NATIONAL OCCUPATIONAL RESEARCH AGENDA (NORA)

NATIONAL OCCUPATIONAL RESEARCH AGENDA FOR MUSCULOSKELETAL HEALTH

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Developed by the NORA Musculoskeletal Health Cross-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 for 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 its 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 seven cross-sectors 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 health and safety issues that apply to all industrial sectors into seven cross-sectors. The Musculoskeletal Health Cross-Sector focuses on the mitigation of workplace-related musculoskeletal disorders (MSDs).

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.

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.

Musculoskeletal Health Council

The NORA Musculoskeletal Health Cross-Sector Council is currently comprised of 29 individuals including 23 external stakeholders and 6 NIOSH representatives (including the Council Co-Chairs). The external members come from academia, industry, insurance, safety organizations and labor safety and health advocates. Membership on the Council is always open to interested individuals who can contact either the Council Co-Chair (MLu@cdc.gov) or the Council Liaison (LMoore5@cdc.gov) for more information. Council members as of January 2018 are listed at the end of this document.

What does the National Occupational Research Agenda for Musculoskeletal Health represent?

The National Occupational Research Agenda for Musculoskeletal Health is intended to identify the research, information, and actions most urgently needed to prevent occupational musculoskeletal disorders and symptoms. This National Occupational Research Agenda for Musculoskeletal Health provides a vehicle for 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 Musculoskeletal Health Cross-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 will use the Agendas created by the sector and cross-sector NORA Councils to develop a NIOSH Strategic Plan. Programs will use the Burden, Need and Impact 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 to be separate but linked.

Who are the target audiences?

The target audience for the National Occupational Research Agenda for Musculoskeletal Health is primarily researchers interested in the mitigation of work-related MSDs. These researchers may be from academia, insurance or workers' compensation groups, healthcare providers, employers or labor safety and health organizations. The National Occupational Research Agenda for Musculoskeletal Health will provide guidance for stakeholders across all industries to prioritize their work in addressing MSDs. Once the research is conducted and thoroughly vetted, safety and health professionals, consultants, workplace safety professionals and the workers themselves can utilize the new discoveries to address issues in their facilities.

How was the research agenda developed?

The NORA Musculoskeletal Health Council began to accept interested parties as members in the autumn of 2016. By January 2017, the 18-member Council began to meet by teleconference on a monthly basis. At the first meeting members were asked to provide research topics that were felt to be gaps in the body of knowledge on workplace MSDs. Over 30 topics were proffered for consideration. With each successive month, additional members were added to fill gaps within the stakeholder representation on the council and each new member was asked for their priority research topics. By July 2017 the Council membership stood at 27 members, 21 external stakeholders and 6 NIOSH representatives including the Council Co-Chair. Between each monthly meeting, individual members or ad hoc working groups comprised of Council members met to develop text for each of the topic areas. As this work progressed, the monthly meeting notes reflected the status of each topic narrative up to that time. In May

2017, the Council Co-Chairs consolidated and edited the draft document to turn it into a more cohesive document rather than individual paragraphs or sections based on topic area created by the working groups. In May, June, and July Council members were given the opportunity to discuss the changes or edits made by the Co-Chairs and the initial draft of the National Occupational Research Agenda for Musculoskeletal Health was completed in February 2018 and prepared for public comment at that time. Minor revisions were made in response to the comments, and the final version was published.

BACKGROUND

Musculoskeletal disorders are ubiquitous in all industries. According to the Bureau of Labor Statistics, these workplace injuries comprise about 40% of all lost-time workplace injuries (356,910 of 902,200) [BLS 2016]. The following occupations reported the highest number of MSDs in 2015:

- Laborers and freight, stock, and material movers, hand -- 21,990
- Nursing assistants -- 19,360
- Janitors and cleaners, except maids and housekeeping cleaners – 15,810
- Heavy and tractor-trailer truck drivers -- 15,320
- Light truck or delivery services drivers -- 10,730
- Registered nurses -- 10,290
- Maintenance and repair workers, general -- 10,290

The distribution of MSDs across occupations is primarily task dependent resulting in a wide variation in the incidence rate across occupations. The incidence rate for all occupations is 32.2 MSD injuries per 10,000 full-time equivalent workers. The following occupations are examples of those that reported MSD incidence rates well above the all-industry rate:

