NORA

NATIONAL OCCUPATIONAL RESEARCH AGENDA (NORA)

NATIONAL OCCUPATIONAL RESEARCH AGENDA FOR CONSTRUCTION

June 2018

Developed by the Construction Sector Council

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INTRODUCTION

What is the National Occupational Research Agenda?

The National Occupational Research Agenda (NORA) is a partnership program to stimulate innovative research and workplace interventions. In combination with other initiatives, the products of this program are expected to reduce the occurrence of injuries and illnesses at work. Unveiled in 1996, NORA has become a research framework for the Nation and the National Institute for Occupational Safety and Health (NIOSH). Diverse parties collaborate to identify the most critical issues in workplace safety and health and develop research objectives for addressing those needs.

NORA enters is third decade in 2016 with an enhanced structure. The ten sectors formed for the second decade will continue to prioritize occupational safety and health research by major areas of the U.S. economy. In addition, there are now seven cross-sector organized according the major health and safety issues affecting the U.S. working population. While NIOSH is serving as the steward to move this effort forward, it is truly a national effort. NORA is carried out through multi-stakeholder councils, which are developing and implementing research agendas for the occupational safety and health community over the decade (2016-2026). Councils address objectives through information exchange, partnership building, and enhanced dissemination and implementation of evidenced-based solutions.

NORA groups industries into ten sectors using North American Industry Classification System (NAICS) codes. The construction sector encompasses NAICS code 23 and subsectors [236, 237, and 238] encompassing construction of buildings, heavy and civil engineering construction, and specialty trade contractors. Construction is a large, dynamic and complex industry that plays an important role in the U.S. economy. The value of construction spending in 2016[1] was estimated at nearly $1.2 trillion dollars. Construction workers and employers build our roads, houses, and workplaces and repair and maintain our nation's physical infrastructure. This work includes many inherently hazardous tasks and conditions such as work at height, excavations, noise, dust, power tools and equipment, confined spaces, and electricity. NORA groups health and safety issues into seven cross-sectors. The construction sector focuses on preventing falls from elevation, struck-by incidents, hearing loss, respiratory diseases such as silicosis, and work-related musculoskeletal disorders.

What are NORA Councils?

Participation in NORA Councils is broad, including stakeholders from universities, large and small businesses, professional societies, government agencies, and worker organizations. Councils are co-chaired by one NIOSH representative and another member from outside NIOSH.

Statement of Purpose

NORA councils are a national venue for individuals and organizations with common interests in occupational safety and health topics to come together. Councils will start the third decade by identifying broad occupational safety and health research objectives for the nation. These research objectives will build from advances in knowledge in the last decade, address emerging issues, and be based on council member and public input. Councils will spend the remainder of the decade working together to address the agenda through information exchange, collaboration, and enhanced dissemination and implementation of solutions that work.

[1] U.S. Census Bureau [2017]. Value of Construction Put in Place at a Glance https://www.census.gov/construction/c30/c30index.html

Although NIOSH is the steward of NORA, it is just one of many partners that make NORA possible. Councils are not an opportunity to give consensus advice to NIOSH, but instead a way to maximize resources towards improved occupational safety and health nationwide. Councils are platforms that help build close partnerships among members and broader collaborations between councils and other organizations. The resulting information sharing and leveraging efforts promotes widespread adoption of improved workplace practices based on research results.

Councils are diverse and dynamic, and are open to anyone with an interest in occupational safety and health. Members benefit by hearing about cutting-edge research findings, learning about evidence-based ways to improve safety and health efforts in their organization, and forming new partnerships. In turn, members share their knowledge and experiences with others and reciprocate partnerships.

Construction Sector Council

The NORA Construction Sector Council was the first council to develop a national occupational safety and health research agenda for construction in October 2008. Efforts are ongoing to answer the question: "What information do we need to be more effective in preventing injuries and illnesses in construction?" A description of research needs and information gaps was one important basis for the agenda. The other basis was "research to practice" (r2p); specifically, a description of how research findings could be used by construction stakeholders to facilitate changes in the industry. The NORA Construction Sector Council seeks to promote the most important research, understand the most effective intervention strategies, and learn how to implement those strategies to achieve sustained improvements in workplace practice. The Construction Sector Council consists of partners from Federal and state agencies; employee and employer organizations; Universities, professional organizations, and other entities.

What does the National Occupational Research Agenda for Construction represent?

The National Occupational Research Agenda for Construction is intended to identify the research, information, and actions most urgently needed to prevent occupational injuries and illnesses in the construction sector. This National Occupational Research Agenda for Construction provides a vehicle for construction industry stakeholders to describe the most relevant issues, gaps, and safety and health needs for the sector. Each NORA research agenda is meant to guide or promote high priority research efforts on a national level, conducted by various entities, including: government, higher education, and the private sector.

Because the Agenda is intended to guide national occupational health and safety efforts for the Construction Sector, it cannot at the same time be an *inventory* of all issues worthy of attention. The omission of a topic does not mean that topic was viewed as unimportant. Those who developed this Agenda did, however, believe that the number of topics should be small enough so that resources could be focused on a manageable set of objectives, thereby increasing the likelihood of real impact in the workplace.

NIOSH used the draft Agendas created by the sector and cross-sector NORA Councils to help inform the NIOSH Strategic Plan. Programs used the burden, need and impact (BNI) method to write research goals that articulate and operationalize the components of the NORA Sector and Cross-Sector Agendas that NIOSH will take up. NORA Agendas and the NIOSH Strategic Plan are separate but linked.

Who are the target audiences?

While not every stakeholder group is involved with research, most construction organizations are involved somehow with converting knowledge into practice for use by either contractors or construction workers. Developing the National Occupational Research Agenda for Construction provides a vehicle for construction industry stakeholders to describe what they believe are the most relevant issues, gaps, and safety and health needs in the industry.

The National Occupational Research Agenda for Construction is important because it will provide guidance for construction industry stakeholders (e.g., industry, labor, professionals, and academics) to prioritize their work among the many competing safety and health issues of interest. It is intended to inspire decision makers to include these topics in their top priorities. It is intended to steer researchers to cohesive topic areas for research proposals. Lastly, it is intended to encourage dialog and partnering among stakeholders on a subset of key issues ---thus increasing our collective ability to make an impact in reducing injuries and illnesses among construction workers. In sum, the agenda has been designed with a wide construction target audience in mind. See Table 1 for examples.

Table 1. National Occupational Research Agenda for Construction– Potential Target Audiences

Research funding sources
Federal Research Agencies
Research foundations
State supported sources
Workers Compensation Insurance research organizations
Industry research organizations
Trade Associations
Building owner associations
Public and Private Researchers
Government researchers
Academic researchers
Association and organization researchers
Construction industry organizations
Trade associations
Labor organizations
Apprenticeship training organizations
Regulatory agencies involved with construction at federal, state, and local levels
Non-profit organizations and community-based construction groups
Engineers and architects
Tool, equipment, and material manufacturers and distributors
Construction management firms
Safety and health practitioners
Professional associations (e.g. ASSE, AIHA, NSC, ASCE)
Individual safety, industrial hygiene and engineering practitioners
Consensus standards groups
Other professionals with safety and health interest (economists, physicians)

How was the research agenda developed?

A variety of information sources were used to develop these objectives. The third decade of NORA was launched in October 2016, however, many of these objectives are based upon the collective wisdom and experience of members of the NORA Construction Sector Council. Two online meetings of the NORA Construction Sector Council occurred in the summer and fall of 2016 (September 7 and October 18) during which the process of developing an agenda was discussed and input from sector council members and other stakeholders was provided. The Council elected to adopt NIOSH's burden, need and impact framework for considering potential objectives.

Meeting participants represented a cross-section of groups and individuals and provided a variety of construction perspectives.

The Sector Council members discussed burden, need, and impact; possible objectives; and supporting rationale during the online meetings. Workgroups were formed around potential construction sector objectives that workgroups began to discuss and develop. The first full face-to-face meeting of the Third Decade NORA Construction Sector Council occurred on November 15-16, 2016. Each workgroup presented their draft objective statement, objective language and supporting rationale, along with corresponding burden, need, and impact related to the particular objective. At an additional online meeting on January 31, 2017, additional feedback was provided on the draft objectives. At the March 14-15, 2018 face-to-face meeting of the Construction Sector Council, final discussions occurred resulting in a total of 16 draft objectives for the construction sector. After considering public comments and making revisions, the final version was published.

THE OBJECTIVES

Objective 1: Falls from heights - Eliminate falls in construction

Construction stakeholders will focus on eliminating falls to lower levels through research, training, communications, grant-making and partnerships. This includes advancing existing efforts (such as compliance with Occupational Safety and Health Administration [OSHA] regulations[2]) promoting concepts including safety culture, safety and health management systems, prevention-through-design, research-to-practice activities, and other pertinent concepts and assets.

Burden

In 2016, 10.3 million U.S. workers were employed in construction, a 16% increase after construction employment bottomed out in 2012 [CPWR 2017]. Displaced workers are returning to this industry. The Bureau of Labor Statistics (BLS) expects construction employment to increase over the next 8 years [BLS 2015a]. Falls remain the leading cause of work-related fatalities in construction, accounting for around one-third of the total number of fatalities in this industry. Although fatal falls followed the overall injury trends, fall deaths rose faster than overall deaths in construction during the economic recovery. Between 2011 and 2015, the number of fall fatalities in construction increased by 36.4% from 269 to 367, compared to a 26.1% increase in overall fatalities [CPWR 2017]. Between 2003 and 2015, 4,439 construction workers died from falling to a lower level, accounting for 97% of fall fatalities in construction [CPWR 2017]. The trend of nonfatal fall injuries resulting in days away from work (DAFW) among construction workers mirrored employment and fall fatality trends in this industry. The number of fall injuries with DAFW increased by 21% from 2011 to 2015, after the lowest level of 18,100 in 2010 [CPWR 2017]. The rate of nonfatal falls also rose from 36.2 injuries to 40.3 injuries per 10,000 FTE during this time period. In 2015, 23,860 nonfatal fall injuries occurred in construction [CPWR 2017].

Work-related traumatic brain injury (TBI) is the most common occupational injury to be associated with morbidity and mortality. Studies have also identified TBI as one of the most costly in terms of lost time worker's compensation claims [Colantonio et al. 2009], and construction industry is a high-risk population for serious TBI due to falls [Wei et al. 2010]. Furthermore, construction workers are more likely to be hospitalized due to TBI, either fatal or nonfatal but serious, compared to workers in other industries [Liu 2011; Kim et al. 2006]. A Centers for Disease Control and Prevention (CDC) study showed that the incidence of TBI is increasing and that survivors of TBI are often left with neuropsychological impairments that result in disabilities affecting work or social activity [Adekoya et al. 2002]. A World Health Organization (WHO) study found that all categories of TBI, encompassing both work and non-work injuries, will be the leading cause of disability by the year 2020 [Yuan et al. 2012].

