NORA

June, 2017

Promoting the implementation of evidence-based occupational safety and health practices in the Manufacturing Industry

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*Manufacturing Sector Co-chair, Bayberry EHS Consulting, LLC

Manufacturing Sector Council

The Manufacturing Sector Council includes representatives of different organizations and constituencies. Its membership is engaged in the generation of safety and health knowledge and tools, the distribution and dissemination of such information, or as users of information.
http://www.cdc.gov/niosh/programs/manuf/

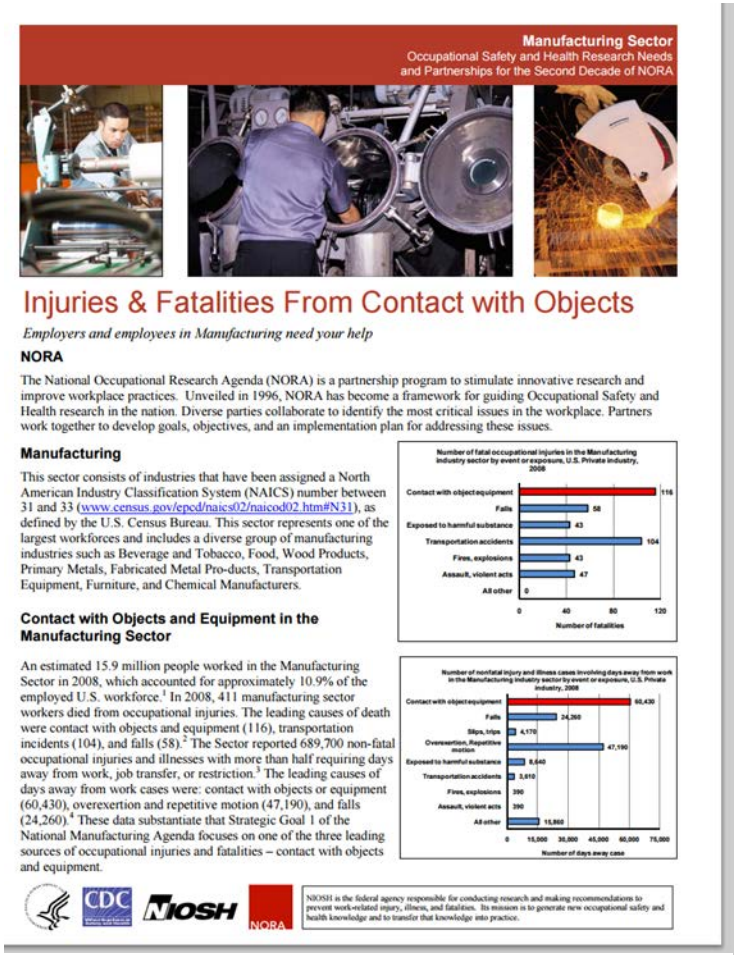
Manufacturing Sector

North American Industry Classification System (NAICS) codes 31-33 (21 subsectors)

Largest Sub-sectors

- ✓ Transportation equipment manufacturing
- ✓ Primary metals and fabricated metal products manufacturing
- ✓ Food manufacturing

2010 NIOSH Fact Sheets



Manufacturing Sector
Occupational Safety and Health Research Needs and Partnerships for the Second Decade of NORA

Injuries & Fatalities From Contact with Objects

Employers and employees in Manufacturing need your help

NORA

The National Occupational Research Agenda (NORA) is a partnership program to stimulate innovative research and improve workplace practices. Unveiled in 1996, NORA has become a framework for guiding Occupational Safety and Health research in the nation. Diverse parties collaborate to identify the most critical issues in the workplace. Partners work together to develop goals, objectives, and an implementation plan for addressing these issues.

Manufacturing

This sector consists of industries that have been assigned a North American Industry Classification System (NAICS) number between 31 and 33 (www.census.gov/epcd/naics02/naicod02.htm#N31), as defined by the U.S. Census Bureau. This sector represents one of the largest workforces and includes a diverse group of manufacturing industries such as Beverage and Tobacco, Food, Wood Products, Primary Metals, Fabricated Metal Pro-ducts, Transportation Equipment, Furniture, and Chemical Manufacturers.

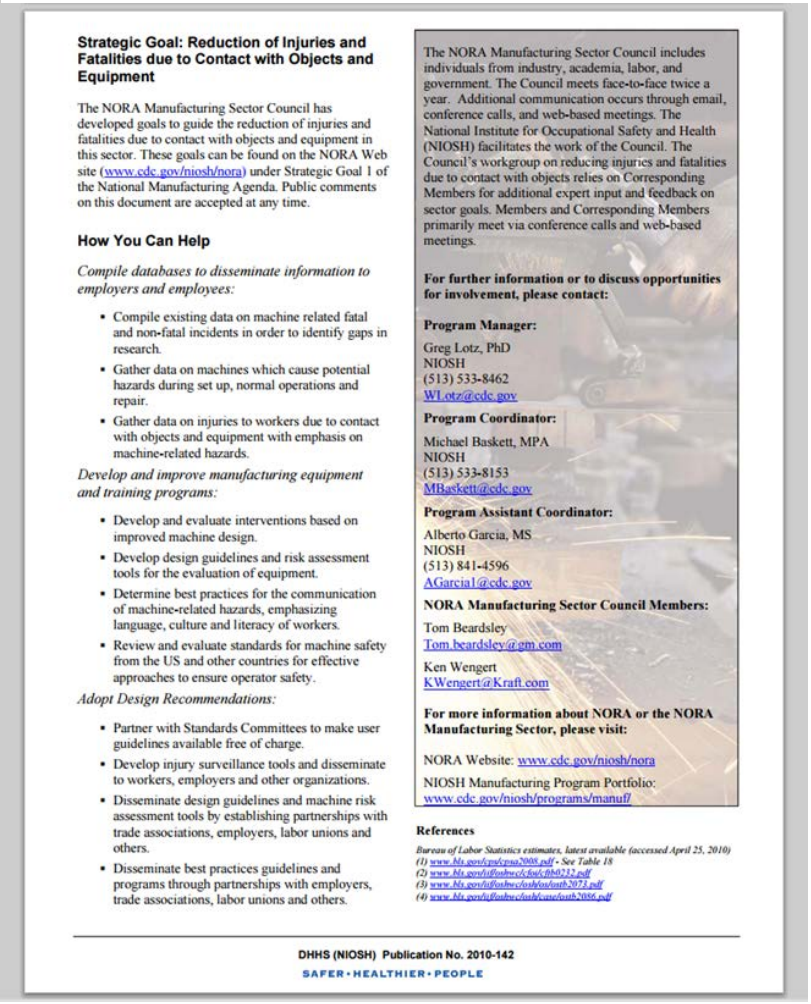
Number of fatal occupational injuries in the Manufacturing industry sector by event or exposure, U.S. Private industry, 2008

Contact with Objects and Equipment in the Manufacturing Sector

An estimated 15.9 million people worked in the Manufacturing Sector in 2008, which accounted for approximately 10.9% of the employed U.S. workforce.[1] In 2008, 411 manufacturing sector workers died from occupational injuries. The leading causes of death were contact with objects and equipment (116), transportation incidents (104), and falls (58).[2] The Sector reported 689,700 non-fatal occupational injuries and illnesses with more than half requiring days away from work, job transfer, or restriction.[3] The leading causes of days away from work cases were: contact with objects or equipment (60,430), overexertion and repetitive motion (47,190), and falls (24,260).[4] These data substantiate that Strategic Goal 1 of the National Manufacturing Agenda focuses on one of the three leading sources of occupational injuries and fatalities – contact with objects and equipment.

Number of nonfatal injury and illness cases involving days away from work in the Manufacturing industry sector by event or exposure, U.S. Private industry, 2008

NIOSH is the federal agency responsible for conducting research and making recommendations to prevent work-related injury, illness, and fatalities. Its mission is to generate new occupational safety and health knowledge and to transfer that knowledge into practice.



Strategic Goal: Reduction of Injuries and Fatalities due to Contact with Objects and Equipment

The NORA Manufacturing Sector Council has developed goals to guide the reduction of injuries and fatalities due to contact with objects and equipment in this sector. These goals can be found on the NORA Web site (www.cdc.gov/niosh/nora) under Strategic Goal 1 of the National Manufacturing Agenda. Public comments on this document are accepted at any time.

How You Can Help

Compile databases to disseminate information to employers and employees:

- Compile existing data on machine related fatal and non-fatal incidents in order to identify gaps in research.
- Gather data on machines which cause potential hazards during set up, normal operations and repair.
- Gather data on injuries to workers due to contact with objects and equipment with emphasis on machine-related hazards.

Develop and improve manufacturing equipment and training programs:

- Develop and evaluate interventions based on improved machine design.
- Develop design guidelines and risk assessment tools for the evaluation of equipment.
- Determine best practices for the communication of machine-related hazards, emphasizing language, culture and literacy of workers.
- Review and evaluate standards for machine safety from the US and other countries for effective approaches to ensure operator safety.

Adopt Design Recommendations:

- Partner with Standards Committees to make user guidelines available free of charge.
- Develop injury surveillance tools and disseminate to workers, employers and other organizations.
- Disseminate design guidelines and machine risk assessment tools by establishing partnerships with trade associations, employers, labor unions and others.
- Disseminate best practices guidelines and programs through partnerships with employers, trade associations, labor unions and others.

The NORA Manufacturing Sector Council includes individuals from industry, academia, labor, and government. The Council meets face-to-face twice a year. Additional communication occurs through email, conference calls, and web-based meetings. The National Institute for Occupational Safety and Health (NIOSH) facilitates the work of the Council. The Council's workgroup on reducing injuries and fatalities due to contact with objects relies on Corresponding Members for additional expert input and feedback on sector goals. Members and Corresponding Members primarily meet via conference calls and web-based meetings.

