
THE US DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTERS FOR DISEASE CONTROL AND PREVENTION

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND
HEALTH (NIOSH)

BOARD OF SCIENTIFIC COUNSELORS (BSC)

SEVENTY-SEVENTH MEETING
VIRTUAL ON ZOOM, OPEN TO THE PUBLIC
MAY 19, 2021

Table of Contents

| | |
|---|----|
| Summary Proceedings | 3 |
| Attendees..... | 3 |
| Welcome and Meeting logistics..... | 3 |
| Announcements, Introductions, and Agenda | 4 |
| Announcements..... | 4 |
| Introductions | 4 |
| Agenda | 5 |
| Director’s Opening Remarks | 6 |
| The Evolution of Workplace Fatigue Research | 10 |
| Presentation..... | 10 |
| Discussion | 12 |
| NIOSH Center for Work and Fatigue Research | 14 |
| Presentation..... | 14 |
| Discussion | 18 |
| Emerging Issues in Workplace Fatigue and Fatigue Management in Agriculture, Forestry and Fishing..... | 21 |
| Presentation..... | 21 |
| Discussion | 25 |
| Fatigue Management: Technological Advances and Fatigue Risk Management Systems | 28 |
| Presentation..... | 28 |
| Discussion | 34 |
| COVID-19 and Workplace Fatigue: Lessons Learned and Mitigation Strategies | 36 |
| Presentation..... | 36 |
| Discussion | 42 |
| Global Perspectives on Workplace Fatigue and Fatigue Risk Management..... | 45 |
| Presentation..... | 45 |
| Discussion | 48 |
| Public Comment..... | 50 |
| Action Items..... | 50 |
| Certification Statement..... | 51 |

Summary Proceedings

The Seventy-Seventh meeting of the National Institute of Occupational Safety and Health (NIOSH) Board of Scientific Counselors (BSC) was convened on Wednesday, May 19, 2021 via Zoom. The BSC met in open session in accordance with the Privacy Act and the Federal Advisory Committee Act (FACA).

Attendees

Kyle Arnone - Member
Lauren Barton, MD - Member
Casey Chosewood, MD
Louis Cox, PhD - Member
Maryann D'Alessandro, PhD
Cristina Demian, MD - Member
Mary Doyle – Member
KC Elliott
Michael Foley - Member
Jessica Graham, PhD - Member
John Howard, MD - Director
Grace Lemasters, PhD - Member
Steven Lerman, MD - Member
Patrick Morrison - Member
Emily Novicki - DFO
Kimberly Olszewsky, DNP - Member
Stephen Popkin, PhD
Tiina Reponen, PhD – Member
Kyla Retzer
Robert Roy - Member
Marc Schenker, MD - Member
Christina Spring
Judith Su, PhD - Member
Imelda Wong, PhD

Welcome and Meeting logistics

Ms. Novicki called to order the open session of the Seventy-Seventh meeting of the NIOSH BSC at 10:00 am Eastern Time (ET) on Wednesday, May 19, 2020. A roll call of all BSC members confirmed that a quorum was presented. The roll was also called following each break and lunch to ensure that quorum was maintained. Quorum was maintained throughout the day. A list of meeting attendees is appended to the end of this

document as Attachment A. No conflicts of interest (COIs) were declared. Members of the public were notified that they would remain in listen-only mode until the Public Comment period.

Announcements, Introductions, and Agenda

Announcements

Dr. Reponen welcomed everyone and wished NIOSH a happy birthday, as it is celebrating its 50th anniversary. She invited new member Dr. Kimberly Olszewski to introduce herself to the group, and then asked each additional Board member to briefly introduce themselves.

Introductions

Dr. Olszewski has 31 years of experience in occupational medicine. She has a dual role as a nurse practitioner in occupational medicine in Pennsylvania, and also as the director of an NP and DNP program and holding an endowed professorship at Lynchburg University in Pennsylvania. This is one of the state universities. She was inducted as President of American Association of Occupational Health Nurses (AAOHN) in April of this year.

Dr. Reponen is a professor at the University of Cincinnati, with expertise in exposure assessment, particularly related to aerosols and bioaerosols.

Mr. Aronone is the Director of Collective Bargaining at the American Federation of Teachers with expertise in collective bargaining and labor relations. He has also done research on workplace stress.

Dr. Barton has worked in occupational medicine for many years. She is Chief Physician, and while her job has stayed the same, has changed employers several times, from Chrysler, then with Fiat, and now that Peugeot has come on, with Stellantis.

Dr. Cox is a professor at the University of Colorado, and President of Cox Associates, a consulting company specializing in health and safety, and environmental risk analysis. He is also editor-in-chief of the journal *Risk Analysis* and interested in probabilities of health outcomes.

Dr. Demian is an associate professor at the University of Rochester Medical Center. She is an occupational medicine physician and serves as the Medical Director and Program Director for a clinic that is part of a New York State Occupational Health Clinic Network. This is a relatively unique funding mechanism from the New York State Department of Health to provide prevention and treatment services for underserved workers.

Ms. Doyle is the Deputy Director of the Johns Hopkins Education and Research Center, with a specialty in occupational health nursing.

Mr. Foley is an economist with the SHARP program at the Washington State Department of Labor and Industries, with a focus on precarious work and vulnerable workers, temporary workers, and the economic and social consequences of injury.

Dr. Graham is Director and Head of Product Quality & Occupational Toxicology at Genentech. Her focus is occupational health and safety in the pharmaceutical field, chemical industry, and consumer product industry.

Dr. Lerman retired from ExxonMobile a year ago after a 30-year career and was involved in fatigue risk management. Currently he is consulting for several entities related to COVID on how to manage through this pandemic.

Dr. LeMasters is Professor Emerita at the University of Cincinnati Department of Environmental Health and also Adjunct Professor. She has been doing occupational and environmental epidemiology for over 35 years and serves as the Co-Chair of the National Firefighter Registry Subcommittee of the BSC.

Mr. Morrison works for the International Association of Firefighters, which represents about 324,000 firefighters across the U.S. and Canada. He also has 39 years of experience in the Fire Service as a firefighter. His expertise is in occupational health and safety for first responders and labor relations. Mr. Morrison also co-chairs, with Dr. LeMasters, the National Firefighter Registry Subcommittee.

Mr. Roy is a toxicologist at 3M Company in St. Paul and an adjunct professor at the University of Minnesota and Indiana University in environmental health sciences. His specialty is occupational toxicology, developing health-based exposure limits for workers and consumers.

Dr. Schenker is an occupational physician and epidemiologist, as well as Distinguished Professor Emeritus at the University of California at Davis in public health sciences and medicine. He has worked on many health outcomes, but particularly pulmonary and reproductive health hazards, and in the past years has been very involved in immigrant worker health.

Dr. Su is an assistant professor in optical sciences and biomedical engineering at the University of Arizona. Her specialty is the development of ultrasensitive optical sensors for a wide variety of applications, in particular medical diagnostics as well as environmental monitoring.

Agenda

Dr. Reponen reminded the Board that the meeting would have a new format. Instead of having several different topics, we're going to focus on one topic in each meeting. The topic for this meeting is work-related fatigue. The Board needs to develop with three to five action items. Dr. Reponen asked that members, as they listen to the presentations, think particularly that, what action items would you recommend for NIOSH to seriously consider.

Some of the recommendations could be on building a partnership with a particular organization, consider adding a new variable to a data collection, change communication strategies to reach new audiences, or advise on how to translate research to practice. Those are just examples; there could be also other things. Additionally, most of the presenters also have specific questions relating to their topic that they are presenting that the Board will discuss. At the end of the day, the Board will have time flesh out these action items. Dr. Reponen and Ms. Novicki, will take note of potential action items as they arise.

After Dr. Howard's opening remarks, there are six presentations relating to different aspects of workplace fatigue.

Director's Opening Remarks

Dr. John Howard, MD

Director

National Institute for Occupational Safety and Health

Centers for Disease Control and Prevention

Dr. Howard welcomed the Board members and directed their attention to the Director's Opening Remarks document. He invited Board members to ask questions, noting that he may need to get back to the members at a later date because NIOSH doesn't necessarily have all the subject matter experts at the meeting.