Need

A substantial amount of research and work has already been done to address fall prevention, but more work is needed. Construction stakeholders need to focus on eliminating falls through research, training, communications, grant-making, and partnerships. This includes advancing existing efforts (such as compliance with OSHA regulations), promoting concepts including safety culture, safety and health management systems, prevention-through-design, research-to-practice activities, and related approaches. Translation and intervention research is needed to address engineering and design, education and training, communication, and administrative issues and achieve meaningful results. Continued emphasis on translation and intervention research associated with the National Campaign to Prevent Falls in Construction and the National Stand-Down should continue as a priority as falls remain the leading cause of workplace fatalities among construction workers. There needs to be continued research on most effective ways to reach residential contractors, small businesses and other groups at disproportionate risk. Future research to prevent and protect from falls should consider the effects and

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[2] In this document "OSHA" should be read to include both federal and state-level agencies.

interactions of environmental, task-related, and personal factors that can affect workers' balance. Improvements in the work environment, in construction materials and methods, and in work procedures and practices should improve safety and reduce falls. Research to reduce falls among higher risk groups (such as power line installers, roofers, iron workers, sheet-metal workers, laborers, etc.) is especially needed, along with research to understand and evaluate the safety, productivity, and latent hazards of emerging work methods and technologies.

Some observations and key topics regarding work and related activities that are needed to advance fall protection are described below:

Falls to a lower level will require a multi-pronged approach

While fall prevention is the discrete topic, there are many factors that combine in multiple groupings that can lead to fewer falls to a lower level. This includes compliance with OSHA regulations (e.g., guard rails), safety culture, effective safety and health management systems, prevention-through-design, use of research-to-practice findings, and other pertinent concepts and assets from national construction stakeholders.

Focus on supervisors, managers, employers, and construction service purchasers

One particular need is to educate supervisors and owners of construction companies about fall protection equipment. Worker-level training is likely sufficient, but safety advocates need to focus on fall protection training at the supervisory level.

Use Safety and Health Management Systems to provide a message and access to employers

Construction stakeholders must identify successful safety and health management programs, where fall protection is selected and used and where near-misses are counted and acted upon. National stakeholder partners should encourage use of OSHA's "Recommended Practices for Safety and Health Programs in Construction."

Incorporate safety into all planning phases

Employers must make certain that safety is part of the overall construction process. Fall protection should not be a stand-alone topic. Construction engineers should include fall protection when using Building Information Modeling (BIM) to plan construction work. This could lead to ensuring that there are compliant anchor points for personal fall arrest systems (PFAS), and that no surprises occur midway through the construction process.

Worker empowerment

Workers should be empowered to ask for fall protection equipment and then use it. The nation's safety leaders should also recognize many factors preventing workers from asking for and/or using personal fall arrest equipment.

Access to compliant anchorages

Personal fall arrest systems require anchor points capable of supporting 5,000 lbs. Not all structures have compliant anchorages and updates are needed.

Research on wood-frame construction anchorages

National safety advocates should seek partnerships with the National Framers Council, truss manufacturers, NIOSH, Center for Construction Research and Training (CPWR), OSHA, National Association of Home Builders (NAHB) and university researchers to assess the strength of wooden trusses and wood frame structures, and to determine when it is safe to use these structures as PFAS anchors and others

CPWR has also conducted research on this topic. "Fall Protection: Structural Efficacy of Residential Structures for Fall Protection Systems," (published in *Professional Safety*, May, 2015) concluded compliant, effective personal fall arrest anchors can be installed in wood-frame structures [Bethancourt and Cannon 2015].

International sources of information and fall prevention tactics

Research and other outreach activities should be conducted with commercial builders. Worksafe Australia's residential safety regulations and other countries' fall protection regulations have information that could be adopted in the U.S. Fall protection recommendations must be explicit and focused on a particular job site.

Impact

There is an economic benefit of good fall prevention to employers, in addition to employees. The Liberty Mutual Workplace Safety Index for 2016 (reporting on 2013 data) indicates falls to a lower level for all industries cost the U.S. economy an estimated $5.4 billion [Liberty Mutual Research Institute for Safety 2016]. The efforts described above can help reverse the trend of workers falling to a lower level, saving the lives of nearly one person per day, and helping more than 11,000 persons avoid injurious falls to a lower level.

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Objective 2: Falls from same level - Significantly reduce or eliminate slips, trips, and falls

Burden

The burden of serious injuries and even deaths related to slips trips and falls (STFs) in construction is significant but sometimes overlooked. STFs are some of the most common hazards on construction job sites. In 2010, there were approximately 18,130 nonfatal injuries to construction workers as a result of falls. Approximately 40% of those injuries were the result of falls that occurred on the same level [CPWR 2013]. A 2005 EU report shows nearly 4 million slips in 2005 [European Commission 2008]. They are one of the leading causes of worker's compensation claims [NFSI 2017].

There are many causes of STFs that are unique to construction, easily observable, and need to be addressed. A better understanding of the causes will help in developing effective mitigation strategies to address these hazardous conditions. Inadequate housekeeping, maintenance and site inspection procedures are major contributing factors to most STF accidents. Part of the reason STFs are an issue in construction is related to the changing and dynamic nature of the work. During construction, it can be difficult to ensure safe walkways, with uneven surfaces, potholes, cracks, temporary bridges and walkways, changing elevations and changing routes and conditions, and often muddy soil.

Need

A substantial amount of research and work has already been done to address fall prevention, but more work is needed. Federal and non-federal stakeholders need to focus on eliminating STFs through research, training, communications, grant-making and partnerships. This includes advancing existing efforts (such as compliance with OSHA regulations) promoting concepts including safety culture, safety and health management systems, prevention-through-design, research-to-practice activities, and related approaches.

A better understanding of the causes will help in developing effective mitigation strategies to address these hazardous conditions. Inadequate housekeeping, maintenance and site inspection procedures are major contributing factors to most STF accidents.

Translation and intervention research is needed to address engineering and design, education and training, communication, and administrative issues and achieve meaningful results. Future research to prevent and protect from falls should consider the effects and interactions of environmental, task-related, and personal factors that can affect workers' balance. Improvements in the work environment, in construction materials and methods, and in work procedures and practices should improve safety and reduce falls.

Environmental conditions also play a role. A lot of construction activities occur outdoors. Water from rain and other spills from sources can result in slippery conditions. Winter conditions, snow, and ice can result in treacherous conditions. Soft soil conditions and truck traffic can add to the difficulties. Construction sites also can have many obstructions that increase the risk of tripping. Many are temporary in nature and range from debris, materials and tools to portable equipment, cables, hoses and power cords, etc.

With multiple contractors working at a given time, daily site coordination can be critical to ensure proper access and egress routes, coordination/communication of changing conditions, signage, illumination and a host of other items. Regular planning and inspections can help ensure safety of ladders, scaffolding and walkways. Many construction jobs require workers to carry materials and tools. Carrying heavy and awkward objects can affect their balance and gait. Use of improper footwear or muddy shoes can also increase the potential for STFs. Aging workers and use of medication for chronic pain and other health issues can also affect balance. There is a strong need to develop formal written maintenance, inspection and training procedures to reduce STF accidents to the public, employees and non-employees at the jobsite. This includes compliance with OSHA regulations (e.g., guard rails), safety culture, effective safety and health management systems, prevention-through-design, use of research-to-practice findings, and other pertinent concepts and assets from national construction stakeholders.

Some observations and key topics regarding work and related activities that are needed to advance fall protection are described below:

Focus on supervisors, managers, employers, and construction service purchasers

One particular need is to educate supervisors and owners of construction companies about fall protection equipment. Worker-level training is likely sufficient, but safety advocates need to focus on fall protection training at the supervisory level.

Use Safety and Health Management Systems to provide a message and access to employers

Construction stakeholders must identify successful safety and health management programs, where fall protection is selected and used and where near-misses are counted and acted upon. National stakeholder partners should encourage use of OSHA's "Recommended Practices for Safety and Health Programs in Construction," the National Safety Council's "Journey to Safety Excellence" or other model programs.

Incorporate safety into all planning phases

Employers must make certain that safety is part of the overall construction process.

Impact

There is an economic benefit of good fall prevention to employers, in addition to employees. The impact associated with addressing the hazard of slips, trips, and falls in construction is great and is directly related to the burden. Many of the injuries and associated costs of this hazards are easily preventable.

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Objective 3: Struck by - Reduce fatal and serious injuries associated with struck-by incidents associated with objects, vehicles, and collapsing materials and structures in construction

Burden

This objective addresses the diverse category of risks associated with workers being in the line of fire of objects that are moving relative to them. as well as the specific priority of work-related motor vehicle crashes. Energy transferred from the moving objects to the worker produces harm. This includes small objects moving at high velocity, such as tools or fasteners dropped from height, to those moving slowly but with great mass. Either extreme of this situational continuum, and all points between, has the capacity to produce serious and fatal injury to workers. The incident category is a perennially leading contributor to worker injury for all types of construction.

The burden of serious injuries and deaths related to motor vehicle accidents is significant in the US construction industry. Construction workers are at risk of injury from motor vehicles where the construction work interfaces with traffic and when driving motor vehicles along the roadway for work. At road construction sites, construction workers drive motor vehicles daily where traffic patterns are not normal, frequently having to enter and exit live traffic streams. Additionally, construction workers drive fleet vehicles long distance to and from job sites, at all hours of the day and night. Motor vehicle crashes are the leading cause of work related deaths in the U.S. Millions of workers drive or ride in a motor vehicle as part of their job and the risk cuts across all industries and occupations. From 2003 – 2014, there were approximately 22,000 work related motor vehicle deaths in the U.S. [BLS 2015b]. In 2013, the total cost to U.S. employers of motor vehicle crashes at work was approximately $25 billion [NETS 2015)]. Vehicles and mobile heavy equipment were a major source of fatalities in construction, resulting in 7,681 deaths from 1992 to 2010, about 404 deaths annually. From 2008 to 2010, vehicles were the source of more than half of the fatalities at road construction sites – double the proportion of such deaths in the overall construction industry [CPWR 2013]. Though work zones provide unique risks for workers on foot, motor vehicle related fatalities are not limited to work zones. Of the 937 construction fatal injuries reported in the Census of Fatal Occupational Injuries in 2015, 49 were workers-on-foot, while 136 were involved in Roadway collision and noncollision (e.g. jack-knife) incidents. Based on the Network for Employer Traffic Safety [2015], these 136 motor vehicle crash related deaths cost the construction industry $91.25 million.

While the financial burden of the category is inadequate to describe the suffering workers and their family's experience, it does provide a comparative indication of severity.