- Telecommunications line installers and repairers -- 224.6
- Emergency medical technicians and paramedics -- 187.4
- Nursing assistants -- 180.5
- Firefighters -- 168.5
- Light truck or delivery services drivers -- 135.9
- Labor and freight, stock and material movers, hand -- 111.0

The severity of the MSDs incurred also varies widely across occupations. The median days away from work for all lost-time injuries is 8 days. The median days away from work for MSDs is 12 days. The following occupations are examples of those with median days away from work well above that number:

- Plumbers, pipefitters, and steamfitters -- 80
- Telecommunications line installers and repairers -- 52
- Bus and truck mechanics and diesel engine specialists -- 30
- Heavy and tractor-trailer truck drivers -- 30
- Installation, maintenance, and repair workers, all other -- 25
- Cargo and freight agents -- 21

THE OBJECTIVES

Objective 1: Define the Incidence and Impact of Musculoskeletal Disorders (MSDs)

Knowledge Gaps in Defining the Incidence and Impact of MSDs

1.1 Improve Surveillance of MSDs

Various national and state level statistics show that MSDs are among the most common work-related illnesses and injuries, and among the most common causes of disabling workplace injuries and illnesses in the U.S. Yet multiple research studies on the adequacy of the existing surveillance system(s) of non-fatal occupational injuries and illnesses in the U.S. provide ample evidence of underreporting, especially of work-related MSDs [Menzel 2008; BLS 2008; Dong et al. 2011; Joe et al. 2014; Wuellner and Bonauto 2014]. The problem of underreporting has become more challenging over the past two decades as the U.S. economy experienced major structural transformations, which led to significant changes in business practices. The manufacturing sector experienced outsourcing and movement of operations to other countries, leading to shrinking employment in the sector. More migrant and seasonal workers are working in the agriculture and construction sectors. In the meantime, the service sector grew in size to become the largest industrial sector. There is no standardized national reporting system for chronic work-related MSDs, further complicating the problem of quantifying the national burden of injury.

Surveillance of MSD is also hampered by the ongoing changes in the traditional employer-employee relationship as the population of individuals working as independent contractors and through temporary work agencies and professional employee organizations continues to grow [Wuellner and Bonauto 2014]. These types of work arrangements tend be more prevalent in high-hazard industries such as manufacturing, healthcare and social assistance, construction, trucking and warehousing, and the wholesale and retail trades. Research has suggested underreporting of occupational injuries including MSDs when workers are considered as temporary or independent contractors rather than employees [Welch et al. 2007; Foley at al. 2014; Wuellner and Bonauto, 2014].

There is a need for research to develop new surveillance tools and to improve existing surveillance systems to address the above challenges and provide more accurate accounting of work-related MSDs. Focus areas for such efforts include improved surveillance of work-related MSDs among small businesses, in high risk sectors including construction and health care/social assistance, and in vulnerable populations including migrant workers, temporary workers, younger and older workers, and independent contractors, particularly those in high-hazard industries.

1.2 Quantify Underreporting of Musculoskeletal Injuries

Challenges in surveillance are well documented in studies of underreporting of MSDs in several high-risk industries including healthcare and social assistance, food processing, and construction. For example, studies conducted by Wuellner and Bonauto [2014], Wiatrowski [2014], and Leigh et al. [2004], indicated that the Bureau of Labor Statistics undercounts worker injury and illness cases. Ruser [2008] attempted to match cases from the Survey of Occupational Injuries and Illnesses in selected states with the data from state workers' compensation records in an effort to estimate the extent of underreporting. The results varied depending on methodology and states examined. The estimated undercount ranged from 20 to 70%. Underreporting prevents an accurate assessment of costs and benefits of state-level injury prevention programs, such as safe patient handling, making it difficult to assess the effectiveness of workplace MSD prevention programs [Menzel 2008] or to target intervention efforts to populations with the highest burden and need.