The FY 2021 budget is \$345.3 million, which is actually an increase, of \$2.5 million from FY 2020. As some may know, NIOSH's budget is always reduced in the President's proposed budget. It's always a "nail biter" as NIOSH through the appropriations cycle. In the last four or five years, NIOSH has been pleasantly surprised that Congress has not agreed with the President's proposed budget. In FY 2021, Congress appropriated a \$1.5 million increase to create a new Center for Excellence in *Total Worker Health*[®] for workplace mental health. NIOSH is currently reviewing applications. Additionally, NIOSH receive a \$1 million increase to support underground mine evacuation technologies and human factor issues.

The current President's submission of the FY 2022 budget was later than because this is the turnover of a new administration and came out on April 9. It proposes level funding, and then NIOSH will wait to see what the Congress decides. Dr. Howard hopes Congress might give NIOSH some additional funding, not earmarked, but instead funding that would increase our ability to both bolster the intramural and extramural programs.

One leadership item that Dr. Howard wanted to draw attention to was about laboratory safety. CDC has been criticized over the years for laboratory safety issues. Some Board members may have read those reports in the newspapers. CDC is making a comprehensive effort in the laboratory quality area, which includes NIOSH laboratories. NIOSH does not do the BSL-3 or -4 work that happens in Atlanta or in the laboratory in Colorado, but does have laboratories. Sam Glover, who is talented in this area and was Branch Chief in the Health Effects Laboratory Division, has now joined the Office of the Director as the official Senior Laboratory Quality Advisor. NIOSH is receiving funding from CDC to adhere to new laboratory requirements, and Sam will be leading the effort.

In the American Rescue Plan includes \$20 million to do an education and awareness campaign to improve the working conditions within the healthcare sectors. The funds went to HHS, then to CDC, and then came into the NIOSH budget. The COVID-19 response has been significantly stressful on both healthcare workers on the frontlines, acute care, as well as EMTs, in taking care of folks. Many of these issues fall under the *Total Worker Health* umbrella, and Dr. Howard is pleased to have this \$20 million. He asked Dr. Casey Chosewood, Director of the Office for *Total Worker Health*, to give a thumbnail sketch of NIOSH's plans.

Dr. Chosewood noted the \$20 million project that will help to improve mental health outcomes. He is hoping to shift the conversation of prevention of these outcomes for all healthcare workers. This was a challenge that existed before the pandemic, and his team wants to build a sustainable program that will hopefully help healthcare workers and first responders for generations to come.

They are also going to leverage existing NIOSH partnerships with organizations that are strong contributors to improving work and well-being in this space. Those include NIOSH's close relations with labor unions in the healthcare space, the NORA Healthcare and Social Assistance Sector Council, and the experts that work with NIOSH historically in this space. Associations with member organizations are going to be critical too, in moving forward.

His team will start by conducting an assimilation of current evidence and best practices for the best prevention and intervention. This project will include a multidimensional social marketing and media campaign to advance the right messages around prevention. They will develop new assessment and screening tools that make it easy for healthcare workers to assess their own current situation, to help their coworkers, and to move toward resources and help as needed.

They are also going to leverage some high-quality survey tools that NIOSH has developed. First, the Quality of Work Life Survey that has been around for a long time and is useful in helping better improve working conditions in tough settings. Second, a new survey, the NIOSH WellBQ, the Worker Well-Being Questionnaire that was released earlier this year by our *Total Worker Health* program.

Lastly, the team hopes to leverage research expertise, both intramurally and extramurally, to grow the long-term evidence base for best practices in this space.

Dr. Howard shared that Dr. Chosewood will return for the next BSC meeting to describe the program in greater detail. Dr. Tom Cunningham from the Division of Science Integration is also taking a lead role.

NIOSH has been involved in the COVID-19 response as a part of the all-government response. About 500 NIOSH personnel have been either detailed within the response itself, which is a separate organizing activity at CDC, or have been deployed. Last year, we deployed NIOSH staff to beef, pork, and poultry processing plants, to Native American reservations, and to other outbreak areas that were having significant problems.

The response still goes on, with no shortage of guidance documents, including the one from May 13, that everyone is adjusting both individually as well as occupationally. It has challenged Dr. Howard personally. He has done four webinars in the past week for various employer associations that are trying to navigate their way through what is now a hybridized workplace between the fully vaccinated and the unvaccinated. There are many challenges.

He also acknowledged the tremendous effort that the National Personal Protective Technology Laboratory has been doing for over 15 months, since the beginning of this pandemic. Their many activities are listed in the materials.

Dr. Howard then paused for questions or comments.

Dr. Cox asked for an update on the National Firefighter Registry.

Dr. LeMasters noted that approvals have taken longer than expected and are anticipating a start in 2022. The next Subcommittee meeting is in August and they haven't had a meeting since last summer. Her understanding is that this is a huge study, with many moving parts, and getting all approvals is necessary before they begin registration. She felt they were making great progress.

Mr. Morrison recently did a webinar with Dr. Kenny Fent that covered the issues and the timeline. Initially the plan was to have the Registry up and running by January 1, but that is not going to happen. Another big issue is the security of the data and using or not using Social Security numbers. Asking for Social Security numbers is a barrier for getting buy-in from first responders coming in and being part of the Registry. It's going to take time to do this right. He is pretty pleased about the current status even though they are a little bit behind schedule.

Mr. Arnone asked about the timeline for the mental health project.

Dr. Howard replied that it was no-year money, which is helpful because there is no rush to spend the money in one or two years.

Dr. Chosewood echoed that it is no-year money but added that his team feels a sense of urgency because the acuteness of the pandemic has worsened mental health outcomes for these workers. They will work quickly. End-of-year deadlines for procurement are coming up, and they're already working to get some of the early contracts and other projects launched. The assimilation of the current best evidence is underway, along with work to adapt the new survey tools to the healthcare setting. They are going to do this project incrementally, to have early products to make the soonest impact we possibly can. Overall, the plan is for a three-year project in length, building in sustainability that hopefully lasts beyond the current funding.

Dr. Howard added Dr. Walensky, CDC Director, is very interested in this project. She herself is a former healthcare worker, an infectious disease specialist at Massachusetts General until January 20 of this year. When she and Dr. Howard spoke yesterday, Dr. Walensky pointed out that non-healthcare people just have no idea of the stress that healthcare workers were under in March, April, May, all the way through the third surge in December/January. This is a very significant project, at a very important time,

Dr. Demian asked whether NIOSH promoting the WellBQ questionnaire in any particular way and speculated that it would be a good resource to use with healthcare workers.

Dr. Chosewood confirmed that it can be used with healthcare workers because it's a very holistic look at work and well-being. It is the first tool to look at well-being in such detail in a working population. There are a lot of well-being tools that look more generally, but this specifically looks at conditions of work, people's health and safety climate, people's interaction with their supervisor, and how all of those elements impact their overall well-being.

The TWH team is actively promoting the product. It was released the last week of April, so it's still very new. They featured it in a few of their publications so far, but it will be the centerpiece of the next Total Worker Health in Action eNews that goes out to about 75,000 subscribers now.

Dr. Reponen wondered whether the American Association of Occupational Health Nursing (AAOHN) was one of Dr. Chosewood's partners.

Dr. Chosewood confirmed they were. AAOHN has been a longstanding partner of NIOSH on multiple levels, including with our Healthcare and Social Assistance Sector. They're also a Total Worker Health affiliate. He believes they are an excellent resource, with the right network, to help get the word out and the messages right.

Dr. Schenker noted that in the beginning of the COVID epidemic, there was a rapid designation of so many workers as "essential workers", and what he described as a tragic disconnect between designating them essential and not providing the adequate resources for protection. This included isolation, quarantine, PPE - all the things that were available or more available to non-essential workers who could work from home, and the frontline workers, the farm workers and the healthcare workers, who didn't get that protection and often suffered for it. He asked Dr. Howard how things had changed.

Dr. Howard said he was not entirely sure how to answer the question, but certainly in the PPE area, the country is in an entirely different frame than a year ago.

Dr. Reponen added that there is this new ASTM standard for like facial coverings, and that she thought a NIOSH person was chairing that committee. Dr. Reponen asked whether NIOSH was going to be involved in kind of approval or certification of these facial coverings that are not respirators, but are barrier facial coverings.

Dr. Howard tried to direct this question to Dr. D'Alessandro, but she was unable to connect her microphone. He went on to say that NIOSH did a [science blog](#) on ASTM International Standard, and NIOSH has other materials in preparation. It's something that we could have used a year ago to give consumers and workers some advice about which mask is better than the other, which of these barrier face coverings or cloth facemasks are better than the others. He was not sure if helps that much; it's a little late, but it's certainly ready for the next pandemic.