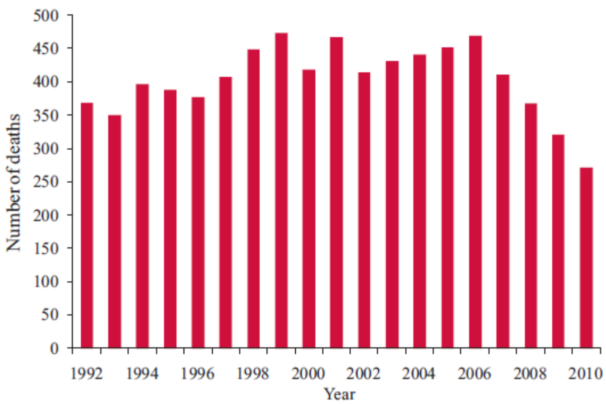
Workplace injuries cost U.S. businesses almost $62 billion per year in 2013—more than $1 billion a week—according to the 2016 Liberty Mutual Workplace Safety Index. The top 10 causes of workplace injuries accounted for more than $51 billion, or 82% of workers' compensation costs. In addition to these direct workers' compensation costs, a company may also face indirect costs related to lost productivity, a drop in employee engagement, and damage to its external reputation. For an employee, suffering a workplace injury can result in physical, emotional, and financial pain.

1. In the Top 10 causes, struck-by incidents ranked #4 in 2013 (the latest year for which data are available) and accounted for $5.31 billion; 8.6% of workers' compensation costs
2. Caught in or compressed by equipment or objects, in the same year, ranked #8 and accounted for $1.97 billion; 3.2% of workers' compensation costs
3. Struck against objects (stationary) ranked #9 and accounted for $1.85 billion; 3.0% of workers' compensation costs

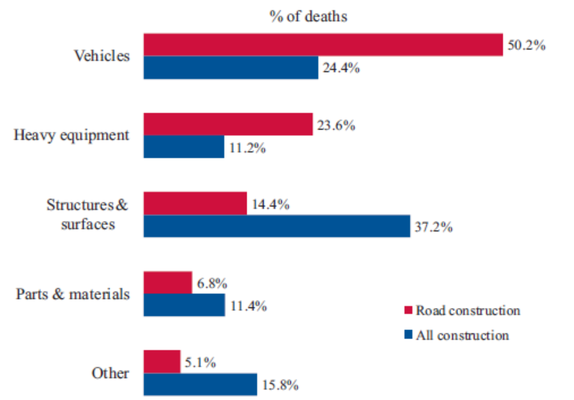
While these findings encompass all industries, the contribution from construction is significant and compounded by the variety of situational risks.

CPWR’s *The Chart Book* [2013] provides insights on the significance of the category in construction.

46a. Fatalities involving vehicles and heavy equipment in construction, 1992-2010



46b. Primary sources of fatalities, road construction sites vs. all construction, 2008-2010 total



Need

These findings are focused on the effects of interactions between workers and vehicles/heavy equipment. Those associated with falling, flying, swinging, rotating, collapsing, etc. objects are very diverse and impact construction of all types and employers of all sizes. There is a need to conduct multidisciplinary research in this area to reduce the burden of injury and death associated with construction workers being struck by or caught between objects. There is a need to research new technologies being developed to address these hazards.

Motor vehicles are one of the most common hazards on construction sites. Motor vehicle incidents are a leading cause of worker’s compensation claims. Since the late 1990s the industry has seen safety improvements that focus on workers on foot, such as improved garment visibility, increased usage of proximity warning alarms, and increasing adoption of strategies to reduce worker runover incidents. To date, there has been little research focus on identifying risk factors for work-related motor vehicle crashes and resulting injuries. It is also important to evaluate interventions to prevent work-related motor vehicle crashes and reduce known motor vehicle crash risk factors, such as workers not using a seat belts, driving while fatigued, and driving while distracted. Administrative and management controls are important elements that help reduce risk factors, but intervention research in this area should also include engineering and technology based controls. Another area of needed research is looking at the safety and health implications of the low-bid contracting system and alternative methods. Additionally, the expanding field of vehicle technology provides opportunities and challenges for construction worker safety related to motor vehicles. Some additional areas of research include: research evaluating policy, program, and training interventions to reduce work-related motor vehicle crashes and injuries, taking into account known and hypothesized crash risk factors for workplace driving, e.g., fatigue, commuting, distraction, medications, and chronic health conditions. In addition, research assessing the work-related effects of the rapidly-expanding fields of vehicle-to-vehicle and vehicle-to-infrastructure technology, highly-automated vehicles, active safety systems, and in-vehicle monitoring systems.

There is a need to conduct new studies of perennial areas of struck-by risks that have increasingly emergent complexity and significant potential for impact. Some of these areas include the following:

1. Tool and component (e.g. battery packs) securement for overhead work
    a. Intervention techniques identified through research translated (r2p) for practical use
2. Worker avoidance of access and movement through areas with unsecured overhead work
3. Worker proximity to moving equipment
4. Personal protective equipment matched to task activity (correct devices for protection needed)

   a. Doffing/donning
   b. Maintenance
5. Enhancing rigging and lifting techniques, improving crane operator/crane flagmen verbal communication and maintaining line-of-sight contact.
6. Work place congestion that creates potential pinch points and work fronts without a safe "retreat/escape" zones

Impact

The impact associated with addressing the hazard of motor vehicle safety in construction is great and is directly related to the combination of the recognized burden and the history of collaboration among labor, management, academia, and government agencies.

Item 3 above (worker proximity to moving equipment) has significant potential impact in the realm of work zone intrusion. Vehicle crashes in general are increasing, as are those that result in fatalities. Just as availability of more sophisticated vehicles equipped with technology for crash avoidance, blind spot monitoring and even lane drift, so are sources of driver distractedness. When coupled with the apparent recognition for more national investment in infrastructure improvement, situational risks to transportation project workers could become exponentially more complex. New knowledge on protection of workers from vehicular intrusion into their work areas is sorely needed.

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Objective 4: Electrical - Conduct research to address electrical safety issues on construction sites

Burden

In today's construction sector, providing temporary power on construction sites for workers to use is frequently a challenge. Fewer qualified persons installing and maintaining the temporary power has opened the door for improper installations and incidents that could result in fatalities on these jobsites. In many cases, the equipment used in temporary installations is not new and is not rated for the environment in which it is being used. Using portable tools that are supplied by extension cords is considered temporary work. National Fire Protection Agency (NFPA) national consensus standard 70E states that when using portable cords or performing maintenance work, either a ground-fault circuit interrupter (GFCI), be used to supply the cord, or an assured equipment grounding conductor program (AEGCP), be implemented to ensure safety of personnel. GFCIs have many installation and use requirements including monthly testing. OSHA has begun to issue citations based upon the requirements of NFPA 70E [Pryce 2015].

Electrocution is one of the leading causes of death in construction. Between 2008 and 2010, electrocution deaths accounted for 9.3% (252 deaths) of the total fatal injuries in construction [CPWR 2013]. Of the 252 deaths, 69 were electricians and 41 were construction laborers. While the number of deaths among electrical power-line installers was smaller (17 deaths), this occupation has a higher death rate than any other occupation in construction [CPWR 2013]. The high lifetime risk of electrocution is not only for electrical workers, but also among non-electrical workers such as helpers, ironworkers, roofers, and heating, air conditioning, and refrigeration mechanics [CPWR 2013].

Construction workers account for a disproportionate share of electrical injuries. From 1992-2002, 47% of workplace electrocutions took place in the construction industry and construction workers have been found to be approximately four times more likely to be victims of workplace electrocution than workers in all other industries combined [Campbell and Dini 2015].

- Construction Trades With Elevated Rates of Electrical Fatalities:
  - Electricians
  - Apprentices
  - Utility Workers and Electrical Lineman
  - Construction Laborers and Other Crafts
  - Bystanders
- Common Causes of Electrical Fatalities:
  - Direct Contact with Power Lines
  - Direct Contact with Energized Equipment
  - No Lockout/Tagout Program in place or enforced
  - Improper Installation
  - Improper Grounding
  - Indirect Contact with Powerlines

Need

There was a criticism that the construction lockout/tagout requirements found in the OSHA electrical construction regulations fall short in their application to ensure a lock is installed preventing accidental or unintentional operation by unqualified persons. While electrical citations may be trending down, electrocution is still part of the "focus four" causes of fatalities developed by OSHA [2011]. Installing and maintaining temporary power on construction sites and locations being remodeled/deconstructed as well as electrical hazards in existing facilities is an essential component of an electrical contractor's work. Proper control of temporary power systems on a jobsite must be done exclusively by the qualified person(s), in this case, the electrician(s). Only "Qualified Person(s)" as defined by OSHA and NFPA standards should be installing, connecting and servicing the temporary wiring installation. Qualified persons should understand proper implementation of lockout/tagout procedures and the appropriate methods to troubleshooting issues such as a "tripped" circuit breaker or bad GFCI. Too often, other trades with little or no training attempt to turn on breakers and reset other components without knowledge of the accidents they could cause. When electricians are beginning to test and commission the building wiring system during the final phase of construction, only these electricians, that are qualified persons, should be responsible for turning electrical circuits on and off. There is a need for translational research targeted at both: 1) electricians, and 2) non-electricians and powerline/utility workers separately to better understand how to encourage wider implementation of safe methods and technologies that will reduce electrical hazards. There is also a need for intervention research targeted at both: 1) electricians, and 2) non-electricians and powerline/utility workers separately to design out the hazards through wider implementation of prevention through design efforts that address the common causes of electrical fatalities.

Impact

Providing research findings and training to construction personnel will help workers understand their own qualifications and limitations when exposed to electrical hazards. By identifying electrical hazards and the proper control measures used to mitigate temporary power issues found on construction sites, workers will gain a new understanding of how electricity can be an unseen hazard not easily recognized by "unqualified person(s)." Updating company policies and implementing best practices will help to provide a safer construction site for all. The goal is always zero injuries and zero fatalities in every safety program, changing the current behaviors that have caused fatalities will move progress in the right direction.

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Objective 5: Respiratory and dermal - Reduce the frequency of occupational disease caused by respiratory and dermal hazards in construction

Burden

More than 53,000 workers die annually from occupational diseases, almost ten times the number who are killed by traumatic injuries [Leigh 2011]. Construction tasks that generate airborne hazards include abrasive blasting, tuck-pointing, cement finishing, wood cutting and sanding, masonry work, painting, gluing, cleaning with solvents, welding, and using diesel-powered heavy equipment among other activities. All of these agents can cause respiratory diseases (e.g., silicosis, asbestosis, chronic obstructive pulmonary disease [COPD], and lung cancer), and can reduce a worker's length and quality of life. In 2010, over 50% of construction workers reported exposure to vapors, gas, dust, or fumes at work twice a week or more. [CPWR 2013]. Older construction workers were about twice as likely to die of respiratory cancer or non-malignant respiratory disease as their white-collar counterparts, after adjusting for smoking and other confounders [Wang et al. 2016].