Previous research has shown a variety of factors related to underreporting of the burden MSDs [BLS 2008; Dong et al. 2011; Joe et al. 2014; Wuellner and Bonauto 2014]. For example, bringing injured workers back to work on "light duty" to avoid lost days; some employer incentive programs that pay bonuses for lower recordable injuries and thus encourage underreporting; inadequate reporting by employers; and treating workers as independent contractors rather than as employees [Welch et al. 2007; Dong et al. 2011]. Underreporting by employees occurs through a number of mechanisms, including complicated compensation procedures, fear of lost wages, pressure from peers or the employer to under-report, and fear of losing employment.

1.3 Quantify the Human and Economic Burden of MSDs

The true cost to the nation, employers, and individuals of work-related injuries and illnesses is much greater than the cost of workers' compensation insurance alone. Organizations such as the National Safety Council also estimate the total economic costs of occupational deaths and injuries. It is estimated that for the year 2013 the cost per worker, which includes the value of goods or services each worker must produce to offset the cost of a work injury, was $1,400, while the cost per death was $1.45 million. If the injury includes a medical consultation the average cost increased to $42,000, which includes estimates of wage loss, medical expenses, administrative expenses, and employer costs [NSC 2015]. There are additional, largely unrecognized costs of MSDs to employers including cost shifting from workers' compensation to employee health insurance programs meant for non-work related conditions. This obscures the true cost of medical expenses and disability due to work-related chronic MSDs and may affect investment decisions regarding interventions to prevent MSDs. From the perspective of the employer, another large cost of MSDs is lost productivity from workers who are symptomatic or impaired while at work (presenteeism). Many current methods used for quantifying lost productivity are not well validated; it is likely that the true economic costs of MSDs to employers is higher than currently realized. In addition to employers' costs, there are additional costs of work-related MSDs to workers, their families, and society. There is a need to develop and enhance the tools used in the assessment of the human and economic burden that MSDs have outside of their costs to employers. These burdens of MSDs on workers, their families, and society are difficulty to calculate with current tools. In addition to affecting the economic well being of injured workers and families, MSDs may impose additional burdens of long-term disability, pain, and reduced quality of life and functional status leading to early retirement or forced change in careers.

Research Needed to Address the Following Knowledge Gaps in Defining the Incidence and Impact of MSDs

1.1 and 1.2 Improve surveillance of MSDs and Quantify underreporting of musculoskeletal injuries

- Match multiple data sources to arrive at better counts of MSDs and estimate the extent of underreporting, including the type and severity of underreported MSDs.
- Describe the effects of changes in industry and employment patterns on surveillance results.
- Better understand employer and employee factors that lead to underreporting.
- Understand the effects of insurance rate setting and compliance inspection systems that are triggered by specific injury counts (OSHA recordable injuries and lost day injuries) that give employers a strong incentive to under-report. Study alternate surveillance or rate setting practices based on safety factors (leading indicators such as exposure assessment and reduction practices) or other injury / illness estimates (active surveillance) that may give a more accurate estimate of current conditions and future risk.

1.3 Quantify the human and economic burden of MSDs

- Identify and evaluate methods to improve the quantification of lost productivity, reduced function, and reduced quality of life from MSDs.
- Look holistically at the total burden of MSDs, which may be caused by work, exacerbated by work, and occur through cumulative damage on or off work, and through aging or other non-work related processes.
- Examine cost-shifting of MSD treatment and disability from workers' compensation to employer and publicly funded health insurance systems.
- Measure the economic burden of MSDs on active and retired workers, families, and society, through measures such as lost wages and changes in work trajectory.
- Measure other effects caused by work-related MSDs including long-term disability, pain, reduce quality of life, reduced functional status, and early retirement among injured workers.

Objective 2: Understand the Risk Factors for Work-Related MSDs

Knowledge Gaps in Understanding Risk Factors for Work-Related MSDs

2.1 Improved Methods of Exposure Assessment

Accurate measures of biomechanical and other exposures relevant to work-related MSDs are critical to understanding the etiology of MSDs, and to efforts to measure the effects of workplace interventions. Existing methods of exposure assessment include direct instrumentation, video observation and analysis, direct observation, and self-reporting. New technologies such as small wearable sensors and automated analyses of video observations offer significant promise of making the assessment of some exposures more efficient and scalable to larger populations and workers with more varied work. Development and validation of improved methods of exposure assessment are a critical need in MSD research; improved methods are needed for a variety of different study types including large-scale epidemiological studies.