Dr. Reponen asked about the impressive social presence statistics. She wanted to confirm that the seven million website views were for one month, March 2020.

Ms. Spring confirmed that it was for one month. NIOSH has seen incredible spikes in traffic. She anticipates that the numbers probably go back down to where we had been seeing them pre-pandemic, but the first six months of last year, we were seeing numbers that we have not seen previously on the NIOSH site.

Dr. Reponen inquired whether NIOSH separately tracked COVID-related guidance documents.

Ms. Spring responded that she can look at the ones on the NIOSH website. For documents and materials posted on the CDC site, they would need to be the ones tracking those.

Dr. Howard added that there is a url (<https://www.cdc.gov/coronavirus/2019-ncov/whats-new-all.html>) which gives you an update about what CDC published that day. It's the one he uses because otherwise, it's impossible to keep up with. CDC has approaching 7,000 guidance documents total.

Dr. Reponen asked whether documents that are actually authored by NIOSH staff are located on the CDC website.

Dr. Howard confirmed that some documents, like the business guidance, are CDC branded but they're written by NIOSH together with staff other parts of CDC in the response. There are also several documents that are co-branded with OSHA. NIOSH has quite a few folks that are detailed within the worker safety and health part of the response.

Dr. Reponen asked for an update on the Cincinnati building consolidation.

Dr. Howard replied that they are making progress at a fairly glacial pace typical for government. They have a design team of architects that have been working hard, and will be able to inform everybody in Cincinnati, including all of our staff, about what they've come up with. Some of the property acquisitions from the City need to be finalized by the Department of Justice, but the project is moving ahead.

The Evolution of Workplace Fatigue Research

Presentation

Dr. Paul Schulte started by saying this presentation is a short history of workplace fatigue research. The work NIOSH is doing today builds on a rich history, and coloring that history are controversies about the definition and assessment of fatigue that have plagued investigators for more than 150 years.

The issue of the definition is still a major problem. While there is no standard definition, fatigue is commonly thought of as something along the lines of "exhaustion of the body's capabilities for effort and exertion." And as many know, and the presentation will cover today, fatigue has a major impact on workers, their families, enterprises and the economy. It is a critical issue for occupational safety and health.

The research on fatigue, the thinking of fatigue as a scientific object, really begins with the maturation of the Industrial Revolution. And to put this in perspective, during the Industrial Revolution, workers worked almost twice as many hours per year as workers today, as well as under horrendous conditions.

There are three main drivers for fatigue research: physiological science, decrement in workplace production, reform of terrible work conditions. The physiologic foundation of fatigue research began in Europe in the 1800s, and by the late 1890, Angelo Mosso of Italy wrote the first major book on fatigue research, where he looked at muscular fatigue, and it was called "Fatigue": *LaFatica*.

From the reform aspect, William Mather, who ran the Salford Iron Works in the UK, reduced work, the work week, to 48 hours. And he said that this did not decrease productivity, and he did it not because of a scientific basis, but because of his concern for working conditions.

The Boer War in South Africa, the Second Boer War, which started in 1899, was another driver of research because British decision-makers and politicians were chagrined to see the condition of workers who were conscripted to fight in the war, workers, particularly urban factory workers, who were in terrible condition.

The science started to coalesce around the turn of the century, and in 1903, in Brussels at the International Congress of Hygiene and Demography, a resolution was promoted to facilitate research on the problem of overwork, as a result of industrial labor and industrial fatigue. The first American study of industrial fatigue, entitled "Fatigue and Efficiency", by Josephine Goldmark really drove thinking and research about fatigue and the relationship of overwork to fatigue.

The term "occupational fatigue" didn't come into play until the twentieth century. Thomas Oliver in 1914 in a paper first used the term. The beginning of the paper is so poignant. He says, "So tired!" is the cry of thousands of men, women and young people at the close of the day. How to meet this complaint and remedy the cause are among the problems of the present age." So indeed, it was felt that not only the data on fatigue but also the empathy for workers was growing.

World War I was a real driver of fatigue research, and the problem was that the British could not get enough artillery shells to the front. They weren't being produced fast enough, or in good enough quality, and they started the Health of Munition Workers Committee, which drove a lot of fatigue research. And it went through World War I and it then evolved into the Industrial Fatigue Research Board, which was really a major promoter of fatigue research in the UK and throughout the world in the twentieth century.

One of the issues with fatigue research was known as Muscio's Paradox. A famous psychologist, Bernard Muscio, who was on the Industrial Fatigue Research Board, said if we can't define it, how can we know what it means when we measure aspects of it? He was quite critical of the term, and actually suggested that it be dropped. Clearly, it hasn't been. But his point is well-taken. There is a need for fatigue—a firm and operationalizable definition of fatigue.

An example of the role of industrial production is illustrated by the Harvard Fatigue Laboratory and its placement. It wasn't placed in health sciences; it was placed in the business school. It went on, from 1927 to 1946, to do a lot of productive research, or research on the decrement of production, related to fatigue.

Toward the middle of the twentieth century, a lot of fatigue research was driven by emphasis on aviation and concern about the long flights that pilots had, and the impact of those flights on their performance. The Civil Aeronautics Board in 1946 established a committee run by Morris Viteles. He was essentially the father of industrial psychology. They were tasked with determining appropriate standards of operation to avoid excess fatigue.

One of the big areas in fatigue that has emerged is shift work, and this started back in 1959 by Aanonsen and colleagues in Norway, who studied workers in factories in western Norway. It's interesting that this is some 80 years after the invention of the lightbulb, which was really a driver of shift work. But indeed, starting in the 1950s, we've seen a major progression studying the role of shift work in relation to fatigue and in relation to adverse health effects.

As the science grew, it was possible in the early, around the early 2000s, to start to develop quantitative models of work-related fatigue, the Dawson Fletcher model being one such model.

Another series of approaches that yielded a lot of information about fatigue were studies that were done in the Netherlands, epidemiologic studies of the working population of the Netherlands. It was known as the Maastricht cohort study, and it had a model that looked at the interaction of the work situation, the private situation, which, by which they meant workers' family life and related variables, and then the individual situation, by which they meant their health and coping activities. And this is a more complex model, but it was the basis for the epidemiologic research.

The field in general was particularly aware and growing of the problem of fatigue such that a seminal conference by Liberty Mutual was held, the Hopkinton conference, in 2008, and this conference led to the development of a research agenda for fatigue and issues that needed to be assessed.

Further authoritative organizations like the American College of Occupational and Environmental Medicine started to issue guidance on fatigue risk management. This area will be covered more later today. The ACOEM guidance came out in 2012, and then further development of thinking of a systems approach to fatigue came about around that time, a little after, with the meta-analysis and systems model by Techera and colleagues. The Techera approach shows the interactive effects of many different disparate aspects in fatigue. The Investigators at Safe Work Australia had another interactive type of model, to show you the maturation of the research and the thinking about fatigue.

Another guidance document led by NIOSH's Claire Caruso working with nurses to reduce fatigue associated with sleep deficiency in nurses; they developed a position statement. And then there was a consensus standard by the Working Time Society to definitely address managing occupational sleep-related fatigue.

These are some of the kinds of methodologic issues that have been woven through this history. Hours of work and workload are particularly important and in fact, this week, the World Health Organisation and the ILO released a study on the impact of long working hours, showing extensive—showing a strong relationship where workers with 55 or more hours a week to ischemic heart disease deaths and stroke. And this has been growing in the period from 2000 to 2016. Working hours continue to be a major factor of interest in fatigue research.

This figure that shows, essentially, the kinds of risk factors that have been studied, and the kind of adverse effects that have been seen. We've seen everything from deficits, cognitive and performance deficits; mental disorders, particularly depression; cancer, related to shift work; and cardiovascular disease related to long working hours.

But there are still many, many questions to answer in fatigue, and how to manage it is still a critical question.

Discussion

Dr. LeMasters asked how Dr. Schulte would be factoring in fatigue and accidents that occur in the workplace. Fatigue is a top cause of accidents. In hospital situations, she would consider making mistakes and errors in medication as accidents.

Dr. Schulte said yes definitely. There is a great concern that fatigue leads to decrement of performance, physical and cognitive, that can lead to those kinds of situations. So indeed, that's being studied and will continue to be studied.