From Mazurek and White [2015] "…9.0% of adults had asthma and…among ever-employed adults with asthma, the overall proportion of work-related asthma was 15.7%." Across the U.S., this is over 2 million asthma cases. Recent surveillance data from Washington State provides occupation-specific prevalence ratios for asthma symptoms caused or worsened by current or past job. Construction and extraction had the second highest prevalence ratio of 2.0 [Anderson et al. 2014]. From state-based surveillance, the third most common type of agent reported to be associated with work-related asthma, 2009-2011, was mineral and inorganic dusts, which are common in construction [NIOSH 2015].

About 12 million people in the U.S. have chronic obstructive pulmonary disease (COPD), which includes emphysema and chronic bronchitis [NIH 2013]. In 2009, COPD caused 137,353 deaths in the U.S. and was the third leading cause of death [Johnson 2014]. The American Thoracic Society estimates that approximately 15% of COPD cases, a total of about 1.8 million, can be attributed to workplace exposures [Balmes et al. 2003]. Because COPD is a chronic condition that has a long latency, mortality data are useful for assessment of distribution by industry sector. The construction sector was associated with an increased proportionate mortality ratio (PMR) for COPD, and elevated PMRs were observed for roofers, painters, welders, carpenters, plumbers, operating engineers, and construction laborers [NIOSH 2008a].

CPWR found that among construction workers who never smoked, 32% (95% CI=6-42%) of COPD was work-related [Dement et al. 2015]. They found that over a 45-year working life, 16% of construction workers developed COPD. The risk for occupationally-related disease over a lifetime in a construction trade was two to six times greater than the risk in non-construction workers [Ringen et al. 2014]. Estimated annual medical costs are $2.29 billion for occupational asthma and $3.94 billion for occupational COPD [Leigh 2011].

Deaths in the U.S. caused by inhalation of inorganic mineral dust causing silicosis, asbestosis and coal workers' pneumoconiosis exceeded 22,000 between 2001 and 2010 [NIOSH 2015]. Over 2,000 people die annually in the U.S. from mesothelioma, for which asbestos exposure is the only well-established cause [Bang et al. 2009]. These deaths may underestimate the true burden of disease related to silica and asbestos exposures because the current surveillance systems are inadequate [Park et al. 2002]. Also, exposure to silica or asbestos earlier in life can affect workers by causing disease that becomes apparent later in life, even after retirement. Based on the number of deaths among U.S. residents during 1990-1999, construction accounted for 13.4% of all deaths due to silicosis, which was the third largest percentage for any sector [NIOSH 2008b].

Similarly, the construction sector had the highest PMR for mesothelioma deaths in 1999, the last year that industry and occupation was coded from death certificates from a large proportion of states [NIOSH 2008c]. Mesothelioma deaths are a marker of previous asbestos exposure.

Exposure to welding fumes and individual metal exposures in construction often exceed NIOSH RELs [CWPR 2013]. Lead exposures also continue to be problematic. Welding or cutting on lead-painted metal surfaces, abrasive blasting of bridges, or demolition of lead-containing materials can all cause exposures. In 2010, 6,309 occupational cases of blood lead levels over 25 µg/dL were identified from 38 states submitting industry data to NIOSH. Construction cases accounted for 16% of the total, which is disproportionately high given that construction employment accounts for just 7% of the overall workforce.

Several agents in the construction industry such as Portland cement, epoxies, solvents, and preservatives can cause contact dermatitis. Contact dermatitis can be a painful and debilitating disease and is an important cause of occupational disability [Burnett et al. 1998]. In addition to contact dermatitis, workers in construction have significant exposure to sunlight, and a related risk for skin cancer [Espinosa 1999].

Need

Construction workers can be exposed to hazardous levels of airborne contaminants, vapors, and dermal hazards. Individuals working closely with others generating dusts or mists could be at risk. Exposure occurs during many different construction activities. The most severe airborne exposures generally occur during abrasive blasting, jack hammering, rock or well drilling, concrete drilling, welding, brick and concrete block cutting and sawing, as well as other tasks. Likewise, many hazardous dermal exposures occur to construction workers. Many of the dermal exposures are associated with mixing, pouring, and spreading concrete. Much of the work occurs outdoor where workers are exposed to the UV rays of sunlight for long hours. Workers and contractors need to recognize these hazards, understand the risk factors, and take appropriate precautions while working safely. The need varies by agent and exposure, but several problematic areas are in need of research including:

- Improving the ability to determine how much of a reduction in exposure is needed to prevent adverse health effects
- Improving existence and performance of control technologies (engineering controls, PPE, etc.)
- Evaluating effectiveness of interventions (using video exposure monitoring and related tools)
- Improving dissemination and use of known interventions

Impact

Construction jobs are some of the most dangerous occupations in the U.S. While there are many hazards and exposures in their job, some of the most common work-related illnesses relate to respiratory hazards and dermal exposures. The physical demands of the job and limited modified work opportunities suggest that respiratory diseases are costly to construction workers. Ongoing research in this area with many partners has resulted in some major successes including significant reductions in worker exposures during asphalt milling and asphalt paving. Research efforts related to understanding and reducing silica exposures were used extensively to support the technical basis of the 2016 OSHA silica standard. CPWR has also developed a website regarding hand safety that addresses use of gloves to protect the skin: http://www.choosehandsafety.org/

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Objective 6: Hearing loss - Reduce occupational hearing loss in construction through a multifaceted research and outreach effort.

Burden

Occupational hearing loss is one of the most common work-related illnesses in the US [NIOSH 2017]. Over 11% of the working population has hearing difficulty and 24% of worker hearing difficulty is attributable to occupational exposures, which include hazardous noise and ototoxic chemicals (chemicals causing damage to the inner ear) [Masterson et al. 2015; Tak and Calvert 2008]. In the U.S. workplace, 17% of workers (approximately 22 million) are exposed to hazardous noise each year [NIOSH 2017]. At least one in five (21.4%) construction workers reported some hearing trouble in 2010 [CPWR 2010a]. This is approximately one-third higher than the proportion of workers with hearing trouble for all industries combined (16.3%) [Masterson et al. 2015]. Within the U.S. construction industry sector, 44% are exposed to hazardous noise and about 31% of these noise-exposed construction workers report not wearing hearing protection [Tak et al. 2009]. Thirteen percent of all construction workers have hearing difficulty and 7% have tinnitus [Masterson et al. 2015]. However, among noise-exposed construction workers, twenty-five percent have a material hearing impairment in at least one ear and 16% have hearing impairment in both ears [Masterson et al. 2015, 2016a]. Hearing impairment is hearing loss that impacts day-to-day activities. According to the NIOSH Occupational Hearing Loss Surveillance Project, for constructions workers between 2001 and 2010, 21% of construction workers have incurred a NIOSH significant threshold shift (both ears have an average threshold at 1000, 2000, 3000 and 4000 Hz of 25 dB or more). As well for the same time frame, 21% of construction workers have incurred an OSHA Standard Threshold Shift, which is a more serious hearing impairment (both ears have an average threshold at 1000, 2000, and 3000 Hz of 25 dB or more) [Masterson et al. 2014]. Almost three-quarters (73%) of construction workers were exposed to noise levels above the NIOSH recommended exposure level (REL) of 85 dB time-weighted average A-weighted [CPWR 2010b]. Duration of occupational exposures may further increase the risk of hearing loss. Ironworkers had the highest average noise exposures, with 86% above the NIOSH REL [CPWR 2010a]. Many construction workers are also exposed to impulse or impact noise.

Noise exposures are caused by a wide range of sources, including hand tools, larger machinery, heavy equipment, and generators. Noise control engineering solutions are the most effective methods to reduce noise exposures and to assure the exposure levels stay below 85 dB(A). Construction trades with the highest prevalence of hearing loss include welders, iron workers, laborers, boilermakers, carpenters, sheet-metal workers, and brick masons [CPWR 2010a]. Many workers may have an elevated or disproportionate risk, including foreign-born workers and workers with limited English-language skills, workers in small businesses, temporary workers, and younger (teenage) and older (65 and over) workers [Themann et al. 2013]. Hearing loss can have a profound impact on quality of life. It is associated with cognitive decline and cardiovascular outcomes such as hypertension [Chien et al. 2011; Masterson et al 2016b]. It is also strongly associated with depression [Masterson et al 2016b; Hetu et al 1995]. Tinnitus, which often co-occurs with hearing loss, can disrupt sleep and is associated with both depression and anxiety [Shargorodsky et al. 2010]. Construction workers lose 3.1 healthy years, each year, for every 1,000 noise-exposed workers, the second highest loss among industries [Masterson 2016]. Among workers that are 50 years and older who responded to the NHIS, 30% of workers whose longest job was in the construction trades reported fair or poor hearing compared to just 21% of workers employed in white-collar occupations [CPWR 2013].

Need

A general literature review of occupational hearing loss in construction is needed to assess what we know. Where there are gaps in knowledge, conduct research to better understand the scope of the problem and the impact on jobsite quality of life. This would include more research on the impact of hearing loss among affected construction workers and retirees. Along the same lines, it would be valuable to work with the mining industry to understand how miners' hearing is protected, and to determine if some of the mining technologies are suitable for use in the construction industry.

Another need is to assess and use technological advances in acoustical applications. For example, some hearing protection manufacturers now provide hearing protector fit-testing systems that can measure a Personal Attenuation Rating of hearing protectors which provide opportunities to aid in the proper selection of hearing protection appropriate for the worker's noise exposures. In addition, hearing protection researchers and advocates should take advantage of, and make known to employers and employees, new smartphone-based noise metering apps. Use of these will create an awareness of ambient noise, and following from that, take steps to limit or reduce exposure to noise hazards.

Education is needed for employers and workers about noise, including: (1) the proper way to insert foam ear plugs; and (2) provide information to trainers and workers about (a) "Buy Quiet" program; (b) ways to reduce vibration of equipment to possibly reduce noise; and (c) use of administrative controls to limit exposure to hazardous noise, as specified in OSHA regulations 29 CFR 1926.52 that allow for various exposure time/noise intensity levels.

Reductions to the noise hazards posed by power tools and heavy equipment in construction are needed. From hand tools to construction vehicles, researchers could investigate that the noise could be reduced. For example, construction vehicles must have closed cabs to limit noise. Some hand tools have been manufactured to limit noise. Stakeholders should continue to develop and promote a database of tools and the noise levels produced when the tools are operated. Also, because noise is an exposure, construction equipment emitting excessive noise should either be labeled with the level of noise produced or have a Safety Data Sheet documenting the hazardous noise and the means to protect against it. It would be worthwhile to assess the impact of local noise ordinances like the NYC law mandating quitter equipment to see if they are having unintended consequences. Another research need would be to assess the impact of noisy work environments on safety. If it can be demonstrated that a noisy work environment results in more accidents (as workers cannot hear warning signals), that might be a significant motivator for contractors to buy quieter equipment.