2.2 New Risk Assessment Models and Methods

New risk assessment models and methods are needed to advance the adoption of safety and ergonomics in the design and engineering of jobs, workspaces, products, and equipment. There is a need to develop or refine exposure measurement and risk assessment tools and technologies to better predict and prevent workplace injuries, localized fatigue, and musculoskeletal disorders. These tools may encompass new technologies including virtual reality, augmented reality, digital human models, computer vision, image analysis, video analytics, scanners, motion trackers, wearable sensors, and mobile devices. The tools may also be incorporated into existing engineering design software. These models and tools should be easily accessible and usable by engineers and designers during the job and tool design process.

Risk assessment requires new methods of assessing biomechanical exposures more efficiently and inexpensively, yet with demonstrated validity and reliability. More real-time data linked to validated predictive models are needed, and should specifically address variability of work tasks, effects of cumulative loading, and work-rest cycles. Many current methods to assess biomechanical risks of work exposures are best suited to jobs with a limited number of stereotypical movements with minimal variation; such jobs represent only a small number of tasks performed by workers. Measurements of biomechanical exposures at work must also be developed for large-scale epidemiological studies; many current exposure assessment methods are not readily usable in population-based studies.

Practical, simple and user-friendly methods of risk assessment that can be applied by occupational safety and health professionals, safety managers, and workers are a necessary tool for the effective dissemination and implementation of preventive interventions. New methods that allow for a comprehensive assessment of whole-body risk for each task and the overall effect of all tasks performed during a day are recommended.

2.3 The Changing Nature of Job Tasks

The changing nature of job tasks poses new challenges to surveillance, exposure measurement, risk assessment, and workplace interventions.

Change in technology, increased mechanization and automation have resulted in change in many occupational tasks in terms of where and how they are conducted. These changes may have shifted workloads to other areas of the body or increased variability in these workloads. As a result, research is needed to quantify the effects of the changing work environment on the development of MSDs, the revision and refinement of existing tools to take into account increased task variability, and intervention efforts for addressing workloads.

One area of interest is manual material handling (MMH). In spite of the increasing degree of mechanization and automation in industry, MMH tasks continue to be an important feature of many industrial and service occupations. The introduction of mechanization and automation in the workplace may not eliminate the need for MMH tasks, but may modify the nature of the demands and perhaps introduce new hazards. The material handling emphasis in many manufacturing operations since the early 1990s has gone from the handling and delivery of bulk materials to assembly lines by fork truck to *Kanban* or just in time deliveries of small lots by workers handling totes or containers of materials [Fox and Peacock 1995]. Marras et al. [2009] noted that manufacturing increasingly involves work where employees perform a variety of tasks and may rotate through different workstations throughout the day. Job rotation involves the movement or rotation of workers in work groups through the various jobs within that work group one or more times a shift and have become common in industrial work and factor into many labor agreements. Therefore, the physical and psychological demands placed on workers may be much more varied than in more traditional jobs. Indeed, some ergonomics assessment tools such as the Revised NIOSH Lifting Equation (published 1994) require modification or extension in order to apply to the more varied types of manual handling tasks now common in industry [Waters et al. 2016]. There is a need to compare the current ergonomics guidelines, recommendations and tools to the needs of contemporary working environments and work demands.

A second area of interest is mobile devices. Increasing numbers of business workers are working at home or in multiple locations rather than in a traditional office environment. Some workers use traditional desktop computers, but many others primarily or exclusively use laptop computers, or other mobile computing devices. These mobile devices have become increasingly popular allowing some workers to be in touch with co-workers nearly continuously. While these devices (laptops, smart phones, tablets and pads) were not intended to replace traditional computers for long-term usage, they are being used more frequently for work tasks across many industries and in non-traditional work environments. However, there is very little data quantifying the effects of long term usage and usage of these devices in non-traditional office settings on musculoskeletal health. Research designed to quantify usage and usage patterns, as well as the impacts on the musculoskeletal system associated with non-traditional workstations and with mobile computing is needed.

Research Needed to Address the Following Knowledge Gaps in Understanding Risk Factors for Work-Related MSDs

2.1 Improved Methods of Exposure Assessment

- Develop and validate new methods of exposure assessment applicable to a wide range of study types.