Dr. Wong added that the next presentation will include some of the work across NIOSH on that topic. There are a number of different safety-critical events that can happen that would differ across sectors, and so each sector is taking a unique look at doing some epi/etiological studies using administrative data to identify determinants of fatigue on those fatigue-related events.

Dr. Reponen asked about whether a clear operational definition of fatigue was needed, and if so, that might be something for the board to recommend to NIOSH as an action item.

Dr. Schulte replied that while historically there have been a lot of problems with the definition, more recently, there are some useful operationalizable definitions that can be utilized to help design research studies.

Dr. Wong added there are a number of different definitions but no there is no standard definition. One of the reasons for that is there's a number of different sources that fatigue can be attributed to, and so that may vary across individuals, organizations. But there have been many folks that have tried to operationalize the term "fatigue" as it pertains to their organization or a specific work task.

DR. SCHENKER pointed out that most of the focus was on the definition and outcomes of fatigue and he wondering about the underlying causes. Specifically people working two and three shift,s and enforced overtime, and other realities that are driving long working hours and resulting in the outcomes that you're talking about.

Dr. Schulte replied that it was clearly an issue of concern for many of the early investigators, and all the way through the history, that they were looking for an understanding of the etiology of fatigue and fatigue-related adverse effects. And indeed, working hours, shift work were two of the critical pieces that have been studied repeatedly. It is definitely in the history, and woven into it strongly. And to this day, it's the focus of much of the research.

Dr. Schenker was thinking about people who are forced to work two shifts, for example, or two jobs to make a wage that will support their family. And that goes with the low minimum wage and other realities of the workplace. He understands the connection between working hours and fatigue, but sees the low-wage workers as most vulnerable to this.

Dr. Schulte said, yes, NIOSH has been promoting Total Worker Health® and in some of the more recent work, thinking more holistically about the problems of workers. And indeed, that's what Dr. Schenker is driving at. And so indeed, it's not just working hours. It's the multiplicity of jobs, it's the underemployment, it's the precarious nature of work, it's the wages. Clearly those are factors that are both in fatigue and on the frontier for occupational safety and health researchers in general.

NIOSH Center for Work and Fatigue Research

Presentation

Dr. Wong thanked the Board for the opportunity to give this presentation about the newest center at NIOSH, the Center for Work and Fatigue Research, and some of the work underway on the topic of workplace fatigue across the Institute. And incidentally, the Center just celebrated its first anniversary.

There was a lot of discussion about defining fatigue earlier, and so what do we really mean? There are many definitions. The term “occupational fatigue” was first coined in 1914 by Thomas Oliver, as heard from Dr. Schulte. There is no one standard definition. What becomes evident is that fatigue is more than just sleepiness, and its effects are more than falling asleep. And knowing this difference can help us better develop targeted fatigue mitigation strategies.

The National Safety Council has described fatigue as “a debilitating and potentially deadly problem affecting most Americans”. This is a snapshot of what fatigue looks like in the United States. In the occupational realm, worker fatigue is most commonly associated with nonstandard shift schedules and sleep disruption. Approximately 21 million workers— nearly 20% of the workforce—are employed in schedules that are outside what is considered to be a regular daytime shift. And working these types of schedules has been associated with disrupted or impaired sleep. A recent survey found that 37% of workers get less than the recommended seven hours of sleep and while almost two-thirds of night shift workers report not getting sufficient sleep, surprisingly, almost one-third of day shift workers also do not get enough sleep. This suggests this problem can affect any worker, regardless of their work schedule.

Ninety percent of employers report that their workplaces have been negatively impacted by tired employees, in terms of reduced productivity and absenteeism. Only half say that they will adjust employees’ schedules or tasks accordingly, but 70% will issue a warning or disciplinary action. There is a bit of a disconnect between the problem and the solution. Over two-thirds of American workers report experiencing a level of fatigue where an additional effort is needed to perform tasks at a desired level. This affects their ability to perform critical tasks, which can not only affect their safety at work but also the safety of their coworkers.

Fatigue can have a significant impact on cognition, such as slowing down reaction times, reducing attention or concentration, limiting short-term memory, and impairing judgment. This all increases the risk for fatigue-related incidents such as work injuries, as was mentioned before. Fatigue as related to shift work has also been suggested to have long-lasting effects on cognition. A recent study found that working ten or more years in nonstandard schedules may accelerate cognitive aging. And these adverse effects may continue for several years after leaving nonstandard schedules.

Fatigue adversely affects mood and increases the propensity for risky behavior, and working nonstandard schedules doubles the risk for work injury compared to those working regular daytime schedules. Fatigue also increases with time awake, or even time on task. The injury rates for those working more than 60 hours per week is over double than those working less than 20 hours per week. And there is a dose response effect with increasing work hours.

Chronic poor sleep and shift work can have gastrointestinal, reproductive and metabolic health effects. Metanalyses suggest that shift workers have a 20% increase for cardiovascular disease, morbidity and mortality, with a dose response effect with increasing years of shift work. The International Agency for Cancer has determined that night shift work is a probable human carcinogen based on the strength of current evidence. And as we are becoming more aware during these pandemic times, fatigue and mental health are very closely related. Fatigue is a symptom of mental health issues, and it can exacerbate existing mental health issues.

Worker fatigue can also have a devastating public safety impact, particularly in occupations with high-risk consequences. Some examples where worker fatigue was cited as a contributing factor included the nuclear meltdown at Three Mile Island, the grounding of the Exxon Valdez oil tanker, and the crash of American Airlines Flight 1420. Most recently, the train derailment at Lac-Mégantic in Quebec, Canada resulted in the explosion and subsequent fire, and 47 fatalities. Almost half the downtown core was destroyed and all but three remaining buildings had to be demolished due to petroleum contamination. And on a less dramatic yet more frequent scale, tired workers drive on public roads, raising public health and safety concerns. The point here is that the effects of workplace fatigue can be severe and widespread, with spillover effects to coworkers, family life, and public health and safety.

Dr. Wong put this into dollar terms for conceptualization but prefaced it by saying this is not an in-depth, comprehensive economic analysis but is really used just for illustrative purposes. These are really rough estimates gathered from a number of different sources and converted into present-day dollars for a better comparison. It's reported that 14% of workplace injuries can be attributed to excess risks associated with poor sleep or nonstandard schedules. Knowing this, she roughly calculated that employers paid more than \$1 billion annually for direct costs for disabling, nonfatal workplace injuries. But keep in mind, this is a gross underestimation of the true costs as only a fraction of work-related injuries are reported, a smaller percentage file a claim and of those, an even smaller proportion are awarded compensation.

The National Safety Council estimates that workplace fatigue related to sleep deficiencies, sleep disorders and shift work costs employers about \$151 billion in health-related productivity. And again, this is just a fraction of the true cost as chronic sleep deprivation is also associated with depression, obesity, cardiovascular disease, cancer, and other illnesses that may impact work productivity.

Drowsy driving is also of considerable concern these days. The National Highway Traffic Safety Administration estimates that motor vehicle crashes on and off the job cost employers just over \$72 billion annually. And this is extrapolated further to an additional \$150 billion attributed to the societal harm of drowsy driving crashes.

The RAND Corporation has also recently estimated the cost of poor sleep in the U.S. equates to \$434 billion in losses due to increased mortality rates, presenteeism amongst workers, and considerations for future losses in skill development on adolescents who do not get enough sleep.

Using these few broad estimations of fatigue based on sleep disturbances and exposure to shift work, we can crudely estimate that the total economic burden of workplace fatigue just costs over \$815 billion annually in

the U.S. However, Dr. Wong uses the term “total” very loosely because it only captures a fraction of the true cost, as we’ll see from the viewpoint of the employer or the industry. What isn’t known is the cost to the workers in terms of how it affects their daily life, such as with items such as household productivity, loss of enjoyment of leisure activities, or loss of income which may occur with workplace fatigue-related injuries or illnesses.

Given what is known about the effects of workplace fatigue and its extent of its consequences, why are we not doing a better job at managing it? Fatigue is unlike any other workplace hazard. On the surface, it may seem like an easy hazard to address and mitigate. Why don’t we just change the hours of work, or why don’t we get enough sleep? Dr. Wong suggested that it’s really not that simple. From the industrial hygiene perspective of anticipation, recognition, evaluation, control, you’ve seen that there is no standard definition for fatigue, making it difficult to assess. There is no standard measure, making it difficult to quantify or compare. And unlike any other work hazard like chemical or biological exposures, there are no threshold limits, making it difficult to determine how much is too much.