For further information or to discuss opportunities for involvement, please contact:

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For more information about NORA or the NORA Manufacturing Sector, please visit:
NORA Website: www.cdc.gov/niosh/nora
NIOSH Manufacturing Program Portfolio: www.cdc.gov/niosh/programs/manuf/

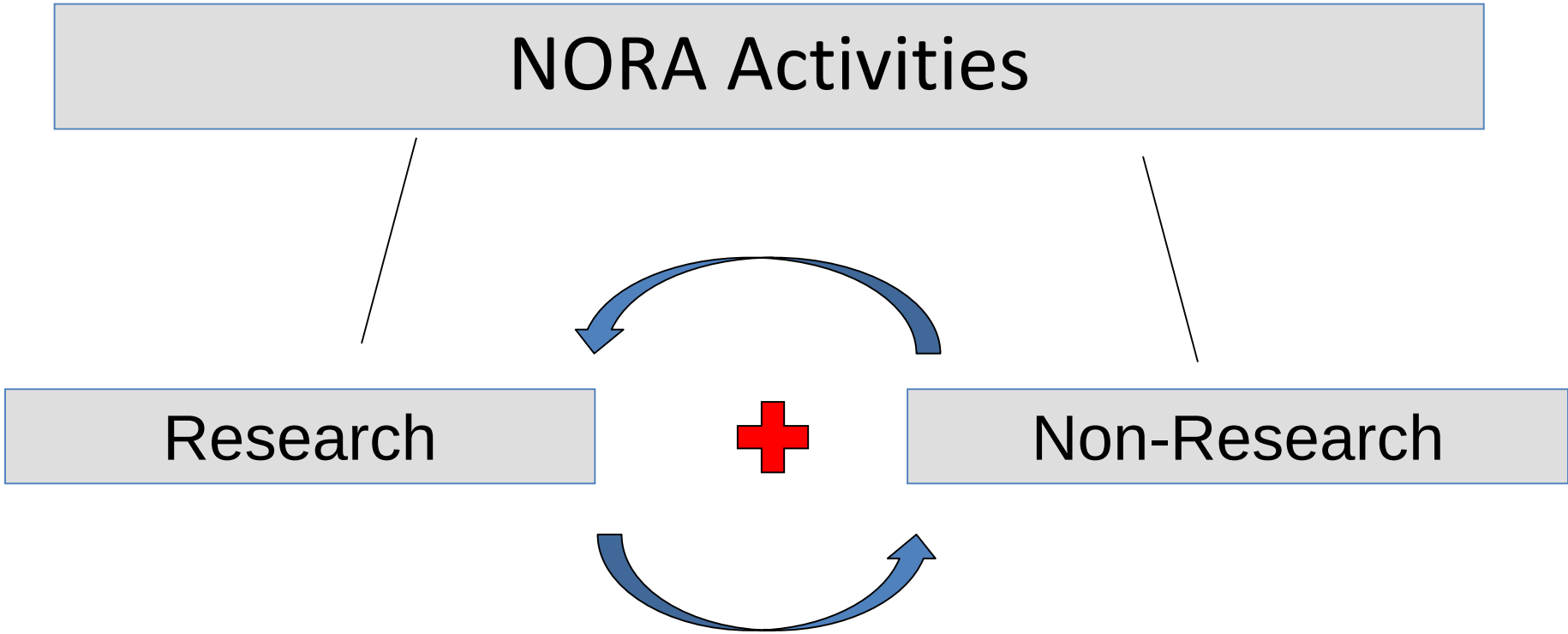
References

Bureau of Labor Statistics estimates, latest available (accessed April 25, 2010)
(1) www.bls.gov/cps/cpsaat2008.pdf • See Table 18
(2) www.bls.gov/iif/oshwc/cfoi/cftb0232.pdf
(3) www.bls.gov/iif/oshwc/osh/os/osnb2075.pdf
(4) www.bls.gov/iif/oshwc/osh/case/osnb2086.pdf

DHHS (NIOSH) Publication No. 2010-142
SAFER • HEALTHIER • PEOPLE

http://www.cdc.gov/niosh/docs/2010-142/pdfs/2010-142.pdf

National Occupational Research Agenda: Range of activities



Program Performance One-Pagers

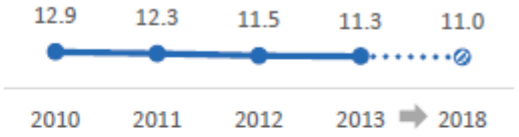
NIOSH Manufacturing Program

May 2016

What have we accomplished?

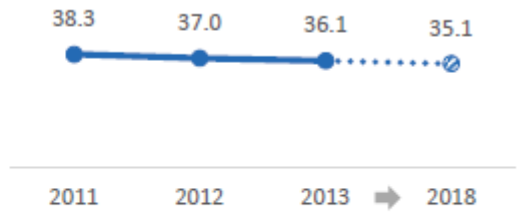
- Published study of saw-related injuries and their causes and compared with national data from the Bureau of Labor Statistics.
- The National Institute of Standards and Technology adopted NIOSH-recommended hearing loss prevention practices.
- The Occupational Safety and Health Administration (OSHA) began using NIOSH recommendations for hearing loss prevention in the training of their field inspectors. The Dept. of Defense's new regulation (DODI 1474E) and the National Academy of Engineering Technology for a Quieter America both expressed support for NIOSH recommendations.
- Published study of smartphone sound measurement apps, which became most read article in the past year from the Acoustical Society of America journal and the most visited NIOSH Science Blog, with over 109,000 visits, from April 2014 to February 2016.
- Published a NIOSH Science Blog with resources for preventing MSDs. It became one of the top ten most visited NIOSH Blogs of 2015.
- Published and promoted a report on the best practices for engineering controls to reduce exposure to nanomaterials at the source.
- Posted a video on YouTube for manufacturers on the benefits of a Buy Quiet program to reduce noise exposure for their employees. Published intervention descriptions, updates and testimonials from the 2016 Safe-in-Sound Excellence in Hearing Loss Prevention Award™ recipients.

At-A-Glance



Source: U.S. Bureau of Labor Statistics

Incidence rate of musculoskeletal disorders in manufacturing (per 10,000 full-time workers)



Source: U.S. Bureau of Labor Statistics

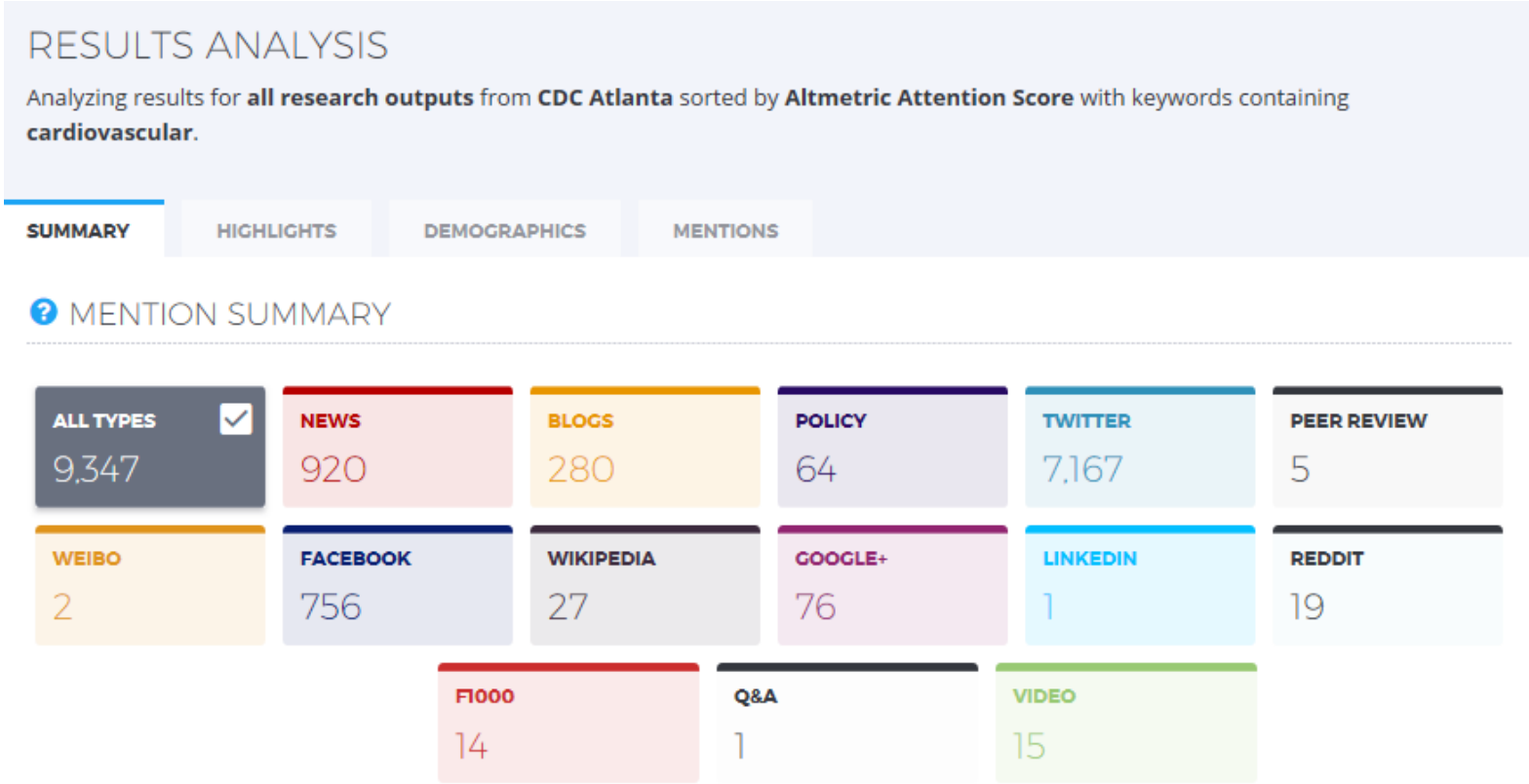
https://www.cdc.gov/niosh/docs/ppop/

Looking at metrics for evaluation

Summary of Citations of NIOSH publications (2007-2014) as Outcomes by Sector

Sector	Intramural Publications	Average Citations	Range	Extramural Publications	Average Citations	Range
Manufacturing	480	11.6	0-783	90	13.1	0-37