Research is needed on back-up alarms on heavy equipment and trucks to assess the frequency and quality of this noise to determine optimum warning and ability to hear it. Methods to integrate back-up alarm technology with newer electronic hearing protection devices can help to overcome auditory deficits of hearing-impaired workers wearing hearing protection and improve the safety when working around moving vehicles.

Finally, it would be beneficial to have an annual hearing protection research event (similar to the OSHA/NIOSH/Mining Safety and Health Administration Noise Safety Challenge) to assess the state-of-the art in noise reduction controls and techniques, as well as hearing protection applications that are specific to the construction industry. Hearing protection devices are often used following engineering and administrative controls to keep workers under the OSHA Permissible Exposure Limit.

Impact

The benefits and impact of reducing noise levels at the source include reducing the risk of hearing loss at the worksite, minimizing the impact of noise on communities, and helping companies comply with OSHA and other noise regulations. These efforts may also reduce the long-term costs of audiometric testing, personal protective equipment, and workers' compensation. Addressing the top of the hierarchy of controls is the preferred approach to preventing noise induced hearing loss. Development of guidance documents and public outreach materials can help workers improve selection and use of hearing protection devices. Integrating fit-testing with hearing loss prevention programs is also helpful. Under most circumstances, noise-induced hearing loss is preventable, however with more emphasis on hearing protection usage and improved designs this could reduce construction workers exposure to hazardous noise levels.

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Objective 7: Musculoskeletal disorders - Reduce the risk and burden of musculoskeletal disorders (MSDs) in construction.

Burden

Musculoskeletal injuries in construction date back to the building of the pyramids, according to the Edwin Smith papyrus [Schneider 2001]. They continue to plague construction workers due to the nature of the work, which is physically demanding [Schneider et al. 1998]. In 2014, 20,340 "sprains and strains" represented 27.3% of all construction injuries and illnesses while another 12,910 (17.3% of injuries and illnesses) were from "soreness, pain," also clearly related to musculoskeletal disorders (MSDs) [BLS 2016a, b]. In some trades it is even higher (e.g., flooring contractors for whom sprains and strains represent 54.5% of all injuries). Lifetime risk of "overexertion" injuries in construction is about 21%, so over 1 in 5 construction workers might be expected to get an overexertion injury during their career [Dong, et al. 2014]. The Liberty Mutual Workplace Safety Index [2016] estimates that over one-quarter of all costs from disabling injuries was from overexertion and repetitive motion injuries.

The construction workforce is also aging with a median age in 2015 of 42.7 years [BLS 2016]. When older workers are injured, their injuries are more severe injuries and their compensation costs are higher. A longitudinal study of older construction workers found that 40% of those over the age of 50 years had persistent back pain or related problems [Dong et al. 2012].

Recent U.S. national initiatives and campaigns to address chronic pain recognize it as a significant public health problem in the United States. The National Pain Strategy [DHHS 2016, pg 9], adopting the World Health Organization (WHO) definitions, describes "high-impact chronic pain" as "substantial restriction of participation in work, social, and self-care activities." An additional consideration is the impact of chronic pain on workplace *presenteeism* (or working while sick), in addition to absenteeism. An individual can be in significant chronic pain, with impaired quality of life, and have to continue working without substantial restriction to support their family. Data from the 2010 Quality of Worklife (QWL) supplement to the General Social Survey (N=1,019) indicates that over a quarter of U.S. workers work with pain. Back pain and arm pain had a prevalence rate of 25%-30% among working adults, consistent with the prevalence reported in the 2002 and 2006 QWL surveys [Dick et al. 2015]. Operators, fabricators and laborers, the occupational category that would include construction work were among the occupational groups with higher pain prevalence (29.3% and 36.4% for back and arm pain, respectively) [Dick et al. 2015].

These injuries not only cause days away from work, they also can shorten careers and have a dramatic impact on quality of life in retirement [Welch et al. 2010, LeMasters et al. 2006]. Many construction workers retire in their mid-50s due to MSDs. MSDs are also a main contributor to the pain epidemic [Carnide et al. 2011], which has resulted in the overuse of opioid pain relievers and addressed in the National Pain Strategy [DHHS 2016]. During their careers, construction workers often go to work with injuries because they do not normally get sick days as a work benefit, and will lose pay otherwise. Working while injured further exacerbates these chronic conditions, often causing permanent injury. MSDs can impact productivity as well [Conway and Svensen 2001]. These injuries constitute an enormous economic burden on workers, their families, companies and the health care system [OSHA 2015].

Need

Prevention of work-related musculoskeletal injuries has been a priority and focus of major research for many years. Ergonomic interventions in construction, in particular, have been highlighted in publications like *Simple Solutions: Ergonomics for Construction Workers* [NIOSH 2007]. Numerous interventions are included in the Construction Solutions database maintained by CPWR—The Center for Construction Research and Training. CPWR has had an active construction ergonomics research program for many years. The main issue now is diffusion and adoption by the industry [Weinstein et al. 2007].

Ergonomic interventions often pay for themselves by improving productivity as well as reducing injuries [Hendricks, 1996]. Yet contractors may not understand the return on investment that comes from making ergonomics changes. Too often ergonomic changes are seen as slowing down the job or requiring two workers when one had previously done the job. More research is needed on the impact of ergonomic changes to productivity. Another area for ergonomic research is how proper planning can reduce ergonomic risk.

While pilot projects are underway, much more research is needed to understand the barriers to diffusion and adoption of ergonomic interventions in construction and measure the effectiveness of interventions. Additionally, the social marketing of ergonomics to contractors is important.

Among other areas, the research needs to be conducted in:

1. Identify (a) barriers to the diffusion and adoption of ergonomic interventions in construction; (b) how these barriers differ in small versus large firms; and (c) effective ways to address those barriers; and (d) perform research to measure the effectiveness of the interventions
2. Identify and evaluate social marketing strategies to encourage the adoption of ergonomic interventions in construction.
3. Quantify the return on investment, e.g., productivity gains, from ergonomic interventions in construction as well as the economic impact of MSDs in construction.
4. Develop new, and enhance existing, databases of ergonomic interventions tailored to the needs of contractors and workers.
5. Increase awareness of ergonomic risks among contractors and construction workers.
6. Design and evaluate interventions for reducing construction related MSD risks for low back, shoulder, upper extremity, and knee injuries and disorders. Evaluations can be laboratory or field evaluations but the methods should be relevant for real construction work.

Impact

The enormous burden posed by MSDs in construction presents an opportunity for high impact from research focused on reducing these injuries. Many solutions already exist that could substantially reduce the risks associated with construction work. Dissemination and adoption research could help identify and overcome the barriers to implementation of these solutions resulting in dramatic reductions in risk. The rate of technological change in construction is increasing. Adoption of new technologies offers the potential for adoption of better, safer work processes as well. The sub-objectives above describe a research agenda for moving forward with a huge potential impact on both workers and the industry.

References

BLS [2016a] TABLE R1. Number of nonfatal occupational injuries and illnesses involving days away from work by industry and selected natures of injury or illness, private industry, 2014. Washington DC: U.S. Department of Labor, Bureau of Labor Statistics, http://www.bls.gov/iif/oshwc/osh/case/ostb4367.pdf.

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Objective 8: Workers at disproportionate risk - Conduct research to eliminate disproportionate risks in construction.

This objective focuses on eliminating disproportionate risk of injury or illness to a worker, work group, or population due to a wide range of dynamically changing socio-technical factors at a workplace. These factors include personal characteristics of workers, technologies (methods, equipment, and training systems), management and organizational systems, failure to follow existing occupational safety and health standards, work site conditions and environmental conditions, and macro-level factors such as policies and economic factors. This objective characterizes vulnerability as a shifting, contextual dynamic in society and the workplace. Shifts may result from a number of factors including, but not limited to, implicit biases affecting culture or climate, influxes of new workers, misclassification of workers, increases in physically demanding work, introduction of work methods or equipment, staffing shortages, extended work hours, high productivity demands, or extreme weather.

The propensity of injury is most pronounced at the interfaces among these dynamic socio-technical factors. As an example, worker deaths during the City Center build in Las Vegas were partly outcomes of inadequate training at the interface between technology and personnel, such as inadequate training provided to employees by contractors and subcontractors [Gittleman et al 2010]. The negative outcomes may have been associated with economic factors from the external (corporate) environment and/or management expectations in the management/organizational subsystem [Hecker and Goldenhar 2014]. Risks to workers increase as the number of these factors increase. Another example is found in research on occupational carcinogens. African-American and other non-White men are exposed to more carcinogens compared to White men in the same occupations [Briggs et al. 2003].

Burden

During the last recession, the construction industry saw a 23% decrease in the number of construction workers [CPWR 2013]. Many workers displaced during the recession are not returning to the construction industry. An influx of new workers is entering the sector. Eight percent (8%) of construction firms hired construction workers using temporary staffing agencies and nearly one quarter of construction firms operated with no full-time employees [CPWR 2013]. A growing number of these new entrants, such as temporary workers, day laborers, new immigrant workers, and contingent workers may belong to one or more of the groups at disproportionate risk for occupational injury or illness. For instance, workers employed through temporary agencies were more likely to be African-American and Hispanic [BLS 2005]. Temporary workers, who accounted for roughly 14% of the construction workforce in 2013, are more likely to be younger than in the overall construction work force [CPWR 2013]. About 35% of temporary workers were under age 35 years, compared to less than 30% of permanent construction workers between 2011 and 2013. Many temporary workers hold multiple jobs, and are also more likely to be poor [CPWR 2013]. Temporary workers are more likely to experience occupational hazards than regular workers; including performance of outdoor work, exposure to vapors/gas/dust/fumes, and skin contact with chemical substances [CPWR 2015]. The average age of construction workers is now 42 years and more construction workers plan to delay retirement because of economic need despite evidence of worsening self-reported health [CPWR 2018]. Older construction workers have an elevated risk of caught-in/ between fatalities, and workers under 20 years old have an elevated risk of both fatal and nonfatal caught-in/ between injuries. Hispanic workers, foreign-born workers, and workers aged 55 or older have an elevated risk of fatal falls [Dong et al. 2017, Wang et al. 2017].