Fatigue can stem from a number of different sources. There are work-related factors such as shift timing, duration, and organizational factors. There are the influences on individual characteristics, such as age and chronotype. And then there’s life or lifestyle factors such as health behaviors, commuting and dependency care that can also have a significant impact on fatigue. And since there is such a wide variability of these factors across individuals, there is no one magic solution that can fit all situations for all sectors, organizations or individuals.

And this is probably one of the biggest challenges. In some industries, there is a bravado surrounding working long hours and getting very little sleep. These pervasive attitudes about fatigue make it difficult to manage and mitigate. Fatigue is ubiquitous to all situations; it can affect any worker regardless of age or background, and any organization or sector. And yet, some have accepted that workplace fatigue is the norm, an inevitable cost of doing business.

NIOSH has a longstanding history of addressing occupational health and safety concerns related to nonstandard work schedules and sleep. These earliest publications date back to 1977. And more recently, following our Fatigue Forum in 2019, the Center for Work and Fatigue Research (CWFR) was launched last year in May. It has approximately 50 NIOSH members from various disciplines, with representation across most divisions, sectors, and cross-sectors. CWFR is a diverse, a cohesive group, using an interdisciplinary approach to address this topic.

CFWR’s vision is safe and health workplaces free from the effects and consequences of fatigue. Through partnership and collaboration, CFWR focuses on raising awareness of different sources of worker fatigue, multiple jobs or the other internal or exogenous and endogenous factors. There are associated health and safety risks. CFWR also focuses on identifying effective methods of assessing fatigue risk in workplaces, and developing and communicating strategies to reduce health safety risks associated with workplace fatigue.

The goals of Center include providing a service to the Institute by coordinating and promoting the growing portfolio of working hours and fatigue research. CWFR leadership helps NIOSH researchers expand their

studies by providing resources and subject matter expertise. And again, this is all built on strong collaborations, both internally and externally, to develop a multidisciplinary and multi-institutional approach to achieve greater synergy and impact. CFWR continues with the NIOSH tripartite approach where research, industry and labor groups are equally valued and included, to develop practical, responsive solutions and novel outreach initiatives. And because fatigue is more than just sleepiness, the Center will extend upon established work to include other sources of fatigue, such as physically and mentally demanding work, comorbidities, hot environments and other co-exposures. CFWR work and activities, of course, are always derived from sound evidence-based research and shared frequently and transparently.

In its first year, the Center has been active with a number of partnerships and projects. They are currently working with colleagues from the NIOSH Health Effects Laboratory Division to review biomonitoring methods of identifying fatigue. There are hopes that this may be a precursor to developing a novel biological measure of measuring fatigue.

Innovations in fatigue detection projects draw from increasing interest in identifying and quantifying fatigue risk, with the emergence of many fatigue detection technologies now available on the commercial market. The Center is collaborating with the NIOSH Center for Motor Vehicle Safety and the NIOSH Center for Direct Reading and Sensor Technologies on a series of research and informational activities. They just published their first science blog on what to consider when choosing these technologies, and have another blog in the works for tips on implementation. They are also planning other science blogs, infographics, a literature review of current technologies, a survey study of technologies that are being used, and a focus group of challenges and barriers to their implementation.

CFWR has partnered with the Department of Transportation, the National Transportation Safety Board and again, the NIOSH Center for Motor Vehicle Safety, and also the NIOSH Center for Occupational Robotics Research, to produce a series of products related to automation and assisted driving technologies. And this will really emphasize the caution of overreliance and increased fatigue with assisted technologies, when vigilance is still really needed. Lessons learned from these activities can be used to inform about fatigue and situation awareness risks. In other industries such as manufacturing, employers are relying more and more on automated technologies.

Their work really benefits most when it reaches a wide audience. In addition to our scientific community, CFWR leadership also strives to reach out to the general workforce population. As such, knowledge translation is a core component of the Center. They have hosted the NIOSH Director's Seminar Series on Work and Fatigue highlighting seminal work from top researchers in this field, both internally and externally. Past presentations are archived on our website. They will assist NIOSH researchers gain a wider reach their products. They have a special issue of *American Journal of Industrial Medicine* that will be dedicated to the manuscripts and partnerships developed from our 2019 Fatigue Forum. They will continue to build partnerships with other federal agencies to disseminate information through their existing channels. And one effort is a series of articles on worker fatigue and fatigue risk management to be published in *Synergist*, the official publication of the AIHA. Their first article was published in November, with more to come.

But activity on this topic is not just limited to activities within the Center. They have an increasing number of NIOSH researchers doing studies in this area, and fitting into the four elements of industry hygiene: anticipation, recognition, evaluation and control. We have a number of different projects in most of the NORA industry sectors. They have extensive, longstanding partnerships and, consequently, many projects, particularly in healthcare, protective services, and transportation. However, in recent times, they have also expanded to other sectors.

For the Center's anticipation-related projects, they have a number of surveillance and epidemiological studies to identify determinants of fatigue which may be industry-specific, as we had discussed in the prior segment. Under recognition and evaluation, they are using a number of different methods, including standardized surveys, objective measures such as actigraphy. They are also examining the effectiveness of some of these fatigue detection technologies, again with the cautionary advice to not use these as their primary fatigue mitigation measure.

For control measures, they have a rich array of online training, infographics, toolbox kits and other educational efforts. They're starting to move into more widely accessible methods such as podcasts and short course modules which can be dropped into existing training programs, or tailored together to suit a specific purpose. They have resources devoted to the times of emergency such as Ebola and, more recently, with respect to COVID-19. They are working on developing more general educational efforts, more evergreen type products to help employers and employees during challenging times, and not just during these more high-profile situations. CFWR has a lot of activity going on right now, but continues to look forward and anticipate future needs and directions for research.

Going back to the goals of the Center and knowing that fatigue is more than just sleepiness, Dr. Wong examined other sources of fatigue and how they may interact with one another. The term "fatigue threshold" has been mentioned a lot lately but in most cases, the term is generally used without a full understanding. There is no quick fix or standard cutoff for fatigue. In addition to providing specific mitigation strategies as they are doing right now, they'd like to place a greater emphasis on fatigue risk management systems. They are investigating providing a course for NIOSH researchers to learn more about developing fatigue risk management systems so that they can share this knowledge with their sector base. And they are also currently involved in forming additional partnerships with AIHA, ACGIH, and the National Safety Council.

Dr. Wong raised two questions to help them better shape the Center for Work and Fatigue Research:

- 1) how should we measure the success of the Center?
- 2) What other gaps in the knowledge base should we address?

Discussion

Dr. Su asked whether is anyone looking into studying the fatigue of new mothers in the workplace?

Dr. Wong replied no, but that is a great idea.

Dr. Reponen noted there was a link in the chat to a study published by the World Health Organization and International Labour Organization on the link between working long hours and death from heart

disease: <https://www.who.int/news/item/17-05-2021-long-working-hours-increasing-deaths-from-heart-disease-and-stroke-who-ilo>

Dr. Reponen brought up a comment from the chat, that several studies conclude that smartphones are an important modern driver of fatigue, and asked whether Dr. Wong was considering that in the Center's activities.

DR. WONG affirmed there that yes, they have included the use of smartphones in a number of their educational efforts. It's almost become addictive for some folks and they use them into late night hours, or prior to sleep. And so they're trying to raise more awareness of how exposure to the blue light from smartphones, or even just the content that they're receiving through their smartphones, may be affecting their sleep.

Dr. Reponen asked if there are any activities related to manufacturing.

Dr. Wong said they are in discussions with the NIOSH manufacturing sector leadership on what types of information would be valuable for them. Again, they're still in our first year and we're still forming ideas so, as Dr. Howard said, they're moving forward but at a glacial pace.

Dr. Reponen directed the group to move on to Dr. Wong's questions to the Board. The first one was, "How should we measure success of the Center?" Any comments? Recommendations?

Dr. Graham said that it seems like one of the main goals is to increase awareness, and the Center is already keeping track of the number of downloads of documents and views of websites. Another idea would be just polling for awareness of the Center, but she did not know how that could be done.