- Develop practical and simple means of exposure assessment that can be applied by occupational health practitioners and safety personnel to measure and ameliorate risk.

2.2 New Risk Assessment Models and Methods

- Develop and refine risk assessment tools and technologies to better predict and prevent workplace injuries and MSDs.
- Develop capabilities to use real-time data linked to validated predictive models to specifically address variability of work tasks, effects of cumulative loading, and work-rest cycles.
- Develop practical and simple methods of risk assessment that can be applied by practicing occupational health professionals; such tools are a necessity for the diffuse implementation of preventive interventions.
- Determine the validity, reliability, and accuracy of risk models.

2.3 The Changing Nature of Job Tasks

- Quantify the effects of changing work environments on the development of MSDs, and on the feasibility of current approaches to reduce exposures.
- Revise existing tools and develop new methods to take into account increased task variability and other changes in the nature of work.
- Assess the effects of new technologies such as mobile computing on physical and psychosocial exposures relevant to musculoskeletal health.
- Investigate the effects of psychological, psychosocial, and work organizational factors on the occurrence of MSDs, including the effects of hours of work shift work, paced work, piecework, teamwork, alternate work sites (telecommuting), temporary work, extended hours, and other supervisory or management arrangements.

Objective 3: Describe the Underlying Mechanisms of MSDs

Knowledge Gaps in Describing and Understanding the Underlying Mechanisms of MSDs

Musculoskeletal tissues reside in a complex physiological environment, and exhibit highly dynamic attributes as a result. Depending on loading and rest conditions experienced, these tissues may become strengthened, may atrophy, may incur damage, and may be able to heal such damage. As a consequence, the etiology of MSDs is a complex process, eventually manifested by outcomes including pain, limitation of movement, limitation of activities, and disability. The interplay of multiple physical, biological, social, and psychological factors at different stages of causation, development, and treatment of MSDs remains poorly understood.

3.1 Underlying Mechanisms of Damage and Healing in Musculoskeletal Tissues

A substantial research effort is required over the next decade to illuminate fundamental aspects of tissue damage accumulation and healing in the maintenance of musculoskeletal health. The interaction of damage accumulation and tissue healing can be thought to encapsulate the very essence of musculoskeletal health, and an expanded foundation of knowledge regarding these fundamental processes will lead to improvements in our ability to prevent, treat, and rehabilitate musculoskeletal injuries.

Several lines of evidence suggest that damage accumulation in musculoskeletal tissue is the result of a fatigue failure process, in which repetitive stresses placed on tissues eventually cause a microfailure in the tissue, followed by the propagation of damage with continued loading [Brinckmann et al. 1988; Schechtman and Bader 1997; Andarawis-Puri and Flatow 2011; Barbe et al. 2013; Gallagher and Heberger 2013]. But unlike traditional fatigue failure processes in metals or plastics, biological tissues have the capacity to self-heal. Fundamental research is

needed to better understand the factors affecting both damage accumulation and healing, and conditions under which the healing process is successful as opposed to unsuccessful. Knowledge of these processes is currently hampered by insufficient data necessary to understand the complexities of this relationship [Gallagher and Schall 2017]. There are several areas where research is needed to improve our understanding of the processes of damage accumulation and healing that influence the etiology of work-related MSDs. These include defining the important material characteristics of musculoskeletal tissues, improving understanding of the stresses experienced during cumulative loading of tissues, and enhancing understanding of critical thresholds affecting musculoskeletal health status. Also important is to develop a more sophisticated understanding of the inflammatory process and factors affecting the healing response of musculoskeletal tissues.

