decrease in the average spine compression (73%) and also had mixed effects on the productivity depending on the characteristics of the support structures under the subflooring. The vertical lumber handling system created significant reductions in both the peak (70%) and average (32%) spine compression forces as well as a significant improvement in productivity (increase of up to 77%). Several of these interventions had positive effects in other body regions (primarily shoulder loading) but these were not quantified in the rigorous way that the low back stress was evaluated. Finally, subjective assessments by the workers varied across the interventions and were heavily weighted by their effects on productivity.
Madgwick P, Houdmont J, Randall R. Sun safety measures among construction workers in Britain. Occup Med (Lond). 2011 Sep;61(6):430-3.	Observational design with no active intervention using a one time mail questionnaire to 1,360 British construction workers to determine demographic and occupational characteristics as well as use of sun safety measures.	Logistic regression associated employer sun safety training with wearing of protective clothing and sunglasses (Odds Ratio = 1.85).

Appendix 2. Intel matrix of time versus complexity for adoption of various types of innovations

Rinder and coauthors (2008) reproduced an interesting "matrix" of construction ergonomics innovations that was originally developed by Intel Corporation. The matrix is useful for visualizing innovations from the standpoints of time (i.e. the time required for effective implementation) and complexity (i.e. the organizational complexity involved in adopting various example innovations). Some innovations (and some research to practice applications) can be easy, low cost and exploited to become effective in the short term. Others will require time and organizational change before they begin to have an effect. Rinder and coauthors described the value of the matrix at the conclusion of their review as follows:

> "…construction ergonomics intervention(s) can be grouped into 4 categories: first, a short-term and simple intervention; second, a long-term and simple intervention; third, a long-term and complex intervention; and forth, a short-term and complex intervention. The interventions in the first category, which consist of special personal equipment (knee pads, shoe inserts), tool modifications or power tools, and adjustment of work place, are the easiest and least expensive to implement and can be applied in a short-term period as well. These interventions are called field fixes because they can be very easily implemented in the field and do not need too much effort from the company's side. Since parts of them are consumable, it may be necessary to change them periodically, thus raising the question of whether they are as cheap as initially assumed. In our systematic review, three articles use this type of intervention: introduction of devices to raise the bricklayers (Luijsterburg et al., 2005), adjusting working height (Van der Molen et al., 2004), and wearing of belts (Holmstrom & Moritz, 1992). The interventions in the second category of the matrix consist of simple, yet long- term interventions. In this group, we can consider the use of ergonomic tools, change of materials, and change in work practices. These interventions may not be so expensive, but may be used for long periods of time. None of the articles from our systematic review considered this type of intervention. Through these interventions, we can open the path to more complex and comprehensive interventions, like trade-specific tool design, worker training, and building design changes that are considered to be evolutionary interventions. These are considered complex and long-term interventions, requiring time and financial resources from the company. In our review, we have five interventions from this group: introduction of new devices such as skid plates (Hess et al., 2004), pneumatic wall lift, nail gun extension handle, and vertical lumbar handling system (Mirka et al., 2003), and split floor in scaffolding and shores (Vink et al., 2002). These interventions reduced stress and discomfort on the lower back, reduce spine compression, and diminish the frequency and duration of twisting and bending, all of which improve health. The last intervention group is short-term and complex (fourth category) and includes planning, schedule adjustments, material lifts/carts, and worksite logistics. This group also includes the mechanization of transport (Van der Molen et al., 2004), which is represented by

the introduction of a crane to help workers to transport bricks and mortar. The effects of introducing this intervention are reduction of frequency and duration of awkward postures, and reducing the frequency of manual handlings. When making this type of intervention, we have to consider that other risk factors, such as prolonged sitting, whole body vibration and even other awkward postures, may occur. … Considering the above classification of intervention, we may recommend that before introducing a new intervention, it is necessary to understand what the MSD risk factors are and accordingly determine the most intervention(s) to significantly reduce their risk. In addition, the costs of the new intervention and what the results will be must be clearly understood."



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