DR. COX raised that a closely related question is: how should we, and how can we, measure the success of interventions? In terms of awareness, a lot of people in marketing actually struggle with a very parallel question, which is: how can we see whether our efforts are making a difference in what people do? In that field, awareness is early-stage; behavior change is what we're really interested in. He imagines that CWFR might be able to borrow some of the causal analysis methods of experimental and quasi-experimental, observational, that marketers use to see whether interventions lead to behavior change. And if they do, they will certainly lead to changes in awareness, interest, intent - all the things leading up to behavior change. But this difficult problem of how do we measure the effect that we are having, there's a huge literature that addresses that in the marketing world that Dr. Wong might borrow from.

Dr. Wong agreed that was a great idea. A NIOSH Researcher, Beverly Hittle, is evaluating the effectiveness of one of our online training programs that was developed by Claire Caruso, the nurses' training on long work hours and shift work. We're looking to see what the outreach is across the national population of nurses, and we're also doing a little bit more in-depth study on how it may improve sleep and fatigue. They want to continue to do more of those types of studies. As you can imagine, it requires a bit more of a longitudinal approach and takes a bit more time.

Mr. Arnone said that one of the things he's heard when representing nurses, health professionals, teachers and school staff, is that there is a real labor cost rationale for why fatigue happens. For many employers, it's

cheaper to work one of your workers more than it is to add a new FTE or a partial FTE and then provide them with full benefits when you already have someone who has health insurance coverage or retirement coverage. If there were a way to show the impact of fatigue on medical claims, not just workers' compensation, that it would be a helpful way to make the argument that it's a more economically efficient way to organize your workforce than to get 60 hours out of somebody rather than 40. Controlling all the other factors, you know, all else equal, what is the impact of fatigue on medical claims? He thinks that there's probably even wider implications rather than just GI health outcomes.

Dr. Wong agreed. This also builds a lot on work done by Dr. Belzer. He's an economist from Wayne State University. He's done a large body of work on compensation and safety, and he talks about how compensation affects worker safety and incidents. Relating to fatigue and medical claims, they have a paper in the works that's ready to be submitted that looks at the economic cost of fatigue actually on medical claims. And the authors look at comparing adding additional staff versus having staff work longer hours.

Dr. Reponen read a comment from the chat: "Increased workers' awareness of rest hygiene, behaviors that ultimately reduce the additional effect of fatigue, of risk factors, starts as lack of exercise, excessive use of smartphone, etc." So is that a recommendation for the Center, basically increased awareness of rest hygiene, to say it shortly.

Dr. Wong agreed it was a great idea. The online training for nurses takes about three and a half hours to go through, and it's full of so much useful information. But as you can imagine, folks don't really have the time to sit through the full three and a half hours. So they're trying to find ways of shortening that up and sharing that similar information in shorter snippets so people can incorporate that change and again, the behavioral change, incorporate it into their daily lives and adopt those behaviors.

Dr. Lerman shared that he's on the Board of the National Sleep Foundation and they're reevaluating their strategic focus. They've been involved in fatigue-related health issues and safety issues for a long time, but they want to increase that focus. And he recommended to them that they reach out to NIOSH, and I'd recommend to NIOSH that you reach out to them, and can help facilitate that if that would be helpful.

Dr. Lemasters raised the issue of gender, not just returning mothers to the workforce, but gender issues more broadly. Men and women sleep differently. They have different demands on who gets up at night with kids, and increasing public awareness of what the difference is in fatigue related to gender is an important issue.

Dr. Wong replied that this reminded her of some prior work, a gender analysis of men and women that worked shift work, and the risk for work injury. And she did find that women that were working shift work had a stronger risk for work injury than men did. She would love to revisit that.

Dr. Lemasters clarified that it's not just shift work, you know. Women in manufacturing, etc. who are working machines, and have maybe gotten two or three hours of sleep that night, on a regular basis. Workers' Compensation could tell us a lot about injury rates between genders. It seems like those data would be more easily accessible.

Dr. Schenker commented in the chat, raising gender but also age, race, income and other demographic factors.

Dr. Wong responded that yes, absolutely they include all those factors in our epidemiologic studies.

Dr. Schenker spoke up and added awareness is not adequate. He's been doing studies on heat stress and risk among farmworkers, and awareness does not correlate with behavioral change and risk. It's really important that NIOSH both look at the impact of awareness as well as look at change in behavior, as outcomes, because ultimately that's what's going to make the difference.

Dr. Graham asked whether Dr. Wong had considered some of the undiagnosed medical issues like obstructive sleep apnea and long-hauler symptoms of COVID and ongoing fatigue? That's come up recently, especially with the transportation industry, and looking at those factors.

Dr. Wong shared that the NIOSH transportation researchers have done a lot of work on obstructive sleep apnea. They continue to do so. With long-term effects and COVID, covered presentation a little bit later on, that is one of the issues that she is raising and that NIOSH will also look at as well.

Emerging Issues in Workplace Fatigue and Fatigue Management in Agriculture, Forestry and Fishing

Presentation

Ms. KC Elliott is the Sector Coordinator for the NIOSH Office of Agriculture Safety and Health. She started by thanking the Board for allowing her to present on emerging issues in fatigue and fatigue management in agriculture, forestry and fishing—or what NIOSH calls AgFF.

When they say “emerging issues” for this sector, they don't mean that fatigue is an emerging issue. Instead, given the overall advances in sleep research in the past decade, and our better understanding of the safety and health risks of sleep deprivation and chronic fatigue, NIOSH partners are increasingly concerned about the issue and are interested in new research and interventions designed specifically for this sector.

This presentation covers the unique environmental, economic, geographic and social contexts for AgFF work which makes traditional sleep messaging like “sleep at least seven hours at night” or “make your room as dark and quiet as possible” are often incompatible with the realities of working in this sector. Secondly, it will include possible approaches for creating new fatigue interventions and changing the way that we communicate sleep and fatigue messaging. Finally, Ms. Elliott has some questions for the Board to help NIOSH better focus future efforts.

Why are best practices for sleep hygiene and fatigue prevention often incompatible with AgFF work? If one were asked to think of an occupation that wakes up before dawn and goes to bed long after the sun goes down, many would think of a worker in this sector. A farmer getting up to milk the cows or still working long past sundown to get the harvest in before a storm. One might think of a fisherman in Bristol Bay, Alaska

hauling in nets full of salmon as long as there's light—and there's always light in summer. Or one might think of a logger who travels 100 miles to and from work each day depending on where they're working that week.

AgFF workers are found in every region, and span from owner-operators and family farms, to multinational corporations. But what they all have in common is long hours, extreme environments and dangerous work that takes focus, good judgment and quick reflexes. And while hours can vary by the type of commodity produced and by season, the National Agricultural Workers Survey reports that U.S. crop agriculture workers work much longer hours than the typical U.S. worker. And, according to the Bureau of Labor Statistics, this sector consistently has the highest fatal injury rate and a high rate of nonfatal injury and illness despite almost certain underreporting.

What is the current state of fatigue research in this sector? In 2008, the National Occupational Research Agenda (NORA), for AgFF stated that fatigue was a significant safety issue and a cultural norm. And in the third decade of NORA, fatigue was again described as an area of concern, and included a priority to explore risk factors for fatigue and to develop interventions. For other sectors such as healthcare and transportation, there have been considerable etiologic and interventional studies on work hours, sleep and fatigue. But in the 2019 systematic scoping review of the literature by both NIOSH intramural and extramural partners, they confirmed that there has been little research specifically for the AgFF sector. Most studies they found did not focus specifically on issues related to sleep deprivation, work hours or work schedules, but instead discussed fatigue in the context of a broader investigation of occupational injury and illness. However, the review did provide some evidence that long hours, sleep deprivation and chronic fatigue contributes to increased injury and illness, especially during peak harvest and production seasons. And also, many of the studies outlined why fatigue is such a considerable problem across the sector, as well as the unique barriers and specific disparities that make addressing fatigue particularly tricky.

Workers in the AgFF sector often have extended hours—sometimes 16 or more hours per day, especially during planting and harvesting seasons, and operations may run 24 hours a day, and shift work is prevalent. Especially in fishing, schedules can be erratic and unpredictable, making it difficult to plan ahead. And economic and organizational factors may result in workers taking shortcuts and working despite high levels of fatigue. And likewise, workers are often paid by how quickly they work, or by the size of the harvest, which leads to fast-paced work, reluctance to take breaks, as well as potentially long hours and less recovery time between shifts.