Manuf= 33%

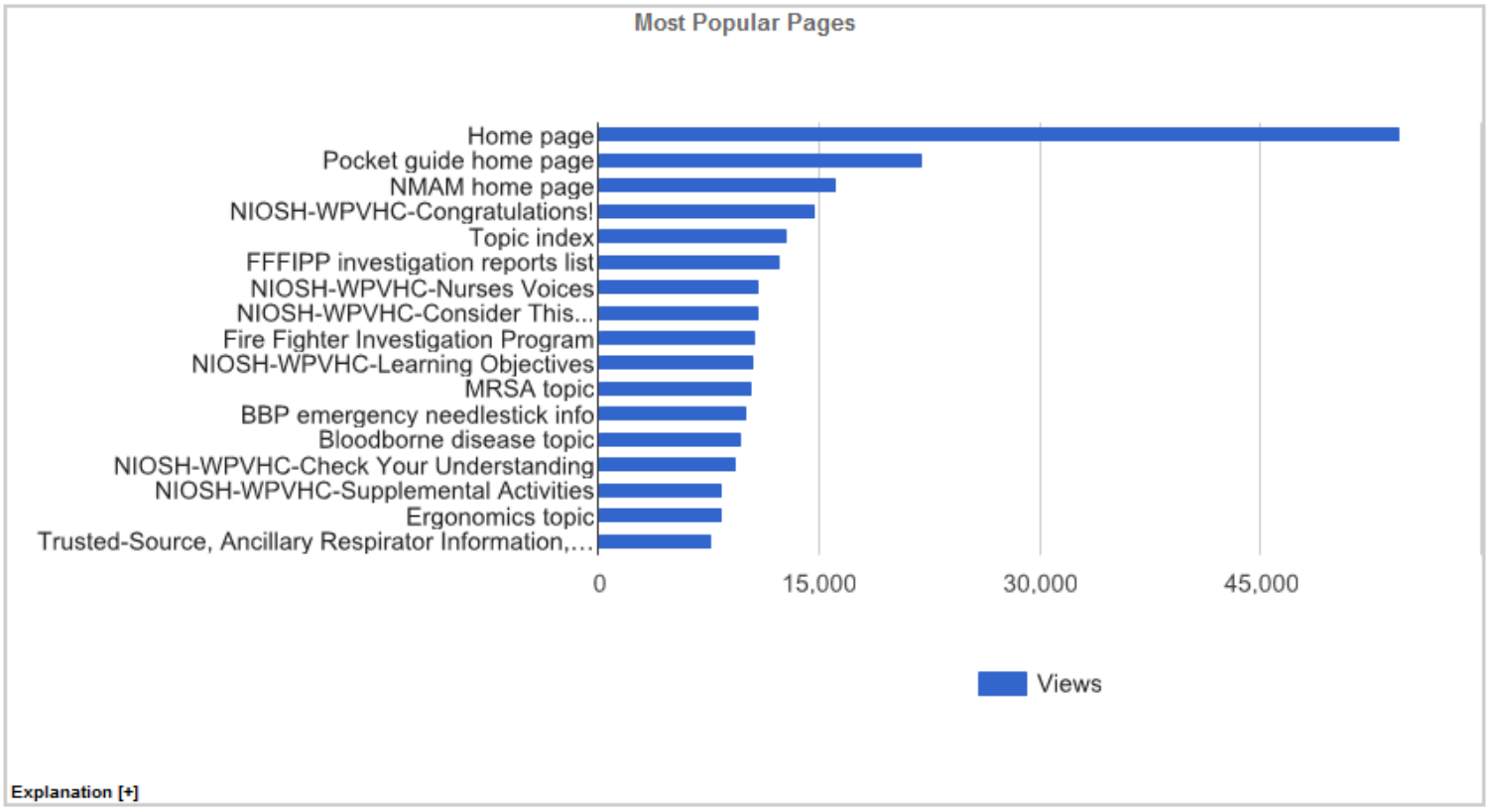


http://inside.niosh.cdc.gov/DigitalDownloads/December2016.pdf

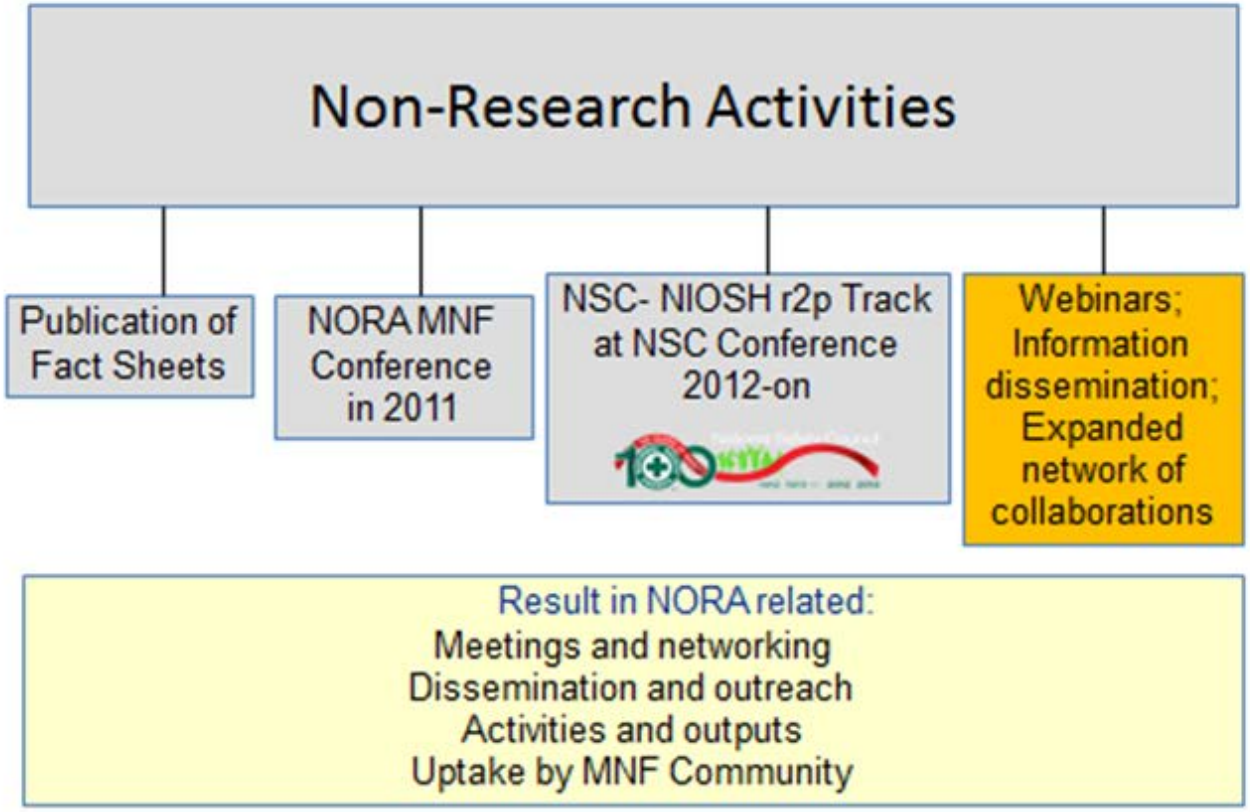
NIOSH Alt Metrics

Dashboards: Reach | **Web** | Blog | Twitter | Sectors | Cross-sectors | Search | GovDelivery

Web dashboard, data through February 29, 2016



NORA


Non-Research Activities
Publication of Fact Sheets
NORA MNF Conference in 2011
NSC- NIOSH r2p Track at NSC Conference 2012-on
Webinars; Information dissemination; Expanded network of collaborations
Result in NORA related:
Meetings and networking
Dissemination and outreach
Activities and outputs
Uptake by MNF Community

Beyond research:
Promoting the implementation of evidence-based occupational safety and health practices in the Manufacturing Industry

Council Members growing involvement on the dissemination of the activities of the Council, by:

- coordination of activities, communication efforts and events
- co-authorship of publications, in particular the NIOSH Science Blog
- development of new page in the NIOSH website

Coordination of activities, events and communication efforts

Organized joint session of the NORA Manufacturing Sector and Services Sector Councils on the hazards of temporary employment and published NIOSH Science Blog

CDC Centers for Disease Control and Prevention
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NIOSH Science Blog

Addressing the Hazards of Temporary Employment

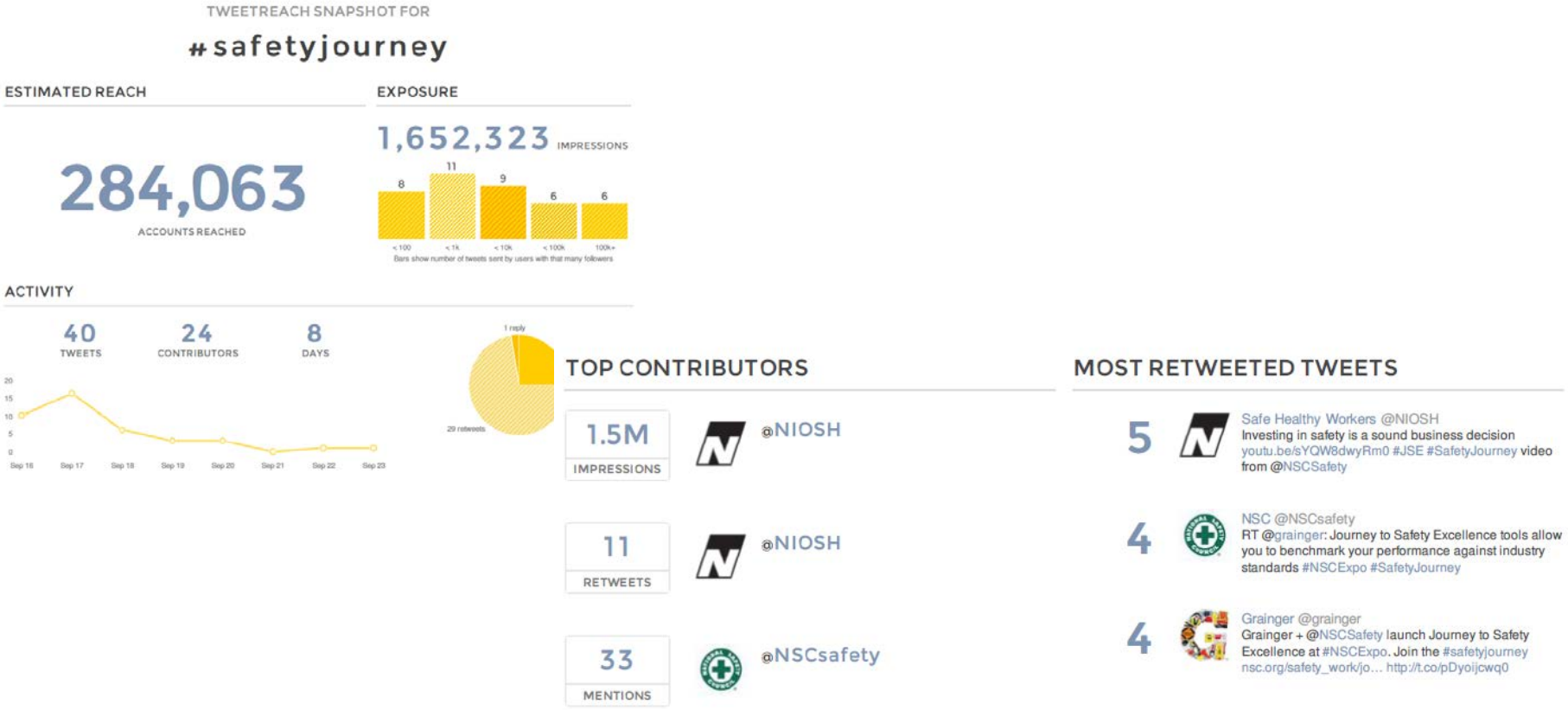
Posted on June 16, 2015 by Cheryl F. Estill, Thais Morata,Terri Schnorr, Barbara Materna

A Joint Session of the NORA Manufacturing Sector and Services Sector Councils

Factors such as fluctuations in the economy, changing social habits and access to technology have boosted a rapid growth in temporary work arrangements [Luo,T]. Under many names–temporary workers, contingent workers, contract workers, long-term temps, workers in dual employer situations, on-demand freelance–these workers seem to be ubiquitous in most industrial sectors. These arrangements are impacting work organization, career paths, and health and safety. According to various reports, there were an estimated 17 million workers engaged in some type of temporary employment in the United States in 2013, the most in the nation's history. [MBO Partners] There is also evidence that this upward trend will continue. Complexities of temporary employment arrangements have created some ambiguity over the responsibility for complying with health and safety standards, which can result in increased health and safety risks in the workplace. A growing body of research demonstrates that temporary workers have higher rates of workplace injury [OSHA, 2013; Fabiano, 2008]. According to ProPublica research, temporary workers have double the risk of suffering severe injuries on the job, including crushing incidents, lacerations, punctures and fractures. [Luo,T]

Coordination of activities, events and communication efforts

NIOSH and the NSC held the third r2p track at the NSC conference. Newsletters and social media were used by both to bring attention to events and initiatives, such as the NSC Congress, the Campbell Awards and the Safe-in-Sound Award or other news items.