3.2 Investigate the Role of Work-Related Psychosocial Factors on Musculoskeletal Health

Work-related psychosocial factors such as such as job satisfaction, mentally demanding work, monotony, job pressure, supervisor and co-worker support, and limited control over work may mediate or modify the relationships between physical factors and musculoskeletal health. Models linking modifiable, work-related psychosocial factors to work-related musculoskeletal disorders include the balance theory of job design and stress [Smith and Carayon 1996], the biopsychosocial model of job stress [Melin and Lundberg 1997], the ecological model of musculoskeletal disorders [Sauter and Swanson 1996], and the workstyle model [Feuerstein, 1996]. Evidence supports a relationship between low back disorders and such work-related psychosocial factors as job satisfaction, monotonous work, work demands, and job stress [NRC/IOM 2001]; associations are also seen between upper extremity symptoms and such factors as high job stress and job demands. A number of research questions on work-related, modifiable psychosocial factors are important for better understanding and promoting musculoskeletal health. These include better knowledge of how physiological mechanisms are affected by psychosocial stressors, and how feedback mechanisms between psychosocial and physical factors may serve to increase the risk of adverse impacts on musculoskeletal health. Also important is the question of whether unique causal mechanisms are associated with psychosocial stressors and adverse musculoskeletal health outcomes, and what effective interventions may exist for addressing psychosocial stress as a means to mitigate musculoskeletal disorders.

Research Needed to Address the Following Knowledge Gaps in Describing and Understanding the Underlying Mechanisms of MSDs

3.1 Understand Underlying Mechanisms of Damage and Healing in Musculoskeletal Tissues

- Improve characterization of the mechanical properties of musculoskeletal tissues, including responses to repeated stress (including viscoelastic effects, process of damage nucleation and propagation, age-related changes, etc.) both *in vitro* and (where possible) *in* vivo.
- Enhance understanding of the impact of variable loading regimens on musculoskeletal tissues, including the effects of duty cycle, load rate, and rest on musculoskeletal health.
- Define the impact of individual characteristics on the rate of damage accumulation and tissue healing
- Advance biomechanical modeling to permit more detailed predictions of stress concentrations in tissues, and how stress is shared when multiple tissues are involved.
- Improve imaging modalities and other technologies to better understand the effects of tissue loading and damage development *in vivo.*
- Improve understanding of the healing capacity of tissues. For example, how much damage can be healed on a daily basis for various musculoskeletal tissues? Under what cases is loading beneficial to healing, and under what cases is it detrimental? How is the body's healing capacity affected by factors such as age, lesion size, rest, exercise, and co-morbidities?

- Determine the expression of specific biomarkers (or combinations of biomarkers) that may presage the development of significant physical tissue damage, pain, or disability.
- Improve understanding of factors influencing the success or failure of the inflammatory/healing process. For example, exposure to a limited number of high stress exertions can strengthen exposed tissues. However, a large number of exertions at the same stress level will lead to tissue damage [Andarawis-Puri and Flatow 2011]. What are the factors responsible for crossing this threshold, and can we use this knowledge to better optimize tissue loading to improve musculoskeletal health?

3.2 Investigate the Role of Workplace Psychosocial Factors on Musculoskeletal Health

- Define mechanisms linking psychosocial and physical factors that may increase the risk of adverse impacts on musculoskeletal health.
- Describe relevant physiological mechanisms that may be influenced or affected by workplace psychosocial stresses.
- Define the causal mechanisms associated with observed associations between psychosocial stressors and adverse musculoskeletal health outcomes.
- Develop and test effective interventions for addressing work-related psychosocial factors as a means to improve musculoskeletal health.

Objective 4: Develop and Evaluate Interventions to Prevent MSDs and Limit Disability due to MSDs

Knowledge Gaps to Develop and Evaluate Interventions to Prevent MSDs and Limit Disability Due to MSDs

Musculoskeletal disorders are the leading cause of occupational injuries and represent the largest burden for workers' compensation costs; they also result in significant disability and productivity losses. Many interventions have been designed to lower risks of injury, disability, and lost productivity by reducing exposure to MSD risk factors. Although simple and effective interventions exist to reduce many harmful workplace exposures relevant to musculoskeletal health, adoption of these interventions by employers is slow. There is a need to conduct additional intervention research that demonstrates the effectiveness of workplace changes in improving musculoskeletal health across a variety of outcomes, and to understand the facilitators and barriers to adoption of existing interventions by employers. Research to speed the adoption of effective interventions has the potential to dramatically reduce the frequency and severity of MSDs in the workplace.