And then, environmental factors can contribute to fatigue. Since most work in the sector is done outdoors, light and darkness can impact worker fatigue. For example, loggers often have long commutes on rural roads in the early hours of the day before the sun comes up, and these are all known risk factors for drowsy driving. Exposure to heat and cold stress can also increase fatigue. However, at the same time, in an effort to avoid heat stress, farmworkers may start long before the dawn in order to avoid the hottest parts of the day, interfering with natural circadian rhythms.

But the overarching issue regarding work hours and schedules in AgFF is that, unlike some other industries, there are no regulations mandating rest times, watchkeeping standards on vessels, or minimum levels of staffing. The only exception to this is that there are some of the largest commercial fishing vessels require

licensed operators. And now, for industry-specific training in fatigue management—and there's also very little, especially in agriculture and in logging.

AgFF workers often live where they work, and this means that it is truly hard to be off the clock, especially for crew members at sea who cannot walk off the vessel to escape worksite stress. At the same time, many workers across the sector may be separated from family for weeks, or even months, which several studies also reported as a stressor. And agriculture workers and onshore seafood processors may live in congregate and substandard housing, and these conditions can contribute to poor sleep and fatigue, especially in cramped housing conditions and ones that lack access to air-conditioning or heating. And likewise, fishermen and offshore seafood processors sleep aboard vessels, and they may be bothered by vibration, noise, light, and the constant movement of the vessel.

Finally, AgFF workers are less likely to have health insurance, and as mainly rural populations, they experience health disparities compared to urban populations. And several studies also mention fatigue and sleep disturbances disproportionately affecting older, younger, new, female, and immigrant workers.

Long hours and sleep can sometimes be a part of the social and cultural identity of these workers, one that is resigned to or perhaps even a bit proud of just how little sleep and time off they're getting. Or as the bumper sticker says, "sleep is for the weak." And in a 2019 Oregon State University study of Dungeness crab fishermen's perceptions towards safety, researchers found that questions about fatigue and sleep were generally discredited, and one participant even suggested that there was no reason to ask about fatigue on a survey as "everybody's tired." Another fisherman noted, "I would think the biggest causation of all accidents is probably sleep deprivation. People are tired and don't know when to quit." While another said, "Well, you're crab fishing. You're always tired, and you're always rushed."

However, Ms. Elliott does not want to imply here that there's a cavalier attitude towards safety, or even fatigue. These workers want to be safe, and they very much understand the conditions they work in are dangerous, and that working while fatigued is risky. At the same time, these industries are also under constant and tremendous stress to work as much as possible. When there are so many demands, there is one variable that does not cost a small family farmer more money: their time. Hours working are one of the only variables which they can control. AgFF workers are very much aware long hours are risky, but their time spent working is often the only thing they can budge.

You can perhaps see how, now, why ideal sleep habits might ring a bit hollow for these workers, especially during harvest periods or unexpected events.

So, how can we flip the script on fatigue? It's like the fisherman said: everybody's tired. To start, we must change the way we talk and educate on fatigue. In this environment, fatigue is a ubiquitous hazard that cannot be eliminated, so we must develop fatigue management interventions which can be implemented by workers who have little control over how many hours they will be working, often cannot take off time, increase staffing, or change the weather. Also, we must work to change the cultural norm that fatigue is inevitable, or weakness, or even a personal or moral failing.

However, a cultural shift requires us to discuss fatigue in a way that is concrete, standardized and hopefully even measurable. If everyone is tired, we need to be able to say what too tired looks like, as well as based on evidence, describe specific job tasks which are higher risk based on levels of fatigue. And we must begin to teach the benefits of sleep, not just the disadvantages of working while fatigued. Sleep should no longer be for the weak. Instead, we could start talking about how to teach sleep as a tactical advantage, one that improves not just safety but performance, productivity, and overall well-being.

The United States Army has recently revised and augmented its Health and Fitness Manual in an effort to change the culture surrounding sleep, advising officers to set up opportunities for napping, track sleep among their subordinates, lead by example, and encourage others to prioritize sleep as a part of battle readiness. The military is focusing on the benefits of sleep and fatigue management in a highly unpredictable and demanding environment. Perhaps we can learn from them to tackle these issues in our own sector.

However, as much as we can borrow from other sectors and the military, we must also take into account the unique and diverse workspaces within this sector, as well as the very different circumstances of individuals who are workers. And this is why the NIOSH AgFF program will be adding a Healthy Work Design goal specifically on work hours, sleep and fatigue to the NIOSH Strategic Plan in 2021. This will help spur extramural research in this area. For their FY 2022 renewal, the NIOSH Agriculture Centers will be able to write this goal, proposing new research and practical, tailored interventions for this sector.

Ms. Elliott acknowledges that Dr. Schenker is the founding director of the Western Agriculture Center, and his work on heat stress and immigrant farmworkers has been very influential in NIOSH's increased focus on health disparities and nonstandard work arrangements in this sector.

Finally, currently NIOSH and the U.S. Coast Guard funded a research study on fatigue in commercial fishermen, and it's currently ongoing. The Northeast Center is collaborating with researchers and safety trainers on the West Coast to better understand fishermen's sleep patterns and possible effects of sleep deprivation on their health and safety.

Now, this is all a really good start, but more can be done to develop practical and relevant interventions. What they've learned from this literature review, as well as speaking with partners, is that the ideal way to develop interventions is by starting with the community-based consultation and evaluation. Because without buy-in from workers, they are much less likely to adopt future interventions. And what is developed must be culturally competent and sympathetic to the very real challenges these workers face, as well as tailored to the specific industries, worksites and operation size.

And we must also develop interventions which focus on fatigue management, not sleep, as prevention is seldom an option. And as such, interventions must work from a place of harm reduction. For example, there are fishermen who pull all-nighters on a regular basis, and some crews average three to four hours of sleep for weeks at a time. For them, it's too late for primary and secondary prevention, and recovery sleep is not an option. So, what additional controls can be put into place for the duration of their acute fatigue event?

Finally, and most importantly, any intervention we create must be focused on individuals and small business. The vast majority of AgFF workforce are in operations with ten or less workers, and many are in nonstandard

and precarious work arrangements. It's not often that there is a dedicated safety person. So, any intervention must be easy to implement, affordable, and adaptable.

To sum up, AgFF workers face financial and regulatory pressures, several health disparities, an aging workforce, increased stress, and at the same time, work in unpredictable and harsh environments. Best practices and ideal sleep habits are often unattainable, not culturally, not economically, or not even realistically. And AgFF workers want to be safe, and realize the dangers of fatigue, but they do not yet have the tools and the training to respond appropriately. Fatigue management solutions must help prepare for both acute fatigue events, and also for persistent chronic fatigue, in order to mitigate risk, while addressing the sector's unique challenges and diverse workspaces.

Ms Elliott raised two questions to the board:

- 1) How can NIOSH encourage behavioral change and improve outreach in a culture that believes that long hours and fatigue is inevitable, or even a badge of honor, and where long work hours cannot be avoided due to the nature of the work?
- 2) Given our limited resources, how NIOSH we support our Agriculture Centers to do more in this area?

Discussion

Dr. Cox said there is some evidence—an MIT study, maybe in India, earlier this year, showing that at least among urban poor, extra sleep at night didn't actually lead to improvements in productivity and well-being, but a nap in the afternoon, did. To what extent—without generalizing across continents and cultures and populations—but if it turns out that the big boost comes from naps more than from shutting down iPhones earlier at night or whatever, is that practical in these workplaces? Because for question number one, how do we encourage behavioral change, a follow-up question is: well, what behavioral change? Are we trying to encourage people to take siestas, for example? And is that realistic?

Ms. Elliott had not read that study, but what the U.S. Army is saying is that they see napping as an intervention and to use naps when you can, sleep when you can. Now, this would require both some schedule changes, and you'd have to change the culture to be able to say it's okay to take naps. And then you'd have to decide where do you take naps. So say for instance, you've got immigrant farmworkers that are picking lettuce, where are they going to take a nap? They drive, they get into buses in the morning at 3:00 to 4:00 in the morning and they drive out to where they're going to be picking for the day, and they're harvesting all day until the end of the day. Where are they going to take a nap? It's those sort of things that we have to figure out. Ms. Elliott has always thought about with AgFF, they will adopt anything if it saves them time and money, and makes things safer. We must show them that this is a viable, practical and economically viable intervention. And so whatever those things are, she thinks they'll adopt it.