Co-authorship of publications
NIOSH Science Blog entries

This workgroup authored a *NIOSH Science Blog* on best resources/cases for preventing MSDs (based on contribution by Tom Slavin for the Feb 2013 Council Meeting). A NIOSH expert (Brian Lowe) and Thais Morata co-authored it with external Council members. Several of the Council members provided comments.

http://blogs.cdc.gov/niosh-science-blog/category/ergonomics-2/

Persistent Pain in the Neck! What Resources Help you Prevent MSDs in the Workplace?

Categories: Ergonomics, Manufacturing

January 23rd, 2014 2:56 pm ET - **Tom Slavin, Kristine Krajnak, Brian D. Lowe, Thais C. Morata**

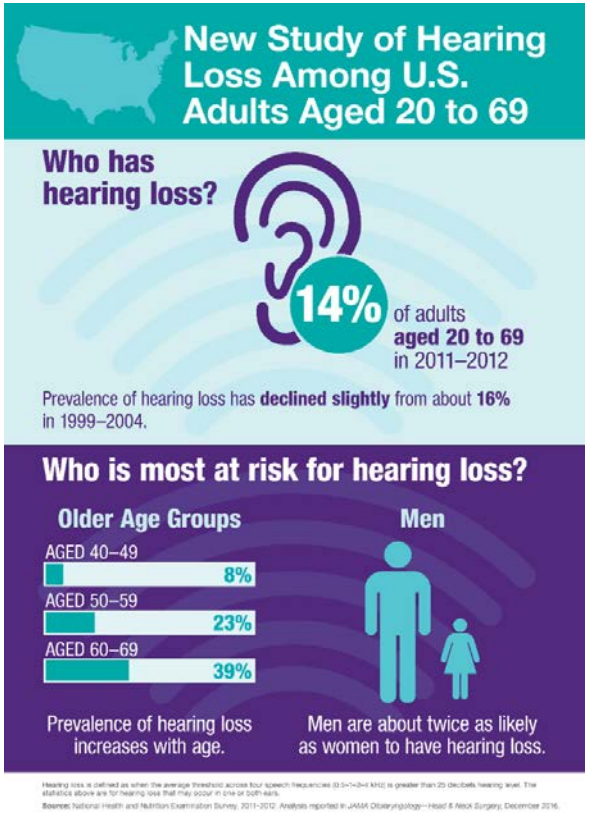
Repetitive tasks, awkward postures, twisting and turning, or forceful exertions at work are often associated with musculoskeletal disorders (MSDs), such as neck or back pain, carpal tunnel syndrome, or tendinitis. These are disorders or injuries that affect muscles, tendons, nerves, discs, ligaments, etc. They remain a leading work-related condition. About 30% of all injuries and illnesses involving lost days from work are associated with repetitive motion and/or overexertion (BLS).

14 Comments - Read more »

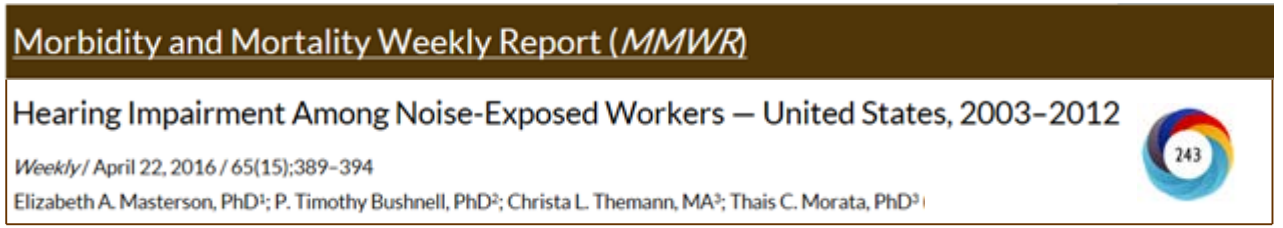
Strategic and Priority Goal

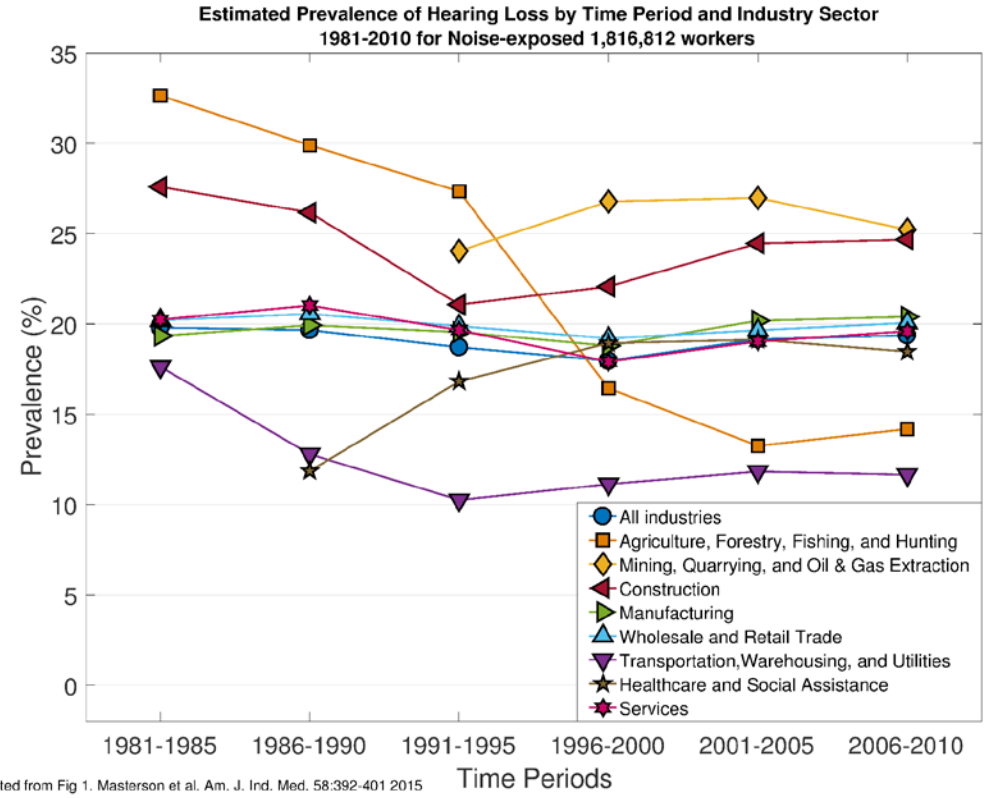
Reduce occupational hearing loss

Research and Surveillance: Updated U.S. Hearing Statistics



Hoffman et al. JAMA Otolaryngology Dec 2016
NIH, National Institute on Deafness and Other Communication Disorders





Adapted from Fig 1. Masterson et al. Am. J. Ind. Med. 58:392-401 2015

Coordination of activities, events and communication efforts

The Safe•in•Sound Award™ was created in 2008 by NIOSH in partnership with the professional organization National Hearing Conservation Association to:

- formally recognize effective practices and
- disseminate the methods of organizations that have achieved results and demonstrated excellence and innovation in hearing loss prevention initiatives.

http://www.safeinsound.us/winners.html

AREA SPECIFIC EXAMPLES

Converting Equipment

- **Area Description:** Drum slitting and disc converting
- **Reason for inclusion into HCP:** Employee exposures could not be validated for a 12 hr shift duration.
- **Controls Implemented:** Acoustical enclosures installed around blower motors
- **Direct Costs:** $600

Before Controls	After Controls
82 - 85 dBA	72 – 76 dBA

- **“**3M Reduced noise in **100%** of areas previously in hearing conservation.
- Eliminated **92%** of areas previously in hearing conservation.
- Removed 195 of 199 employees from the hearing conservation program. Four (4) employees are currently still in the HCP.
- Employees feel better when they are working.”

“Since 2011 UTC businesses have identified and implemented over 250 projects worldwide to reduce noise exposures. Nearly 8,000 employees now have a reduced risk of noise overexposure and physical stress as a result of these efforts.”

Testimonials at http://www.safeinsound.us/impact.html

→ **“Safe in Sound recognition was:**

- Welcome recognition of what Colgate had done prior to 2012, but more importantly…
- A powerful springboard for further successes.”

Outputs

http://www.safeinsound.us/publications.html

Denver, Colorado

NOISE-CON 2013

2013 August 26-28

→ Awarding and promoting excellence in hearing loss prevention, Int Journal of Audiology, 2012

Workplace design solutions

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

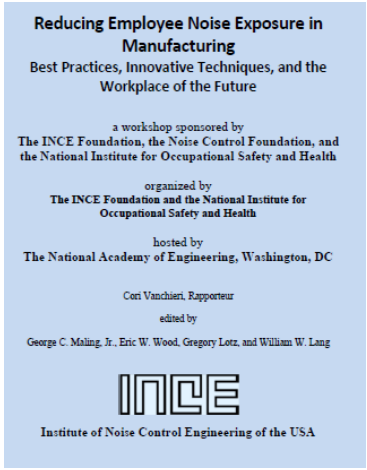
PtD Prevention through Design

Preventing Hazardous Noise and Hearing Loss during Project Design and Operation

2015

→ Uncovering effective strategies for hearing loss prevention, Acoustics Australia Special Issue on Workplace Noise and Vibration – Effects and Control, 2016

Reducing Employee Noise Exposure in Manufacturing: Best Practices, Innovative Techniques, and the Workplace of the Future https://inceusa.org/pub/



Examples of impact of this collaborative initiative

Safe-in-Sound highlighted in OSHA's August 2013 OSHA Technical Manual (OTM), Section III: Chapter 5 – Noise (**APPENDIX G—ALTERNATIVES FOR EVALUATING BENEFITS AND COSTS OF NOISE CONTROL).** The manual provides technical information and guidance to Compliance Safety and Health Officers (CSHOs) who evaluate noise hazards in the workplace.

Round Table "Noise Can Be Beat: We Did it and Won", selected to be in the Virtual AIHce 2016 program

Most popular NIOSH Science Blog to date, following study idea brought up by Council members

NIOSH > NIOSH Science Blog

Recommend Tweet Share

Selected Category: Hearing Loss

So How Accurate Are These Smartphone Sound Measurement Apps?