4.1 Develop New Interventions

The range of potential interventions to prevent MSDs and limit disability is broad – changes in tools, materials, work processes, and work organization have all been implemented as interventions to reduce biomechanical exposures and improve musculoskeletal health. Other potential interventions include the optimization of mechanical work demands (force, movement, and posture) and temporal patterns of exposure, development of alternatives for manual materials handling to decrease harmful exertions of force, posture, and duration or repetition; ergonomics training and education; and new or emerging technologies such as exoskeletons and automated behavioral cues. Continued innovation and the application of new technology to both new and old exposures is an important direction in the prevention of MSDs. New interventions to reduce exposures are needed, and should be developed with future dissemination in mind.

4.2 Evaluate Intervention Effectiveness

As potential interventions are introduced, it is important to evaluate the effectiveness of these interventions in reducing the known risk factors for work-related MSDs, and to identify the barriers to dissemination and adoption of interventions as well as strategies to overcome those barriers.

In addition to engineering control technologies and approaches, testing the effectiveness of other interventions is needed, including participatory approaches to reducing work exposures, educational programs, behavioral interventions, changes in job content and scheduling, and other aspects of work organization.

Additional research is required to measure the effects of exposure reduction on improved musculoskeletal health as measured by decreased symptoms, number of MSDs, and disability, and improvements in functional capacity and productivity. Such research should also measure the costs and benefits of interventions (including productivity advantages). While many studies have demonstrated improvements in musculoskeletal health following interventions to reduce relevant exposures, more data are needed to strengthen the case to employers to adopt and implement new or more comprehensive interventions. This type of research should increase the adoption of effective interventions and has the potential to dramatically reduce the frequency and severity of MSDs in the workplace.

4.3 Medical Management of MSDs

Medical management plays a critical role in the prevention of disability associated with work-related musculoskeletal disorders by appropriately diagnosing the disorder and then recommending evidence-based or best-practice treatments. Early identification, medical evaluation, and intervention among symptomatic workers are recognized as important elements in decreasing disability due to MSDs. The range of treatment options are broad and can range from workplace interventions, such as prescribing work limitations; ergonomic interventions; job rotation; splinting; workplace exercises, to non-work interventions such as work hardening; therapy modalities; injections; or surgery. The appropriate treatment will depend on the diagnosis and severity of the disorder. Treatments or existing medical management protocols that have not been evaluated by rigorous, well-designed interventions should be evaluated to assess their clinical effectiveness. The primary purpose of this research is to identify workplace interventions and treatments at different stages of musculoskeletal disorders that reduce their severity and disability. Secondary purposes are to reduce direct and indirect medical costs and identify treatments that are not effective, or treatments such as over-prescription of opiates that may lead to unintended medical or social consequences.

Post-Offer Pre-Placement (POPP) screening, such as nerve conduction studies, x-rays and functional capacity evaluations are promoted as primary prevention methods for preventing work-related MSDs by excluding at-risk workers from certain jobs. There is currently little evidence that POPP screening is effective at identifying workers at risk for developing MSDs. Furthermore, such screening may lead to the inappropriate rejection for employment of workers who would not have developed the screened-for MSD. Research is needed to evaluate the effectiveness, or lack of effectiveness, of common POPP screening practices.

4.4 Changing Workforce Demographics

The US workforce is aging and the number of workers over age 55 is expected to increase over the next two decades. While older workers are injured at lower rates than younger workers, when injured, older workers are more likely to suffer disabling injuries [Biddle et al., 2003]. Additionally, older workers experience greater durations of disability and a higher likelihood of disability recurrence [Besen et al. 2016]. While best practices exist for return to work in the general population [Franche et al. 2004], there is a large gap in knowledge and best practices when it comes to returning injured or disabled older workers to work. As the workforce ages the burden of disability will also increase, making research, policies and practices essential that prevent injuries in older

individuals and provide worksites that are safer for older workers. There is a need for studies that address the unique attributes of older workers such as chronic diseases like diabetes, obesity, degenerative joint disease, and the accruing effects of cumulative trauma to the musculoskeletal system. There is a dearth of evidence based research and case studies that explicitly address keeping older people safe at work and if injured, returning older workers to work after a disabling injury.

Research Needed to Address the Following Knowledge Gaps to Develop and Evaluate Interventions to Prevent MSDs and Limit Disability Due to MSDs

4.1 Develop New Interventions

- Continue innovation to develop and apply effective interventions that reduce relevant exposures.
- Design and test interventions designed for future dissemination.