Need

About 80% of construction payroll establishments employ 1-9 employees, and small establishments suffer a disproportionate share of fatal work injuries. [CPWR 2013]. As the construction industry recovers from the recession, construction employment is expected to grow 33% between 2010 and 2020, which is over twice the rate projected for the overall U.S. economy [CPWR 2013]. With the demand for workers, there will be an increase in those who fall into the groups identified as being at a disproportionate risk because of the factors identified earlier. Many of these workers will lack experience in the industry, task specific training and knowledge of safe work practices, and will be less likely to be provided with safety equipment. A 2015 report described a need to better understand how to reach and address the needs of workers at disproportionate risk due to overlapping vulnerabilities [NIOSH/ASSE 2015].

More research is needed to better:

1. Identify the groups of construction workers at disproportionate risk, including certain populations of workers and groups of workers who are not traditionally thought to be at disproportionate risk.
2. Understand where and how the identified construction worker groups are employed, the types of work systems in which they are exposed to hazards, and the safety and health needs of these groups of workers to eliminate or reduce disproportionate risk.
3. Develop an appropriate intervention, such as training or mentoring programs and engineering controls with equitable effectiveness and use, for those at disproportionate risk and their employers, including the best way to reach these workers e.g., at work, in their community.

This research is needed to develop and provide training and other technologies with equitable benefits to all workers and to understand how to influence employers to establish safer workplaces. Training based on this research, should be provided to:

1. New and inexperienced workers and other identified groups of construction workers at disproportionate risk and include hazard recognition, safe work practices (both task completion procedures and equipment use), avoidance of unsafe conditions, and workers' rights.
2. Employers, staffing agencies, manufacturers or providers of labor of identified workers at disproportionate risk and include the project management expectations and the aspects of organizational structure that contribute to placing workers at risk. Additionally, a focus should include the benefits of keeping an open line of communication with workers, providing workers with the tools, resources, and training necessary to complete assigned tasks safely.

Impact

Supporting more research on workers at disproportionate risk would help to achieve several intermediate and long-term outcomes. Large and small construction firms will benefit through understanding safety and health differences at individual and group levels that contribute to disparities in hazard exposure. Consequently, this knowledge should lead to more equitable and inclusive training, and inclusive hazard prevention and control practices.

A concentration on risk disparities would focus efforts among researchers to use more advanced and culturally valid research and management practices. These practices might include the use of culturally appropriate methods to address environments, contexts of work, and influences of social stratification. Statistical methods may leverage more modern analytical approaches such as bootstrapping and distribution-free analyses to test hypotheses within demographic groups with different experiences in the workplace. Investment in resources to focus on disproportionate risk will help to eliminate enablers of inequity in hazard exposure, barriers to equitable access to training, hazard protections in temporary and informal economies, and such knowledge advances as fit-accurate personal protective technology (e.g., respirators fitting phylogenetic skull patterns).

The most important impacts would be a reduction in fatality and injury disparities as wells as an overall reduction in all fatalities and injuries for all groups. Actions that reduce risk among certain groups deemed to have “overlapping vulnerabilities” are likely to benefit all groups. Ultimately, the focus of contemporary efforts should use the following to characterize individuals at disproportionate risk and use an “empowerment” model that addresses worker empowerment through the following four areas of “equity”: (1) knowledge and awareness of hazard exposure and ecosystems in which they occur; (2) knowledge of workplace policies and procedures; (3) awareness of hazards, rights, and responsibilities; (4) empowerment to take actions to prevent injuries and illnesses without repercussions, sanctions, or other negative consequences [Institute for Work and Health 2016; Smith et al. 2013].

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Objective 9: Small business - Reduce the number of illnesses, injuries, and fatalities occurring in small construction firms (employing 20 or fewer employees).

Burden

In 2010, 56.3% of construction deaths occurred in establishments with fewer than 20 employees even though these establishments employed only 41.4% of the wage and salary workforce [CPWR 2013]. A recent Associated General Contractors of America (AGC) analysis [Kleiner 2016] reports that 47.5% of fatal construction accidents occurred in firms with fewer than 10 employees, and a National Association of Home Builders' (NAHB) study from 2008 showed that 76% of fatal residential construction accidents occurred in establishments with 1 to 10 employees. Small businesses have higher rates of occupational injuries, illnesses, and fatalities than larger companies, and fewer resources available to prevent them [Sinclair et al. 2013]. In 2012, nonfatal injury and illness rates involving days away from work in residential construction (which has a high percentage of small business contractors) were 177.1 injuries per 10,000 employees versus 147.1 injuries per 10,000 employees for the construction industry [BLS 2012].

Need

In 2010, construction establishments with fewer than 10 employees made up about 80% of all construction establishments and employed 25% of all construction employees [U.S. Census Bureau 2014]. Small businesses with fewer than 20 employees made up 92.5% of all construction establishments and employed 41.4% of all construction employees [U.S. Census Bureau 2010]. Small construction firm employees are at a much higher risk of serious injury and death than those working in firms with more than 20 employees [NAHB 2008]. Small construction firms have limited occupational safety and health resources and knowledge, are less organized, and are less likely to fully implement a safety and health management system [NIOSH/ASSE 2015, CPWR 2016, Cunningham and Sinclair 2015]. These small businesses are also less likely to have staff overseeing jobsite safety, and less likely to provide workers with a safe workplace. Small construction businesses tend to be less aware of regulatory requirements that could reduce injury and illness rates, and those that are aware may not comply because they perceive the cost of compliance to be unaffordable [OSHA 1996]. Congress recognized small employers' concerns by passing the Small Business Regulatory Enforcement Fairness Act, or SBREFA, in 1996 [Small Business Administration 1996]. This Act was intended to simplify and reduce the cost of regulations impacting small businesses and aid small businesses in understanding and complying.

Construction companies with fewer than 10 employees are less likely to adopt safety protections, use appropriate personal protective equipment and Prevention through Design (PtD) to promote safety and health, and are also less likely to provide safety and health training [CPWR 2016]. Small construction businesses have fewer human and capital resources available to devote to the prevention of workplace illnesses, injuries, and fatalities, and because incidents seem to be infrequent within the company, managers and supervisors may incorrectly perceive their incidents to be minor problems. Managers and employees often have more limited time and financial resources, than in larger organizations [NIOSH/ASSE 2015]. Managers in small businesses often work in isolation without sufficient access to peer opinion and industry best practices [Cunningham and Sinclair 2015]. These factors can reduce prevention activities, and even the reporting of illnesses and injuries to government, insurance, and other organizations. Understanding these internal forces experienced by small businesses is critical to addressing them. Small businesses in all industry sectors are isolated and lack the resources to engage in occupational safety and health activities [Cunningham and Sinclair 2015]. Small construction firms are also less likely to demonstrate true management commitment, and small specialty contractors find it difficult to provide their workers with a safe work environment [Olbina et al. 2011]. Kaskutas et al. [2009] found that small contractors are less likely to use personal fall arrest systems than commercial contractors.

Between 2004 and 2014 there were only 35 peer-reviewed articles addressing occupational safety and health issues in small business and small- and medium-sized enterprises [Legg 2014]. Cunningham and Sinclair [2015] found that there is a need for effective occupational safety and health interventions and a better understanding of reaching small businesses.

There is a clear need for more research addressing all aspects of small construction firm (20 or fewer workers) safety and health conditions, which could result in better access, participation, communication and translation of information and most importantly a substantial reduction in injuries, illnesses and fatalities. There is a need to understand the work environment and financial constraints in smaller businesses and the barriers to workplace illness, injury, and fatality prevention efforts. This includes understanding the perceptions and behaviors of employees, managers, and owner/operators of smaller construction businesses and what motivates them. There is also a need to understand the external environment of smaller construction businesses and the ways that it affects their occupational safety and health (OSH) behaviors, good or bad. In this regard, it is important to identify and understand intermediary organizations, and to investigate ways to motivate those organizations to assist small construction businesses to advance OSH. It is also important to make a strong business case for why occupational safety and health is important to the business.

Impact

The potential impact for research focused on improving safety and health in small construction firms is high. The construction industry is dominated by small businesses, and they carry a significant burden of the illnesses and injuries in this industry. The most effective way to reduce the occupational safety and health burden of small construction businesses is to ensure that we fully understand and address their needs through partnerships with key stakeholders who will assist with the adoption and dissemination of key research outputs.

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Objective 10: Emerging issues

Construction safety and health research needs to prepare for and adapt to advances in materials used in building projects, and to new exposures, some of which may pose hazards. It is important to make room in this agenda for research on new methods, approaches, technologies, communication, intervention, types of surveillance, and training that examine hazards, threats and other issues that may not have been known in the past, but which have become a reality in the 21st Century. In many cases, burden, need and impact data are not available, and there should be an opportunity to build those data and justifications. The following list of suggested emerging issues is not exhaustive, and is not meant to be, but rather is meant to prompt researchers to consider topics that are beginning to or may become important in construction safety and health:

- Infectious agents (e.g., Valley Fever [Coccidioidomycosis])
- Nanomaterials and other advanced materials
- Opioids
- Robotics, automation, and exoskeletons
- Smart construction and infrastructure (e.g., drone use)
- Technology in construction (e.g., Building Information Modeling (BIM), applied mathematics and advanced software, virtual and augmented reality, networked blue prints).
- Safe and effective deployment of construction trades during responses to natural and manmade disasters
- The use and the effectiveness of occupational safety and health-related apps on construction sites

Objective 11: Extreme temperatures - Reduce the likelihood of temperature extreme incidents in in construction and develop intervention strategies to protect these workers.

Construction workers perform demanding physical tasks and can be exposed to excessive heat and environmental conditions resulting in heat related illness and injury. A team of researchers, including Dr. Michael Behm began to analyze data related to this topic and produced a conference paper entitled "Heat Stress in the U.S. Construction Industry" [Tymvios et al. 2016].

As stated in Tymvios et al. [2016, p. 3]

"Some research in the US has produced industry suggestions and regulations, examples of which include informational pamphlets and material from National Institute of Occupational Safety and Health (NIOSH) that provide information for preventing heat stress, identifying the symptoms, and guidelines for acclimatization (NIOSH 2014). The Occupational Safety and Health Administration (OSHA) similarly has information and pamphlets available on its website to address heat stress [OSHA 2017]. It is clear to say that guidelines and recommendations are available to US contractors to implement in order to reduce the incidences relating to heat stress (fatalities and injuries) in the US, and yet these incidences occur and they seem to be happening in specific regions of the country and more likely to small contractors".

Burden

Exposure: By the very nature of construction work, construction workers are exposed to temperature extremes more than other industry sectors. Cool down areas are not readily available on most construction sites and depending on the stage of construction little or no covering from sunlight and temperature extremes may exist (e.g. early civil work on a project, excavation activities etc.) [Tymvios et al. 2016].