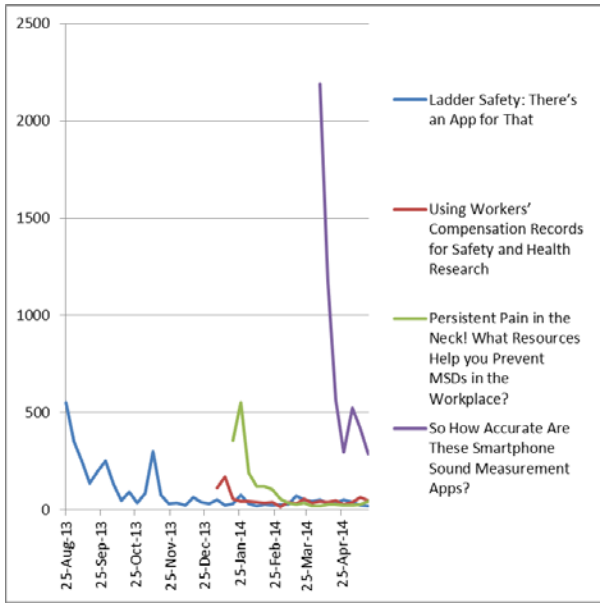
Categories: Hearing Loss, Technology

April 9th, 2014 11:35 am ET - **Chucri A. Kardous, MS, PE and Peter B. Shaw, Ph.D.**

Figure 1. The SoundMeter app on the iPhone 5 (L) and iPhone 4S (R) compared to ½" Larson-Davis 2559 random incidence type 1 microphone (C).

As of June 2013, 60% of all mobile subscribers use smartphones—that's more than 140 million devices. Apple iOS and Google Android platforms account for 93% of those devices [Nielsen, 2013]. Smartphone developers now offer many sound measurement applications (apps) using the devices' built-in microphone (or through an external microphone for more sophisticated applications). The use of smartphone sound measurement apps can have a tremendous and far-reaching impact in the areas of noise research and noise control in the workplace as every smartphone can be potentially turned into a dosimeter or a sound level meter

Reaction measured



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NIOSH Science Blog

New NIOSH Sound Level Meter App

Posted on January 17, 2017 by CAPT Chucri (Chuck) A. Kardous, MS, PE, and Metod Celestina, B.Sc. EE

Image of the main screen of the NIOSH SLM app (shown with a MicW i436 external microphone)

Imagine if workers around the world could collect and share workplace (or task-based) noise exposure data using their smartphones. Scientists and occupational safety and health professionals could rely on such shared data to build job exposure databases and promote better hearing health and prevention efforts. In addition, the ability to acquire and display real-time noise exposure data could raises workers' awareness about their work environment and help them make informed decisions about potential hazards to their hearing.

The idea was so intriguing that in 2014, the NIOSH hearing loss team evaluated 192 sound measurement applications (apps) for the iOS and Android platforms to examine their suitability and accuracy in relation to professional sound measurement instruments (Kardous and Shaw, 2014). Of the 192 apps the team examined, 10 iOS apps met the outlined criteria for functionality, features, and calibration

Strategic and Priority Goal

Improve workplace safety to reduce traumatic injuries

Worker mural by Winold Reiss

Contacts with Objects and Equipment

- 327 manufacturing workers died from work-related injuries in 2012 (CFOI, http://www.bls.gov/iif/oshwc/cfoi/cftb0268.pdf, accessed 5 May 2014). The leading causes of death were contact with objects and equipment (102), transportation incidents (87), and falls (39).

- The leading causes of days away from work cases (BLS, SOII, http://www.bls.gov/iif/oshwc/osh/case/ostb3596.pdf, accessed 5 May 2014) were contact with objects (46,640); overexertion and repetitive motion (46,040); and falls (22,040). There were fourteen industries that reported more than 75,000 nonfatal occupational injuries and illnesses to BLS in 2012; three of these were in the manufacturing sector: transportation equipment manufacturing (75,300), fabricated metal product manufacturing (79,000), and food manufacturing (77,800) (BLS, SOII, http://www.bls.gov/news.release/archives/osh_11072013.pdf, accessed 5 May 2014).

Research Impact

IG 1.2: Injuries/fatalities due to contact with objects/equipment. Projects 9278875 (and preceding ones). Adoption by industry.

- Developed a systematic approach to evaluate risk with industrial machinery
- Injury control strategies identified and introduced to manufacturers and end users
- ANSI B11-TR3 guidelines introduced to six companies
- Partnership to conduct the study with qualified private sector partners
- Validated the TR3 risk assessment/risk reduction methodology in real world
- Demonstrated that safety improvements provide productivity improvements
- Developed sensor technology to mitigate risk
- Transferred the concept to other machinery (stump cutters)
- NIOSH and industry partner (Vermeer) designed, built and tested different prototype systems, which were tested in the field, improved and completed.
- A final, safer system has been standard equipment of manufactured machinery/equipment since 2008.

Co-authorship of publications
NIOSH Science Blog entries

This workgroup authored a *NIOSH Science Blog* asking for input related to the Control of Hazardous Energy. NIOSH experts co-authored with external Council members http://blogs.cdc.gov/niosh-science-blog/2014/07/07/loto/

NIOSH Science Blog

Safer Healthier Workers

NIOSH > NIOSH Science Blog

Recommend Tweet Share

A Wrench in the Gear: Lockout/tagout in the food industry

Categories: Manufacturing

July 7th, 2014 8:43 am ET - **Jim Harris, Ph.D., P.E. ; Susan Afanuh, MA; Frank Renshaw, Ph.D., CIH, CSP; David L. Parker, MD, MPH; Theodore Braun, MBA; Thomas Cunningham, PhD**

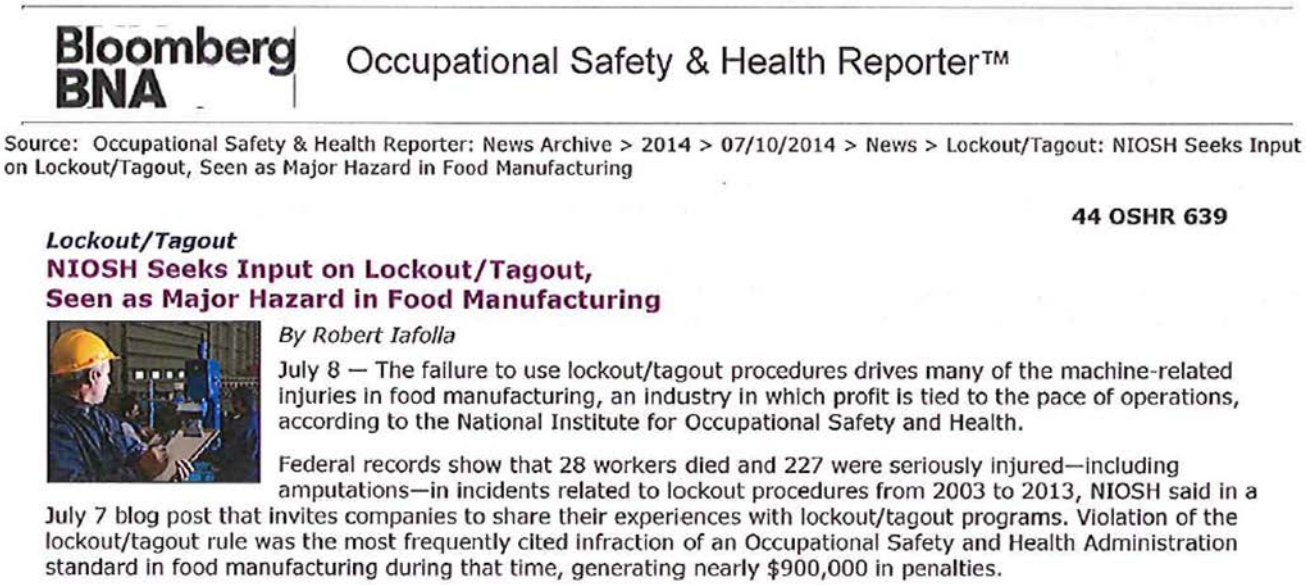
The food manufacturing industry includes animal slaughtering as well as the processing and packaging of meat, dairy, fruit, vegetable, grain, seafood, beverages, and bakery products. The industry employs nearly 1.5 million workers.[1] Work in food manufacturing is typically fast-paced and workers can face exposure to hazards such as slips trips and falls, musculoskeletal disorders, and machine-related injuries.[2]

Although there has been improvement in recent years, workers in food manufacturing have a higher rate of

Good reach and response, even if they provided limited input.

Picked up by several websites and news agencies.

- http://safety.blr.com/workplace-safety-news/equipment-and-process-safety/lockout-tagout-LOTO/NIOSH-Lockouttagout-failures-cause-numerous-injuri/
- http://ehstoday.com/safety/lockouttagout-programs-falling-short-food-industry
- http://www.foodqualitynews.com/Regulation-and-safety/NIOSH-seeks-lockout-tagout-input
- http://www.shrm.org/hrdisciplines/safetysecurity/articles/pages/hazardous-energy-food-manufacturing.aspx
- http://www.pinpointnews.net/wordpress/niosh-highlights-prevalence-of-machine-related-injuries-in-food-industry/



Bloomberg BNA Occupational Safety & Health Reporter™

Source: Occupational Safety & Health Reporter: News Archive > 2014 > 07/10/2014 > News > Lockout/Tagout: NIOSH Seeks Input on Lockout/Tagout, Seen as Major Hazard in Food Manufacturing

44 OSHR 639

Lockout/Tagout

NIOSH Seeks Input on Lockout/Tagout, Seen as Major Hazard in Food Manufacturing

By Robert Iafolla

July 8 — The failure to use lockout/tagout procedures drives many of the machine-related injuries in food manufacturing, an industry in which profit is tied to the pace of operations, according to the National Institute for Occupational Safety and Health.

Federal records show that 28 workers died and 227 were seriously injured—including amputations—in incidents related to lockout procedures from 2003 to 2013, NIOSH said in a July 7 blog post that invites companies to share their experiences with lockout/tagout programs. Violation of the lockout/tagout rule was the most frequently cited infraction of an Occupational Safety and Health Administration standard in food manufacturing during that time, generating nearly $900,000 in penalties.

Development of new online resources

Proposal of new NORA webpage with Resource Guide, proposed and developed by Council members (dev site below)

CONTROL OF HAZARDOUS ENERGY (LOCKOUT/TAGOUT)

It *is* a matter of life and death. Here you will find information on regulatory requirements, general guidance and procedures that your company can use to achieve an effective Lockout Tagout Program and prevent unexpected energizing, start-up or release of stored energy which could harm or kill workers. Machine injuries related to Lockout often occur when an employee services or repairs a machine or tries to clear a jam but fails to de-energize the machine and lockout sources of energy. Often the failure to *use* Lockout procedures is one of OSHA's annual top 10 most frequently cited workplace safety violations. Injuries and fatalities that happen for failure in implementing a Lockout Program are much costlier than the citations (not only in economic terms). A comprehensive, diligently planned and executed Control of Hazardous Energy (Lockout) Program protects the life, and the safety and health of workers; it is a very important part of machine maintenance.