4.2 Evaluate Intervention Effectiveness

- Evaluate the effectiveness of interventions in reducing known risk factors for work-related MSDs.
- Identify barriers to dissemination and adoption of interventions, and strategies to overcome those barriers.
- Conduct intervention research assessing the effects of exposure reduction on relevant musculoskeletal health outcomes including decreased number of MSDs, decreased disability, and improvements in functional capacity and productivity.
- Demonstrate the costs and benefits of interventions (including productivity advantages).
- Evaluate the effects of work organizational and workplace psychosocial factors on the effectiveness of interventions in reducing the risk of MSDs.

4.3 Medical Management of MSDs

- Identify workplace interventions and treatments at different stages of MSDs that reduce their severity and disability.
- Assess the effectiveness of treatment and management of MSD via rigorous, well-designed intervention trials. Secondary purposes are to reduce direct and indirect medical costs and identify treatments that are not effective.
- Evaluate the utility and effectiveness of surveillance programs for early identification and management of MSDs.
- Evaluate the utility and effectiveness of current post-offer pre-placement screening practices.

4.4 Changing Workforce Demographics

- Define best practices for preventing MSD among older workers, including research on how to better design jobs for older workers to reduce MSD risk.
- Define best practices for preventing disability specific to older workers.
- Design and evaluate interventions for accommodating workers with decreased physical capabilities due to injuries, illnesses or demographic changes.

Objective 5: Disseminate and Implement Interventions to Prevent MSDs and Limit Disability

Research Gaps to Disseminate and Implement Interventions to Prevent MSDs and Limit Disability

MSD prevention and control efforts at worksites range from simple reactive assessments to comprehensive programs integrated into the health and safety management systems, with detailed assessment tools either developed in-house or by third-party companies. There is little knowledge of the extent of these mature programs and tools and how well they work, particularly as many company-developed tools and third-party developed tools are proprietary.

5.1 Prevention and Control Efforts

More companies are recognizing the scope of MSD injuries and instituting programs to prevent them. Yet we know very little about what motivates employers to implement organizational policies, programs and practices that support MSD hazard prevention and control as well as the management of MSD injuries. There is a strong interplay between organizational culture/climate and effective hazard identification and control. Understanding what motivates employers and the barriers to adoption might help in the dissemination of effective programs and practices. Little is known about effective partnerships (between labor and employers, insurers and employers, safety councils and employers) that lead to the diffusion and adoption of effective practices. There may be different barriers for small firms that don't have the resources or time (e.g. Building Information Modeling software to plan materials delivery and storage or the resources for manual handling equipment). In construction, there may be different constraints in cities for example, where site footprints are very small vs. in rural areas where space for laydown areas is plentiful. These challenges are amplified in a changing world of work with a growing "gig" economy.

5.2 Dissemination and Implementation of Interventions

A major barrier exists in the dissemination and implementation of interventions in work settings outside of the ones in which they were developed. For example, recent research shows that construction worksites often do not implement simple interventions that could prevent MSDs [Dale et al 2016]; this problem is widespread in other industries. There is a dearth of knowledge concerning barriers and facilitators for the implementation of preventive measures for MSDs, including management practices that are effective in promoting the implementation of best practices to protect musculoskeletal health.

5.3 Treatment of Affected Workers

In addition to prevention, attention must be paid to the treatment of affected workers: while there is good knowledge on how to treat injured workers to limit disability and facilitate return to work, the health care system struggles to provide evidence-based and coordinated care, particularly with complex cases. Research is needed to identify more effective means to ensure that occupational health providers use the best available evidence in treating injured workers in order to obtain the best possible outcomes.

Research Needed to Address the Following Research Gaps to Disseminate and Implement Interventions to Prevent MSDs and Limit Disability

5.1 Prevention and Control Efforts

- Increase employer and worker awareness of the range of potential interventions including engineering and administrative controls and their relative success.

- Describe how safety management systems can better address chronic MSDs in addition to acute injury hazards.

5.2 Dissemination and Implementation of Interventions

- Encourage development of interventions that are designed for dissemination.
- Identify barriers to dissemination and adoption of interventions.

5.3 Treatment of Affected Workers

- Describe how best practices for both prevention and treatment can be better implemented broadly within health care systems.

APPENDICES

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