Injury/Illness: Death from temperature extreme incidents in the construction industry numbered 18 in 2014 according to OSHA. Research reviewed from 58 heat related fatalities in construction from 2009-2013 suggests this number may be grossly under reported [OSHA 2014; Tymvios et al. 2016]. Heat related illness events are even harder to categorize as workers recover and return to work or the short duration job is over and the worker never reports the heat illness to his employer [Tymvios et al. 2015]. The majority of temperature extreme events are listed as heat related and occur in the southern states. There is limited research and reporting of extreme temperature due to cold environments [OSHA 2014]. The requirement to wear special fire retardant clothing while performing construction activities may increase the heat load on the body and can result in greater frequency for temperature extreme incidents especially in the petrochemical industries where radiant heat is present [OSHA 2006].

Disability/Severity: Research has shown once a worker suffers a heat related incident the body's ability to tolerate heat is greatly reduced [NIOSH 2016]. Many workers who experience heat related illnesses never report this condition to their employer and are placed at greater risk for an extreme temperature incident. Issues of the aging construction workforce increase the risk of construction workers experiencing an extreme temperature incident during their working careers.

Cost: Construction workers employed by small employers on contracts under $1 million are at greatest risk for an extreme temperature event and represented 79% of the heat related cases investigated by OSHA [Tymvios et al. 2016]. No cost data was found to determine the cost burden on the construction industry for extreme temperature events.

Need

The U.S. does not have specific regulations for occupational exposure to heat. Some OSHA state plans states do have regulations (e.g. California) but no federal standards exist. According to the General Duty Clause of the Occupational Health and Safety Act (OSHA), Section 5(a)(1), it is up to the employers to provide their employees with a workplace that is "free from recognizable hazards" that might cause harm to the workers.

OSHA and NIOSH have both recognized the need to inform construction workers to the risks of extreme temperature events. OSHA modeled a national heat awareness campaign of rest, water and shade from the California OSHA outreach program and it has been highly successful in educating construction workers and employers about extreme temperature events [OSHA no date]. NIOSH and OSHA have each addressed the hazards of working in extreme temperatures by using their methods of communication, including social media, to alert employers and workers to the potential hazards of working in extreme cold (https://www.cdc.gov/niosh/topics/coldstress/) and in extreme heat (https://www.cdc.gov/niosh/topics/heatstress/), and making recommendations for preventing illness. In fact, NIOSH and OSHA worked together to develop the OSHA-NIOSH Heat Safety Tool App (https://www.cdc.gov/niosh/topics/heatstress/heatapp.html?s_cid=3ni7d2XHST-HP-Banner06.2017) which was released in June 2017. Surveillance efforts need to be increased to document and analyze extreme temperature related injuries/illnesses in U.S. construction workers. Some of this might occur through the modification of existing surveillance systems. It is important to catalog the hazard, occupation, and geographic location of those workers are most at risk. There is also a need to better understand the relationship between extreme temperatures, work hazards, fatigue and productivity, and other factors. Some of this could involve evaluating the impact of chronic exposures as compared to acute. It also might involve evaluating a worker's tolerance to temperature extremes. A specific area of research to explore is the potential for adverse acute and chronic renal outcomes from heat exposure in construction. Another need involves evaluating mitigation strategies and hazard controls to address extreme temperatures. This could include looking at the impact of the heat stress standard in California. Finally, translational research is need to develop guidance documents and risk communication for best addressing the hazard.

Impact

More research into temperature extreme incidents will result in greater awareness and intervention strategies to protect construction workers especially those hired by small employers. Development of work/rest guidelines for manual labor activities would increase worker protection from extreme temperature incidents. Training and education strategies would result in increased reporting of extreme temperature events and further safeguard construction workers from repeated heat related illnesses. Increase medical surveillance and fitness for duty evaluation could reduce risk from extreme temperature events for construction workers.

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Objective 12: Prevention through Design (PtD) - Increase the use of PtD approaches to prevent or reduce safety and health hazards in construction.

Burden

Research in the U.S. [Behm 2005] and the United Kingdom [Haslam et al. 2005] has shown that design is an attribute that can influence eventual construction site safety. Compared to Australia and the United Kingdom, where safe design practice has been developing for over 20 years stemming from legislation, the U.S. construction fatality statistics lag behind. See Table 2.

Table 2. A Comparison of US with UK and Australia Construction Fatality rates

Country	Year(s)	Fatality rate / 100,000 employees	Source
UK	2014-15	1.62	Health and Safety Executive [2016]
Australia	2009-13	3.29	Safe Work Australia [2015]
US	2014	9.8	BLS [2016]

Need

As part of the Prevention through Design (PtD) initiative, NIOSH and its partners are developing a framework to create awareness, provide guidance, and address occupational safety and health issues associated with green jobs and sustainability efforts. Despite the popularity of PtD within the safety and construction professional communities, there has been little interest and uptake within the design professions (architectural, engineering, etc.) who are in the principal position to implement the PtD approach in the conceptual and detailed design phases of built environment projects when the potential efficacy to positively enhance life cycle safety would be most effective. There is a need for translational research to better understand and help to remove barriers that prevent greater implementation of PtD in construction. There is also a need for more designers to consider PtD into all of the designs that impact workers. This could involve designs for workplaces, tools, facilities, equipment, machinery and processes that impact workers. It is important that this design work occur as early as possible in the lifecyle of the item or workplace. Construction stakeholders remain in a strategic position to influence other agencies, non-governmental organizations, and professional organizations who are leaders and influencers in design-related activities, as evidenced by the recent U.S. Green Building Council PtD Pilot Credit.

Impact

Wider adoption of PtD approaches in the U.S. is likely to reduce the number of occupational safety and health hazards that result in fatalities and other adverse health outcomes.

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Objective 13: Research to Practice (r2p) - Build capacity for and a body of research on effective translation research and r2p strategies to advance the use of evidence-based interventions in construction.

Burden

Construction is a large, high-hazard, complex industry that employed 10.3 million people in 2016 [CPWR 2017]. Each year, a disproportionate number of workers are killed, injured, or made ill on the job. While construction represents roughly 6% of the total workforce, it accounts for 21% of all fatalities across all industries, and has one of the highest death rates (11.8 deaths per 100,000 workers in 2014 compared to 3.3 per 100,000 FTEs for all workers) [CPWR 2016].

Construction's decentralized structure and the diversity encompassed in its employers and workforce, all contribute to the complexity and the high hazard nature of the industry. The industry has different segments (residential, commercial, industrial, and heavy construction) as well as a diverse range of contractors and subcontractors, trades, tasks, and attending risks. The hardest to reach workers, and even employers, are often at greatest risk, contributing to existing disparities by race/ethnicity, immigration status, age, and employer size [NIOSH/ASSE 2015]. Also adding to the complexity is the constantly changing mix of contractors, workers, tasks, and environments on construction jobsites. It is common for a construction worker to work for multiple employers and on multiple jobsites in a single year, and the safety information, work practices, and interventions used on one jobsite may not be applicable or available on the next.

Need

Over the last two decades, health and safety research in construction has made advancements – beginning with surveillance and needs determination to intervention evaluation, and then towards dissemination of evidenced-based best practices – research to practice (r2p). R2p conceptual frameworks are now being tested, concepts are being operationalized, measured and validated, and more sophisticated strategies for examining the way research is making its way into practice are underway [Chambers 2012]. However, the impact of the research continues to be limited due to the dissemination, adoption, and implementation challenges resulting from the complex nature of the industry. Much remains to be done to build upon existing efforts and fully develop the capacity (sometimes described as the "infrastructure") to systematically support such efforts. The lack of such an infrastructure in public health has impeded the movement of evidence-based interventions out into the world of practice [Krueter and Bernhardt 2009].

Best estimates from biomedicine suggest it takes nine years for evidence-based research to move into common practice [Green et al. 2009]. In construction, decentralized systems and varied, ever-changing contexts and players make it likely that the path from research to practice may be even longer. With the high rates and numbers of fatalities, injuries, and illnesses in construction, it is critical to accelerate the pace of dissemination and implementation of promising research-based safety and health interventions and solutions. During the lag between the development of critical health and safety research and interventions that could save lives and protect health and the actual uptake of findings, hundreds of thousands of workers in construction remain at risk for dying or becoming injured or ill.

In addition, rapid changes in communications, technology, and media require researchers and practitioners to be adaptable and flexible to the changing preferences of target audiences in the way they receive and act on information. As new platforms and channels replace older ones, users both access and block information in evolving ways. With the diversity of construction stakeholders and the diversity of workforce by age, ethnicity, language, and other characteristics, researchers and disseminators will need to be positioned to accelerate their responses to these changes. This will require new tools, skills, and capacities to solicit and use feedback, conduct audience research, and support users in interpreting and applying new information.

Finally, the need to conduct high-quality evaluation and translation research is critical. While increasing emphasis has been placed on r2p, dissemination and implementation over the past two decades the accumulation of evidence in the area of translation research is still in its early stages [Colditz and Brownson 2012]. And in studies of the published health literature, only 2% to 20% of articles were focused on r2p compared with basic research [Colditz and Brownson 2012]. Researchers and disseminators will also need to be able to interpret the metrics generated by new tools and platforms to gauge whether or not they are having the intended outcomes and impact. A better understanding of the processes and conditions that yield the greatest likelihood of r2p success is imperative.

Impact

Preventing injuries and illness in construction is becoming increasingly dependent on the ability to effectively translate existing research into practice. The potential to reduce the many preventable injuries and illnesses in the construction industry by accelerating the transfer of effective research-based solutions into the hands of contractors and workers is clear. A two-pronged strategy will be required, involving the encouragement and support of more researchers and partnerships engaging in and emphasizing r2p, while at the same time conducting evaluation and translation research to better understand the processes that result in improved implementation and health and safety outcomes.

Such efforts also promise to make research more relevant and responsive to real-world problems through the collaboration and exchange between researchers and practitioners. When research is designed with input from the audiences it intends to benefit, findings are more likely to be ready for dissemination and usable by end users. Furthermore, the more that effective partnerships can be facilitated among researchers and contractors, workers, and the intermediaries who influence them, the more likely researchers will be able to successfully draw on the collective expertise and respond to changing communication methods, media, and preferences of targeted construction audiences.

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Objective 14: Work organization - Improve conditions in construction by studying safety culture and safety climate and how work is organized

Burden

The construction industry is made up of businesses of varying sizes and missions that are not easily characterized. Workers in this industry have a spectrum of relationships with their employers ranging from long-term employment with a single employer to multiple employment relationships lasting for days or months at a time. Construction workers are more likely to be killed, injured, or made ill on the job as compared to workers in other industries [CPWR 2013]. There are many contributing factors that should be studied to improve understanding of construction worker risks.

It is well recognized that strong safety and health programs lead to positive safety culture and climate, as well as reduced death, injury and illness rates. Safety climate is a useful leading indicator of safety and health performance in construction. Strong safety and health programs address many of the issues related to work organization, including management leadership, worker participation, hazard identification and assessment, hazard prevention and control, education and training, program evaluation and improvement, and coordination among multiple employers on a job site [CPWR 2016a, OSHA 2016]. By implementing programs and policies that address these leading indicators, employers can improve their safety culture and their workplace safety climate, as well as improve outcomes for their employees [Schwatka et al. 2016].