Control of Hazardous Energy (Lockout/Tagout) Resource Guide

The Control of Hazardous Energy Lockout Tagout Guide offers sample Lockout materials and templates to help with the implementation of effective strategies to control the release of hazardous energy. Members of the Manufacturing Sector Council compiled, reviewed, and adapted resources to help manufacturers start or improve and maintain their

Thank you!

tmorata@cdc.gov

https://www.cdc.gov/niosh/programs/manuf/

Effects of exposure, solubility and genetic factors on beryllium sensitization and chronic beryllium disease among short-term beryllium industry workers

Christine R. Schuler, PhD
M. Abbas Virji, ScD
NIOSH

The findings and conclusions in this presentation are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health

The workplace

- Primary manufacturing facility
  - Receives beryllium hydroxide feedstock from company's mine/mill
  - Produces beryllium oxide powder for ceramics
  - Produces beryllium metal
  - Produces various alloys – most common is copper-beryllium alloy

Sensitization and CBD

- Sensitization (BeS) – beryllium lymphocyte proliferation test (BeLPT); confirmed positive (abnormal) BeLPT
- Chronic beryllium disease (CBD) – clinical evaluation with biopsies; presence of granulomas or other abnormalities in sensitized person
- A study had been conducted in 1993-94
  - BeS = 6.9%; CBD = 3.8%
- Changes made in late 1990s at highest-risk work processes

Memorandum of Understanding

- In 1997, the company approached NIOSH to conduct collaborative research
- In 1998, a Memorandum of Understanding was signed
- In 1999, a second survey was conducted at the primary manufacturing facility
- The goals were to understand the current status of BeS and CBD, and determine effectiveness of engineering controls

Epidemiologic survey in 1999

- Consenting workers tested for sensitization and CBD
- Medical and work history questionnaire
- Eligible – current employees with no CBD
- Participants divided by participation in earlier survey (1993-94)
- First set of studies on those hired after 1994 (“short-term workers”)

Job-exposure matrix: personal exposure estimates

- Full-shift personal exposure samples (1999; n=4,022)
- Area and task samples (1994-99; n=76,349)
- Job-exposure matrix created
- Work histories applied to job-exposure matrix to create:
  - Average annual exposure ($\mu g/m^3$)
  - Cumulative exposure ($\mu g/m^3$-year)
  - Highest-job-worked ($\mu g/m^3$) – a type of relative peak exposure

Objective – Exposure-response relationships

- Historically, exposure-response relations inconsistent
- Hampered by:
  - Exposure misclassification
  - Exclusion of exposure-related factors and genetic susceptibility
  - Imprecise understanding of timing of BeS or CBD onset
- Our studies:
  - More precise exposure estimates
  - Information on additional exposure factors
  - Information on genetic factors
  - Information on dermal exposure
  - For short-term workers, less exposure misclassification/more precise timing

Earlier results from this short-term worker cohort

- N = 264
  - 91% participation, median 21 months tenure (0.3-73 months)
- BeS = 9.8% (26/264)
  - Average exposure, highest-job-worked
- CBD = 2.3% (6/264)
  - Cumulative exposure
- Higher-risk job processes:
  - Metal/oxide production (BeS), alloy melting and casting (BeS, CBD)
  - No BeS or CBD in admin-plant or admin-office
- Multiple exposure pathways for BeS (inhalation, skin)
  - Skin symptoms, peak exposure metrics associated with BeS

Study aims

- Are exposure-response relations for BeS and CBD different by solubility factors?
  - Soluble salts vs. not soluble salts
- Are exposure-response relations different for those with various higher-risk genetic markers?
  - Glu69 carrier status
  - Allele electronegativity

Methods

- Short-term workers (n=264)
- Same health outcome, questionnaire data collected in 1999
- Same exposure estimates:
  - Average, cumulative, highest-job-worked
- New data – solubility of Be materials
- New data – genetic markers

Solubility classification (chemical factors)

Compounds	Example Processes	$t_{1/2}$ (days) Lung Fluid	Solubility Class
Beryllium salts	Reduction furnace	0.7 - 15	Soluble
Copper-beryllium alloy	Master alloy	319	Poorly soluble
Beryllium oxide	Oxide production and machining	153 - 3,657	Poorly soluble
Complex silicates	Ore extraction	425 - 160,000	Poorly soluble

- Class relative to rate of mechanical clearance from lung
- Class assigned to jobs in work histories based on forms of Be used

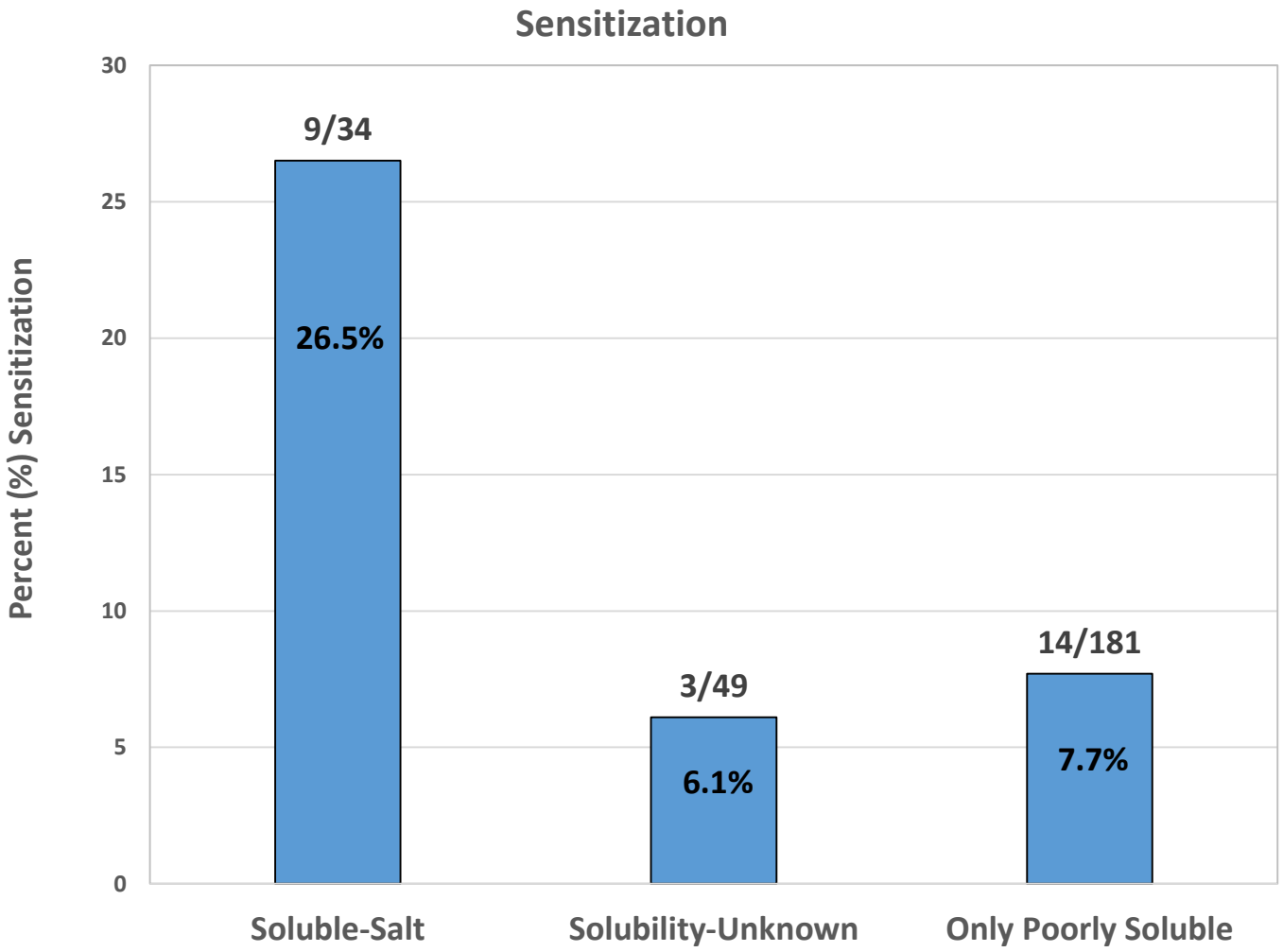
Genetic data

- Separate consent obtained
- Genetic research separate from collaborative work
- *HLA-DPB1*^{Glu69}
  - More common in CBD, BeS; also common in population
- Variables:
  - Glu69 carrier status: yes, no for at least one copy of Glu69
  - Allele electronegativity: -9 charge, -7 charge, -9 *or* -7, other charge

Data analysis

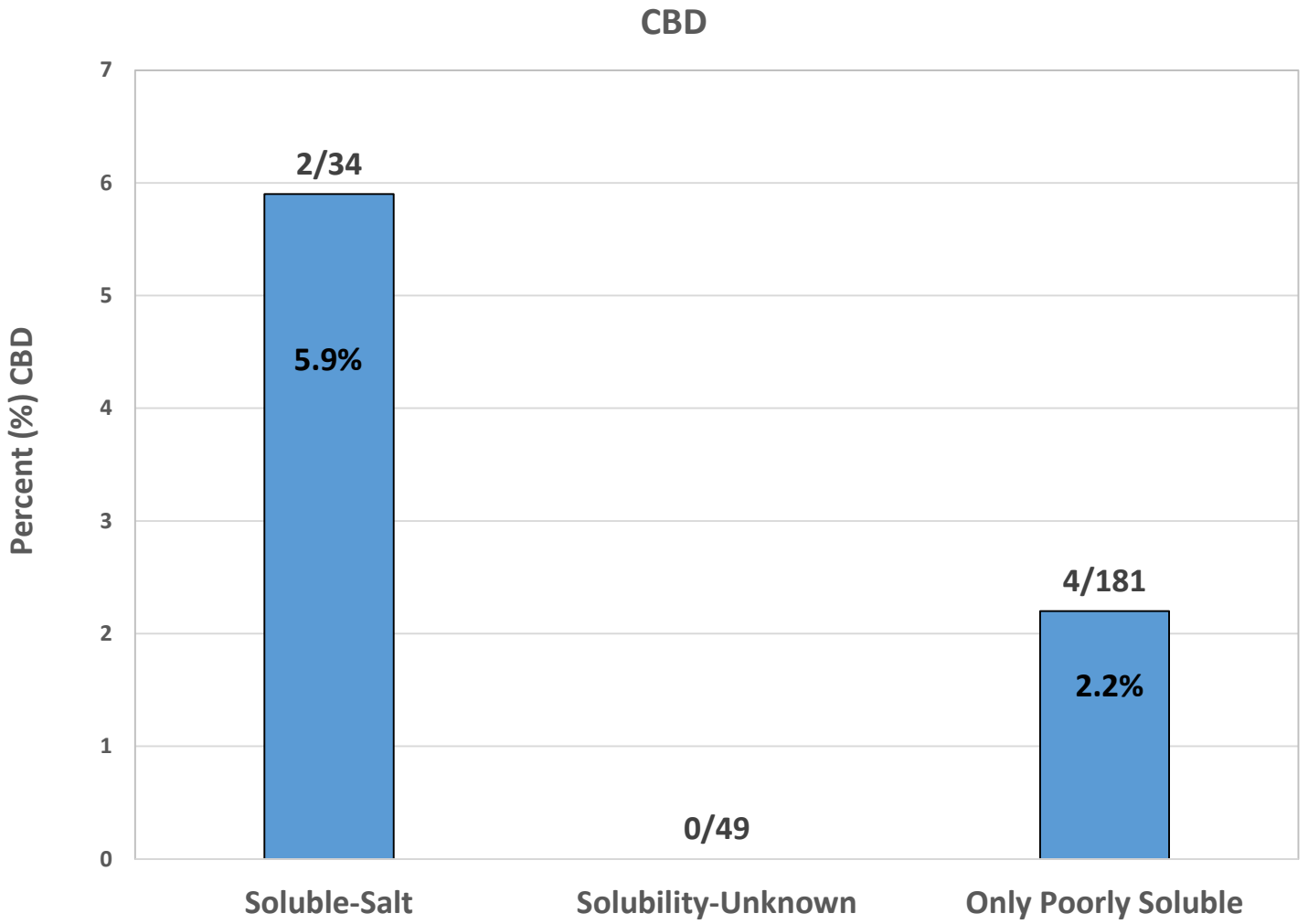
- Logistic regression models:
  - Splined and log-transformed summary exposure metrics
  - Covariates for solubility, genetic markers, and interactions
- Odds ratios and prevalence:
  - Overall and stratified by solubility and genetic markers

Results – BeS by solubility



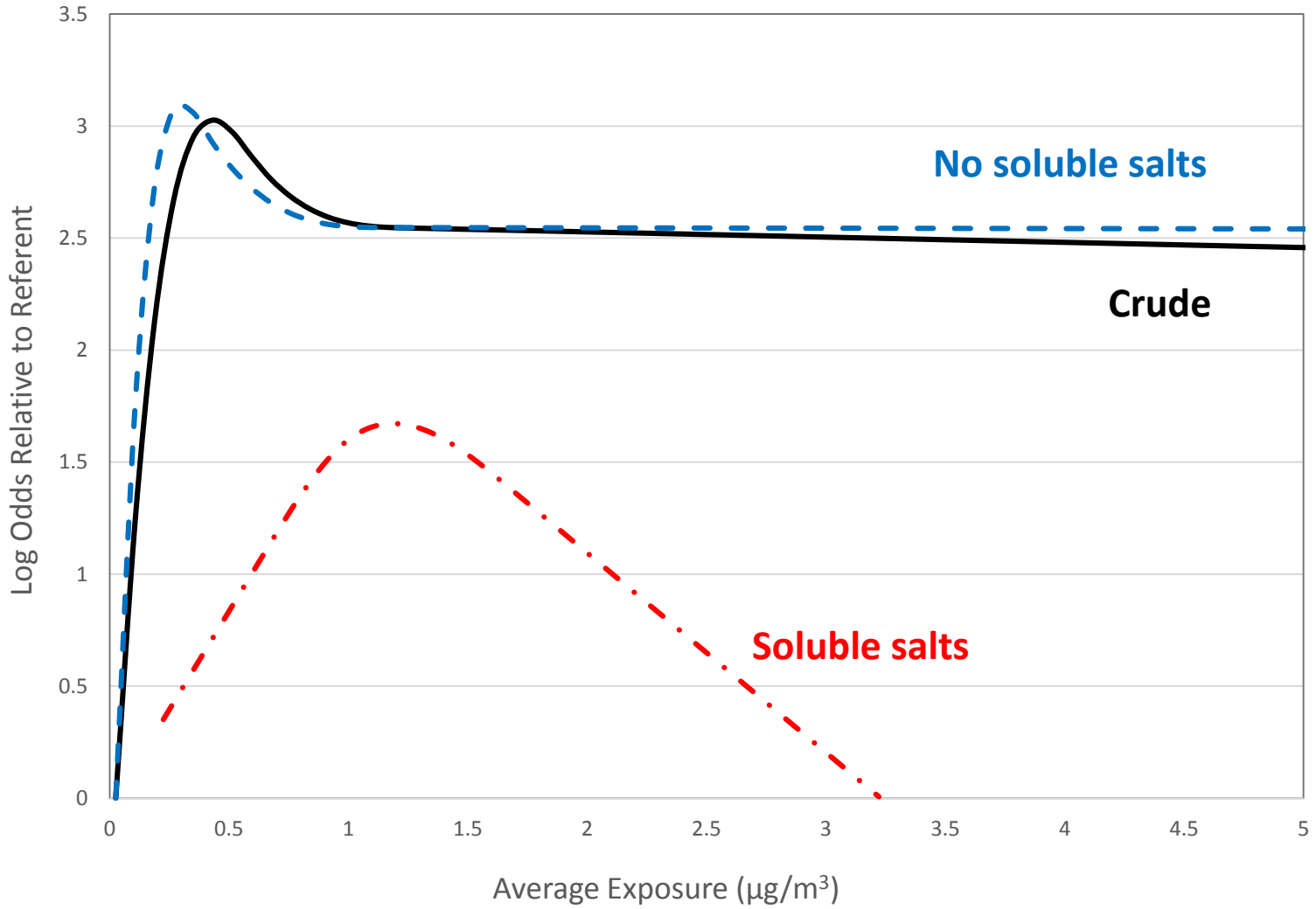
BeS (cohort) = 9.8%

Results – CBD by solubility



CBD (cohort) = 2.3%

Splined average exposure and sensitization - solubility



Summary of solubility results

- Soluble salt exposure associated with higher prevalence of BeS
- Soluble salt exposure also associated with higher CBD
  - All CBD also worked with poorly soluble materials; small numbers
- Non-linear association for BeS and exposure
- Stratified analysis suggests interaction
  - Not significant in model

Results – genetic study participation

- 157 (59% of 264) short-term workers took part in genetic study
- Similar to overall survey population for gender, race, age at hire, tenure
- Similar for BeS = 8.9% (14/157); CBD = 2.1% (3/157)
- Analyses for genetic variables done on reduced dataset
- Small numbers precluded CBD-only analyses

Results – genetic markers

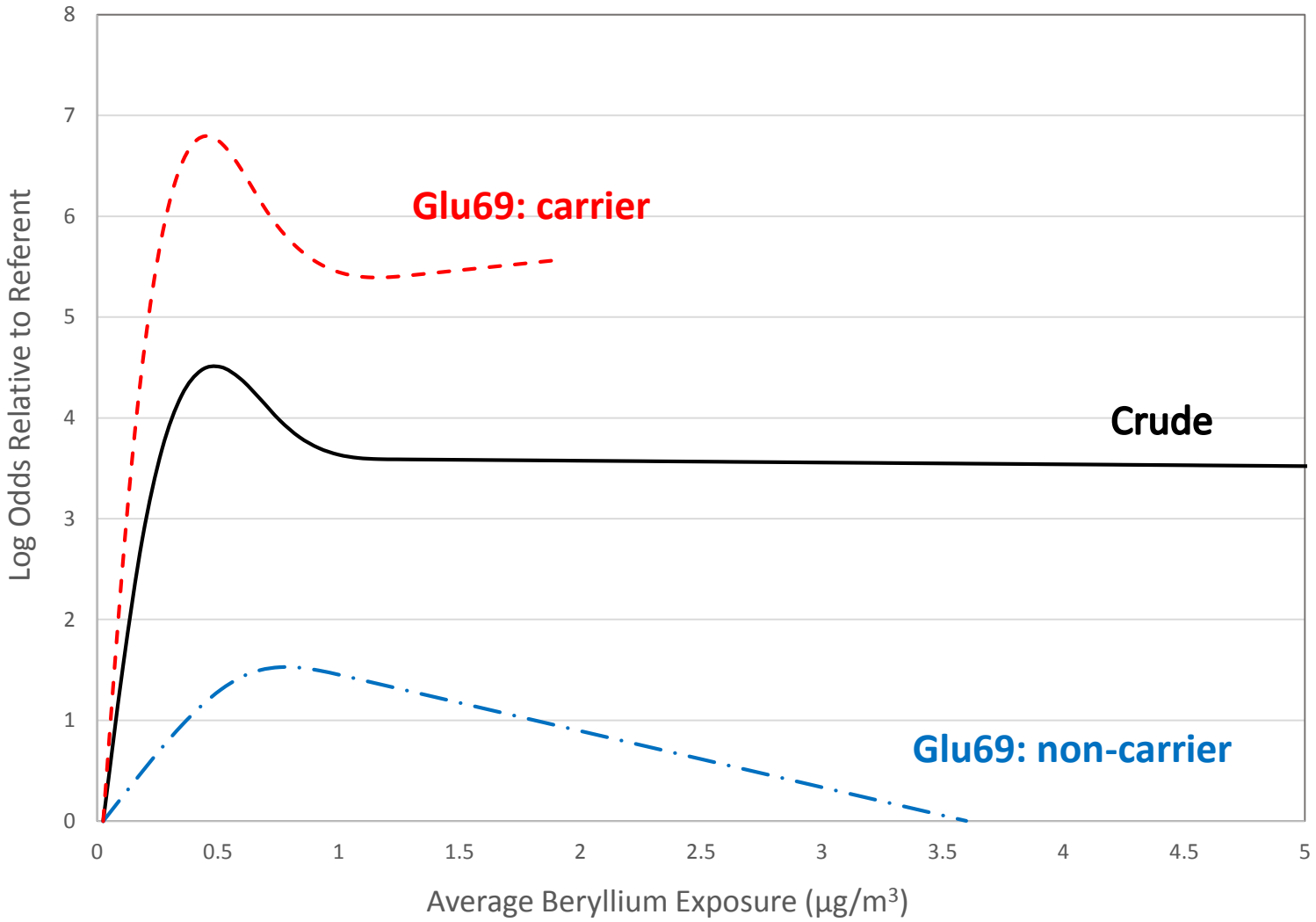
- Glu69 carrier status:

Glu69	Prevalence	OR (95% CI)
Carriers	41.4%	4.0 (1.3 – 15.2)
Non-carriers	58.6%	*(referent group)*

- Allele charge status:

Charge	Allele prev.	OR (95% CI)
-9	13.4%	7.2 (1.7 – 31.9)
-7	25.5%	3.3 (0.8 – 13.9)
-9 *or* -7	38.9%	4.5 (1.4 – 17.1)
Other	61.1%	*(referent group)*

Splined average exposure and sensitization - genetics



Summary of Genetic Results

- Both exposure and genetic factors were associated with BeS
- No separate analysis for CBD, too few cases
- Strong non-linear association between BeS and exposure among Glu69 carriers
- Stratified analysis suggests interaction
  - Not significant in model

Discussion

- Solubility of beryllium materials is a relevant factor
  - Consistent with the kinetics and dynamics
  - Partly masked by narrow range, high concentration soluble exposures; few exposed
- Genetics relevant for BeS
- Exposure-response was non-linear
- Interaction between solubility and exposure suggested
  - Different shape for soluble salts, not significant
- Interaction between genetics and exposure suggested
  - Different shape for non-carriers, not significant

Take home

- Deciphering risk factors for BeS and CBD requires:
  - A multidisciplinary approach
  - Valid and precise estimates of historical exposure
  - An understanding of physicochemical properties
  - Multi-pathway exposure assessment
  - Mechanistic-based exposure-response analyses
  - An understanding of markers of genetic susceptibility
- What is next?
  - Evaluation of long-term worker cohort
  - Dose modeling