About 80% of construction industry employers are small (under 10 employees) [CPWR 2013]. These employers often have fewer safety and health programs in place than larger employers [CPWR 2016b]. Perceptions of workplace safety and job security also vary among regular employees, independent contractors, and temporary employees, with regular employees having the most security and temporary employees having the least [CPWR 2016c].

Need

Over the last two decades, we have seen a lot of progress in understanding how safety culture and climate relate to occupational safety and health outcomes in the construction industry, but more needs to be done. This includes looking at best practices across other industries as it relates to improving safety culture and safety climate. Research on the Total Worker Health (TWH) approach provides scientific evidence to help businesses and communities reduce the impact and cost of injuries and illness, thereby helping to control healthcare costs and disruption to family and community life. As work and work environments change to meet the demands of 21st century economies, comprehensive approaches are needed to address complex realities. TWH is a comprehensive approach that looks for new solutions to long-standing issues related to worker safety and health. Because of the dynamic nature of the industry, the areas in need of research shift, and understanding the way that the industry is organized and structured is essential to improving conditions for construction workers. Among other areas, the research needs to be conducted in:

1. Surveillance (i.e., data collection and monitoring) to follow the trends in the use of leading indicators of safety and health and positive safety climate.
2. Intervention development and evaluation to measure the impact of the interventions aimed at hazard mitigation and improving safety climate in the industry.
3. Exploration of the changing nature of how work is organized through the study of the relationship between quality and safety, fatigue, procurement practices, owner-driven safety, selection of contractors and subcontractors, the use of temporary employees and independent contractors, and novel construction arrangements and their impact on leading and lagging indicators of safety and health.

4. Exploration and understanding of the way the influences and policies of non-employers can impact construction safety and health through examination of the role of the insurance industry, OSHA enforcement policies, OSHA outreach activities, facility owner policies and procurement procedures, union programs, employer association efforts, and other external factors play a role in construction worker safety and health.

Impact

There is great potential to impact safety and health outcomes by furthering understanding of how work in the U.S. construction industry is organized and what factors influence it. Examining the problems of poor safety culture and safety climate, and the challenges in the fragmented structure of the construction industry, will help guide the industry in addressing problems and implementing effective solutions.

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Objective 15: Surveillance - Reduce occupational safety and health hazards in construction through proactive surveillance activities and research.

Burden

In 2016, 10.3 million U.S. workers were employed in construction [CPWR 2017]. Construction is the industry sector with the greatest number of fatal traumatic injuries [Dong et al. 2014]. Construction workers on average face a lifetime risk of greater than 5 per 1000 of dying on the job, with a range upward to over 30 for ironworkers [Dong et al. 2014]. Other outcomes, including fatal and non-fatal work-related illnesses and non-fatal work-related injuries are under-reported, with approximately half of injured construction workers reporting having filed for workers' compensation, and approximately half of those awarded compensation [Dong et al. 2016]. The Liberty Mutual Workplace Safety Index for 2016 (reporting on 2013 data) indicates falls to a lower level for all industries cost the U.S. economy an estimated $5.4 billion [Liberty Mutual Research Institute for Safety 2016]. Hazardous exposure, including both safety and health hazards, are ubiquitous and constantly changing. These include not only the "focus four" safety hazards (falls, electrical, struck-by, and caught in or between) but also physical (e.g., noise, heat, cold, UV), chemical (e.g., welding fumes, silica, isocyanates, and biomechanical (e.g., lifting, lowering, carrying, and pushing/pulling) hazards as well as those related to the organization of work, such as the use of subcontracted labor, the misclassification of workers as self-employed, and the prevalence of small construction firms [OSHA 2011]. Construction also includes the highest proportion of Hispanic workers of any industry other than agriculture, and these workers continue to experience disproportionate fatal traumatic injury rates [Dong et al. 2010].

Need

Enhanced surveillance approaches, especially those that move upstream to include hazardous exposures and those that address organization of work challenges, are badly needed, not only to establish the scope of the problem and target interventions, but importantly to track the effectiveness of interventions[3]. Disincentives to injury and illness reporting leading to systematic under-reporting have reduced the accuracy of BLS counts for non-fatal injuries and illnesses [Azaroff et al, 2003]. Because of the transient nature of construction employment, workers fear reporting work-related illness or injury for fear of being blacklisted from future employment. Workers in small establishments or those misclassified as self-employed and those with temporary or unstable employment or who are otherwise vulnerable are particularly susceptible to under-reporting. High performing organizations have made great strides in identifying hazardous exposures, but this information has not been systematically collected. Almost no information is available about small enterprises. Given fear of job loss and challenges faced by small enterprises, innovative approaches (e.g., advanced data mining techniques) to surveillance are needed. Active surveillance approaches may be required. Innovative approaches to hazard identification have been developed through CPWR Consortium members with NIOSH funding. Active hazard surveillance including job analysis and daily site visits may be available through Safety and Health Management System programs or through participatory training programs. Existing municipal ordinances addressing dust or noise exposure from construction activities might provide excellent locations where surveillance data on novel and effective exposure controls could be collected. Updated estimates of economic burden that include information about delayed health and economic impacts of occupational illness and injury are needed, as are approaches that identify disparities in hazardous exposures and outcomes.

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[3] The use of the term interventions should be considered broadly to include the evaluation of small scale research programs to national programs. National programs could include large, multiparty voluntary efforts as well as regulations or other national standards

Impact

The recent focus on fall prevention and protection in construction has had some impact, but more work is needed. Fall-related fatalities have been hovering around 3.5 per 100,000, down from above 4 per 100,000 prior to the recession (although the numbers are still unacceptably high and have edged up during the economic recovery) [Dong et al 2017]. The best evidence of impact may be available from high-performing organizations that prioritize hazard identification and remediation as part of safety and health management systems. Surveillance is a pre-requisite for improved safety and health outcomes, but must lead to interventions and follow-up to demonstrate impact.

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Objective 16: Training - Research to increase the reach, scope, and effectiveness of training in construction

The construction sector is made up of a wide range of industries that vary greatly in the exposures and protective systems that must be practiced to prevent an injury or fatality. The knowledge, skills, and safety behaviors needed to succeed vary greatly between construction settings; therefore, worker training is required. There is empirical evidence that occupational health and safety training increases worker knowledge , improves safety behaviors, and decreases workers' compensation claims among construction workers [Burke et al. 2006; Evanoff et al. 2006; Robson et al. 2010; Gilkey et al. 2003; Kaskutas et a. 2016; Project Safe Talk 2008; Kines et al. 2010; Dong et al. 2004; Burke et al. 2007] . But not all training is equal. Worksite safety training is most effective if it is well-designed, is delivered by people the learners can relate to, uses high engagement training methods, draws on the learners' experiences , and is contextually relevant [Project Safe Talk 2008, Kines et al. 2010; Burke et al. 2006, Kaskutas et al. 2016; CPWR 2013; Kaskutas et al. 2016]. Opportunities exists to improve the effectiveness, impact, reach, and outcomes of training in the construction industry.

Burden

The construction industry has more fatalities than any other employment sector in the U.S. economy [CPWR 2013]. The risk of sustaining a non-fatal work injury requiring days away from work is 78 per 100 full-time equivalents in the construction industry [Dong et al. 2014]. About 80% of construction payroll establishments employ 1-9 employees, and small establishments suffer a disproportionate share of fatal work injuries, specifically 44% of deaths among wage-and-salary workers occurred in establishments with 10 or fewer employees [CPWR 2013]. In the residential construction sector, inexperienced workers often work at heights before they have been trained in safe work methods [Kaskutas et al. 2009]. Worksite training in construction is often inadequate [Hung et al. 2011]. Some construction workers do not speak or understand English and others have poor reading skills which all can create barriers to learning.

Need

As the construction industry recovers from the economic recession that saw a 23% decrease in the number of construction workers [CPWR 2013], 1.3 million workers are projected to join the workforce by 2020 [CPWR 2013]. This represents a 33% growth in construction employment, which is over twice the rate projected for the overall US economy [CPWR 2013]. Since many workers displaced during the recession are not returning, there is an influx of new workers entering the sector that will need training. As the construction industry works to address the shortage of skilled labor, there is an opportunity to include occupational safety and health content into new educational and training initiatives. This includes looking at incorporating mental health and resilience training as well. Many young workers are not accustomed to the physical requirements, hazardous conditions, and environmental demands of a construction site. Temporary workers, who made up about 14% of the construction workers in 2013 [CPWR 2013], will fill some of these new construction jobs. As will foreign-born workers, which is an ever-growing portion of the construction workforce. Inexperienced workers often learn by working alongside experienced workers who provide on-the-job training at an active construction site. School-based training may be required, but trainers may not use efficacious training methods. Poor or inadequate training places these workers at disproportionate risk for injury. Effective occupational safety and health training is needed that impacts the knowledge, attitudes, and behaviors of workers.

Construction equipment, building methods, and OSHA safety regulations are evolving, necessitating regular contractor and worker training. It is becoming commonplace for public, private, and government agencies, as well as insurance companies, to mandate training for contractors. Refresher training for workers re-entering the workforce after prolonged absence is needed. Construction workers are working longer, often in poor physical health [Dong et al 2014] – training (with a strong safety and health component) can help these workers continue to work while decreasing their likelihood of injury. NIOSH has developed some safety and health training curriculum through the Safe●Skilled●Ready Workforce Program. Similar tools and resources could be developed that combine safety and health with technical training. As the construction market becomes more competitive, the need for training continues to increase.

Among other areas, the research needs to be conducted in:

1. Evaluate the effectiveness of various adult learning methods, such as focusing on work-related experiences, facilitated discussion, mentoring, coaching, problem-solving, and experiential learning, while considering the effects of knowledge, attitudes, beliefs, values, and motivational states.
2. Understand the needs of workers at disproportionate risk due to overlapping vulnerabilities and the best way to reach and train these populations.
3. Evaluate the effectiveness of online, virtual reality and other technology enhanced training approaches.
4. Identify factors that contribute to culturally sensitive training that achieves desired outcomes.
5. Evaluate the effectiveness of mentoring programs in which experienced workers provide on-the-job training to inexperienced workers.
6. Determine methods to make classroom trainers, on-the-job mentors, and foremen effective trainers.

Impact

The long-term aim of this objective is to decrease work-related injuries, illnesses, and fatalities in construction workers across a wide range of industries. Intermediate goals include improvements in worker, management, and owners' knowledge, attitudes, skills, beliefs, and behaviors regarding safety at the worksite. Safety training must reach and impact *all* workers involved in *all* phases of construction across all industries, including workers at disproportionate risk for injury and illness.

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