Thank you

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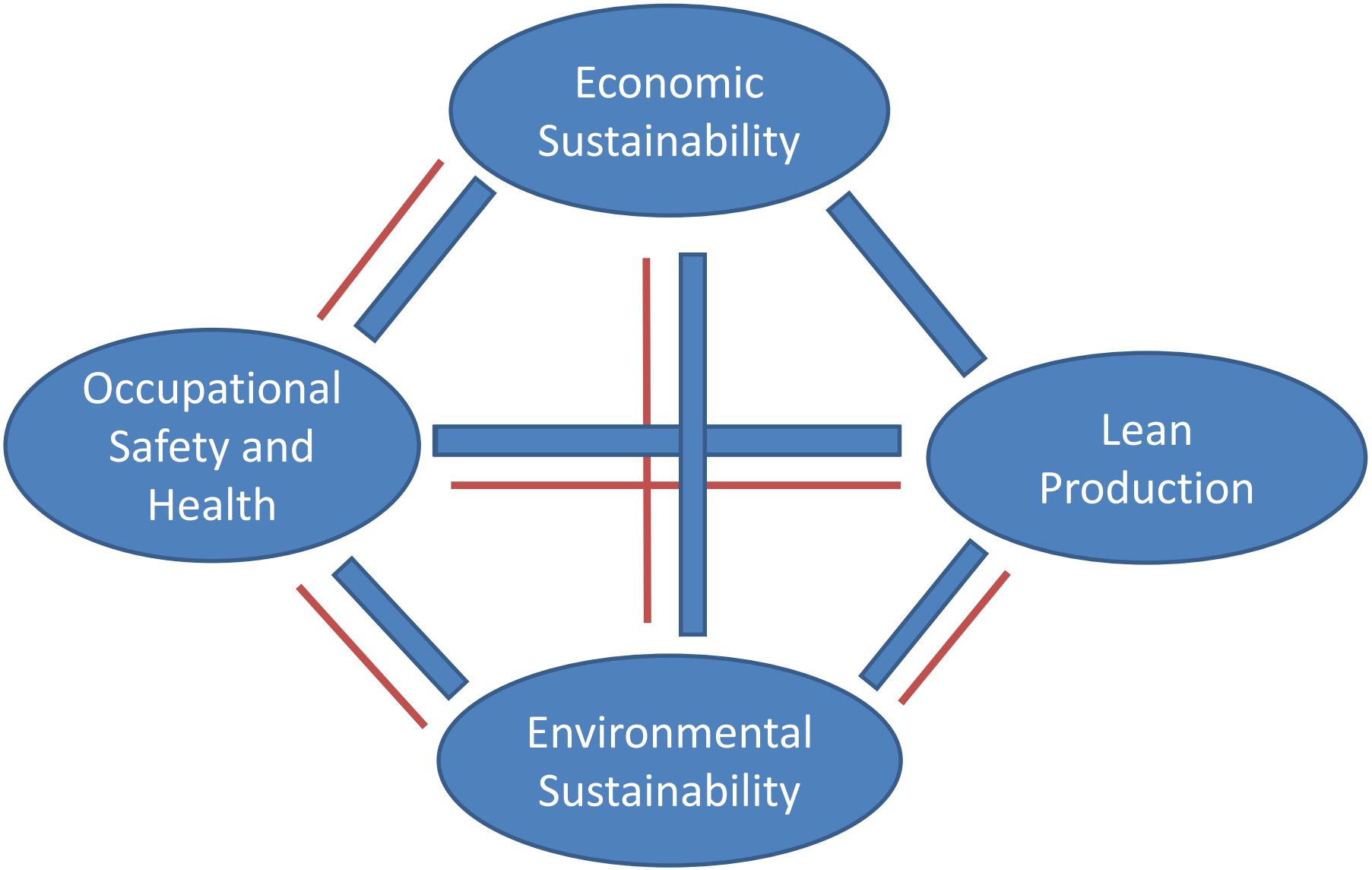
The contributions of occupational safety and health to organizational productivity and environmental goals

2017 Expanding Research Partnerships: State Of The Science Conference at the Colorado School of Public Health, CU Anschutz Medical Campus, Aurora, CO
June 21-22, 2017

Tim Bushnell
Economics Research and Support Office
NIOSH

The findings and conclusions in this presentation are those of the authors and do not necessarily represent the views of NIOSH


Economic Sustainability
Occupational Safety and Health
Lean Production
Environmental Sustainability
Potential support
Potential conflict

Lean Production

(aka TQM, 6 Sigma, etc.)

"Systemic"

Focus on goals that improve systemic coordination,
rather than productivity or costs of individual activities

"Developmental"

Focus on continuous improvement of work processes
by **workers**, rather than relying only on engineers or planners
to generate less frequent changes in process

Bushnell, PT, Transformation of the American manufacturing paradigm. Garland. 1994
Womac JP, Jones DT, Roos D. The machine that changed the world. Rawson Associates, Macmillan. 1990

The systemic goals

Quality: Central value of organization, emphasis on prevention, zero defects

Synchrony: producing on as-needed basis, JIT delivery, zero inventories

The systemic vision

Continuous Flow----from raw material to final delivery,
tightly hitched to customer demand

Quality: Key Tools

- Involvement of workers in quality control analysis and problem solving
- Close process monitoring and use of statistical process control
- Involvement of QC personnel in product and process design
- Close relationship with suppliers on product design and quality problems
- Preventive maintenance
- Housekeeping: Order and cleanliness
- Field study of customer needs and experience

Quality: Value

- Reducing defect rates save time and expense of
  - inspection to identify defects
  - correcting defects
  - wasted materials
  - product returns
- Prevention of errors and malfunctions prevents process interruptions and equipment damage
- Reducing process variation often makes processes more efficient
- Reducing process variation makes downstream processes more efficient
- Protects and builds reputation with customers

Synchrony

Key Tools

- Flexibility: Short changeover and set-up time—drawing on worker skills
- Quality control—drawing on worker skills
- Close relationships with suppliers who deliver just-in-time

Other tools

- Visual systems for signaling downstream production needs
- Forced, stepwise, reduction of inventories to force improvements in flexibility and quality
- Final product production schedules that closely track customer orders
- Cellular production: Integration of separate stages of production in one location for families of similar products (with worker cross-training)

See Hall RW. Zero Inventories. Dow Jones-Irwin. 1983

Synchrony: Value

- Reduces cost of inventories
  - Transport
  - Storage—space and energy
  - Financial capital costs
  - Tracking and counting
  - Spoilage and deterioration
- Facilitates adjustment of processes to meet downstream processs and customer needs

  ---closer proximity of processes and visual clarity

  ---immediate feedback on quality problems
- Develops opportunities for speeding transfer between processes, including progress toward automation
- Ability to provide more product variety efficiently

Environmental Sustainability: Goals for Employers

- Reduce use of materials, energy, and water
- Reduce waste
- Shift to less toxic materials
- Dispose of harmful waste in way that protects people and environment
- Direct management of environmental impacts (for businesses operating directly on land or water)
  - Avoiding: overharvesting and depletion, erosion, habitat destruction,
  - Maintaining: ecosystem balance and diversity
  - Ecological restoration: cleanup, restoring natural water drainage, species management
- Purchase resources from suppliers that meet sustainability goals
- Enable customers to meet sustainability goals

Environmental Sustainability: Value for Employer

- Discovery of cost savings:
  Reduced cost of materials, energy, water, waste disposal
  Example: EDF Climate Corps

- Increased value to customers who save money or value sustainability

- Reduced risks of remediation and compensation costs due to environmental damage

- Long-run costs of complying with regulations lower: longer lead time for developing technology; more uniform standards; cooperative relationship with regulators

- Discovery of product/service improvements; new products
  --Sustainability-related products and services
  --Other products and services

- Attract and retain employees with environmental values

Environmental Sustainability as a Focus that Supports Employer Economic Sustainability

KPMG International. Corporate sustainability: A progress report. 2011

Survey of 378 senior executives, and interviews with key informants

"For a growing number …., [Sustainability] has become the strategic lens through which they view their businesses. For these organizations, sustainability offers an undeniable opportunity to gain competitive advantage, drive innovation and generate real bottom-line results."

Percent saying biggest benefit of sustainability would be increased profitability:

2008 31% → 2010 48%

Environmental Sustainability as a Focus that Supports Employer Economic Sustainability

Nidumolu et al. study of sustainability initiatives of 30 large corporations over time*

"Our research shows that sustainability is a mother lode of organizational and technological Innovations that yield both bottom-line and top-line returns"

"The initial aim is usually to create a better image, but most corporations end up reducing costs or creating new businesses as well."

*Ram Nidumolu, CK Pralahad, and MR Rangaswamy, Why sustainability is now the key driver of innovation. Harvard Business Review, Sept. 2009

Commonalities of Environmental Sustainability and Lean Production

- Greater focus on control of processes
- Continuous improvement of technology
- Emphasis on prevention and the long-range view
- Closeness to suppliers and customers—the larger system
- Primary focus is on physical aspects of process, not on costs

Occupational Safety and Health Outcomes: Value for Sustainability

Reduced injury and illness

→ Lower workers' compensation costs, other medical expenses
→ Less absence, presenteeism, turnover, disruption, delay

Reduced symptoms: pain, discomfort, fatigue, sleepiness, stress

→ Less presenteeism, absenteeism, turnover

Reduced material and property damage associated with injury incidents

Reduced harms to customers and public associated with injury incidents

Occupational Safety and Health Tools: Value for Sustainability

Safety committees and participatory ergonomics

→ Worker participation (Lean production)

Incident investigation

→ Root cause analysis (Lean production – quality)

Ergonomics

→ Reduction of un-needed motions (Lean prod.)

Occupational Safety and Health Tools: Value for Sustainability

Hierarchy of controls

→ Emphasis on elimination of hazardous materials before safe handling and disposal (Environ. Sust.)

→ Reduction of non-value-adding activities such as transport and storage of inventories (Lean prod.)

Housekeeping

→ Housekeeping (Lean prod.)

Training

→ Training (Lean prod.)

Maintenance

→ Maintenance (Lean prod. and Environ. Sust.)

Occupational Safety and Health: Fundamental Contribution to Work Culture That Supports Sustainability

Prevention

Control of process

More focus on physical process, less on cost goals

Respect for workers and their contributions

Need for integration of OSH, lean production and environmental sustainability

Conflicts between OSH and lean production and environmental sustainability also exist.

--Environmental – OSH conflicts (Schulte et al. 2013, Roelofs et al. 2000)

--Lean production –OSH conflicts (Koukoulaki 2014)

But if conflicts are to be resolved in favor of worker safety and health, it may be helpful to highlight ways in which OSH can contribute to achieving lean and environmental goals.

References in previous slide

Koukoulaki T. The impact of lean production on musculoskeletal and psychosocial risks: An examination of sociotechnical trends over 20 years. (2014) Applied Ergonomics vol. 45 pp.198-212.

Roelofs CR, Moure-Eraso R, Ellenbecker MJ. Pollution prevention and the work environment: The Massachusetts experience. (2000) Applied Occuaptional And Environmental Hygiene. Vol. 15(11) pp.843-850.

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