Dr. Cox then suggested refining Question 1. In addition to how do we encourage behavioral change, how do we encourage an allowed set of behaviors within which that change can take place?

Dr. Schenker suggested economic analyses. If NIOSH can show that, in fact, there's an economic benefit to providing naps or longer sleep hours or whatever the intervention is, that's going to be speak to the farm owners and managers and fisher owners and so on. Because ultimately, the cost is what they pay attention to. The other things are nice but they don't have the same impact.

Ms. Elliott agreed and shared that one of her coworkers in the Western States Division, Samantha Case, has studied vessel disasters. If NIOSH could quantify the cost of a vessel disaster due to fatigue, and be able to show that these are all the things that happen to you after a vessel disaster, this is how much on average it costs, we would be able to get a lot more captains and owners on board with some sort of fatigue management system.

Dr. Reponen asked whether NIOSH partnered with the Agricultural Extension Offices?

Ms. Elliott responded that her particular office within NIOSH does not. However, on the other hand, the extramural Agriculture Centers funded by NIOSH are in constant contact with Extension Services all over the country. And this has especially been the case during COVID. They did a survey of Extension Agents specifically asking burnout questions and things like that. Extension is definitely a place to go for agriculture. And they work closely with those Extension Agents, including for outreach.

In many cases, what Ms. Elliott has found with COVID and other examples too, is that farmers are much more willing to listen to Extension Agents. That's who they get their information about crop harvest and particular plant variants and what to grow and how to grow it. And so this is another avenue for health and safety information.

Dr. Graham noted in the chat that there are mobile napping port companies. Perhaps collaborate with one of those to assist.

Ms. Elliott replied that maybe in some instances, that might work, but also reminded the group that they are talking about folks that are out at sea for weeks at a time in the middle of the Bering Sea, or off the coast of California. And for farmers, it all comes down to cost once again. If it's something that becomes cost-effective, that might be one way to do it.

For instance, fishermen often don't have health insurance. They're considered independent contractors. They sign a contract for the season. They may not have any access to healthcare at all. There are a lot of fishermen who really should be tested for sleep apnea and that just isn't getting done. And so, those are other issues too that connect into the fatigue piece. How many of these folks have some sort of sleep disorder to begin with? There are also higher levels of depression in immigrant workers. That has a component that works into sleep as well. That's another link that could be studied. And so there are all of these rural health issues that combine in with fatigue and it makes things worse than they would be otherwise.

Dr. Reponen turned the group to the second question about supporting NIOSH Agriculture Centers to do more in this area. There is the new funding announcement and that has a specific focus on this area. Can they get more funding if they have fatigue as one of their components? That would be one way, if that's NIOSH's goal, to increase research and outreach in that area.

Dr. LeMasters suggested encouraging the Agricultural Centers to work with local ag departments, from forestry to farm, since they're not doing a lot of that.

Ms. Elliot clarified that it's not that they don't want to. Everyone wants to work on this problem. They don't have the information to give to these ag departments and workers that makes sense for these workers. A lot of the fatigue materials we have right now, on fatigue management, either requires you to have a safety person, it requires technology, it requires an investment that a lot of very small workforces and family farms, or immigrant populations, they just don't have access to that, and they didn't have the money for it even if they did. There's a lack of materials, there's a lack of training, and we have to create training that actually works for these workers in their particular situations. So someone who is on a salmon boat in Bristol Bay, Alaska is going to have a very different experience than someone who's driving to and from their house in a logging group, or someone who's in Southern California that's a migrant and seasonal worker.

We have to create these very specific training materials, and we also have to do it knowing full well that they can't get eight hours of sleep. They're working two jobs. For instance on a family farm, you've got a mother who might be working off the farm as, you know, say a teacher so they can get healthcare for the whole family. And then she comes home at night and she works on the farm for a while, and then she's taking care of kids. They call that the third shift.

Dr. Schenker noted that it's important to recognize that NIOSH brings a health focus to this whole issue. And agriculture departments generally are not structured or organized or experienced in addressing health. They're addressing productivity. And collaboration is important, but let's not be naïve and think, oh, we just bring it in the ag department and they'll be able to make these changes. It doesn't work that way.

Dr. Lerman noted that the concepts are universal, in how to manage fatigue. The application has to be customized to the specific. So if NIOSH could create modular, customizable information, training materials, talks about sleep for instance, and it talks about sleep where you can, and if napping is viable, if extending the hours at night or at the end of the work shift is viable, the various other factors, each one the basic concepts are universal even though the solutions are not. There's an approach that is at least possible along those ways, building something that then can be customized by the local Ag Centers.

Dr. Schenker added that it's important that the burden not be placed on the worker. This is really something that the owners and managers and captains need to focus on and recognize the importance. And we need to not place the burden and tell the workers; oh, you need more sleep and get more rest and take naps and so on.

Dr. Lerman feels that one of the key basic concepts that's universal is it's a shared responsibility. Just like you can't put all the burden on the worker, management can't fix the problem by itself either. In his view that's a fundamental risk management concept. **Dr. Schenker** agrees.

Dr. Reponen read a comment from the chat, suggesting that if NIOSH wants to design interventions that promote behavioral and cultural change, look at the literature for other occupational groups having challenged behaviors to change, such as firefighters. She was also planning to bring up firefighters. For a long time it has been that the dirty gear was a badge of honor, but that has changed now that they are more

geared towards looking at really their own health and safety. So maybe there's some lessons to be learned from other occupational groups.

Dr. Graham added that, for instance within NIOSH, they've done PFD studies with personal flotation devices. And there has been a cultural shift in wearing life vests, and that was through targeted intervention, showing that it could be done practically, and you could wear them comfortably, and giving the tools and the resources to the to the workforce, and this has been adopted. This is something that has happened before and it can happen again. There has been cultural and behavioral change around life vests, and this could happen with fatigue as well.

Dr. Reponen addressed one final comment in the chat, recommending collaborating with COSH organizations.

Fatigue Management: Technological Advances and Fatigue Risk Management Systems

Presentation

Ms. Kyla Retzer is the Coordinator for NIOSH's Center for Motor Vehicle Safety. She was honored to be speaking with the Board today about fatigue management through the use of technologies, as well as the broader, data-driven approach to managing fatigue risk called Fatigue Risk Management Systems. Mention of any company or product does not constitute endorsement by NIOSH or the CDC.

The foundations and interest in technologies and procedures to monitor fatigue really started in the transportation industry in the 1980s and it's been mainly driven by the growing need to reduce road crashes as more vehicles take to the road and are capable of greater speeds. There's a growing interest in use of the technology from other industry sectors such as healthcare and mining. We've also seen growing interest from occupational health-and-safety groups in the use of these technologies beyond transportation. A recent survey by the American Industrial Hygiene Association found that information about sensor technologies, such as those used to identify fatigue, are the most sought-after content area among their members. All of this has precipitated an astronomical growth in these technologies.

Market research has estimated that the Driver Monitoring Systems' global market size was \$1.6 billion U.S. dollars and it is anticipated to reach \$2.4 billion by 2027. This growth is driven partially by the need to ensure driver attention is adequate given the increase in use of vehicle automation requiring less actions from the driver. One truck driving study carried out in a simulator found that driving a semi-automated truck produced more drowsiness in the driver than manual driving with standard cruise control. However, with all of these new inventions entering the market, there is the chance that some of these systems may not detect fatigue or may not work as intended.

The most common concern for programs at NIOSH is keeping up with these technologies and if they are valid. The most frequent question they're asked by other researchers, industry experts, and safety professionals is what is the right technology for me or for our organization?

This presentation will cover the different types of technologies that are on the market right now and how they can be used in the context of Fatigue Risk Management Systems. There's a wide array of these different types of devices, each with their own proprietary interpretation. This variety can make the choice for an employer paralyzing. Part of the variety is driven by the fact that there are so many proxy measures for fatigue, none of which give a complete picture and all of which have shortcomings. I'll place five of the broad categories of these technologies on the scale here with ease of use and accuracy. Ease of use refers to interruptions with workflow and general ease of implementation in the workplace, while accuracy and effectiveness refers to the potential for the device to identify a risk of a fatigue-related, safety-critical event. These are broad generalizations based on what we know from literature and interviews with subject matter experts and partners. Keep in mind there are many other considerations as well.

First are biomathematical models. These models are being used to predict potential fatigue of workers based on prior sleep, work schedules, and other worker factors. One example is called the SAFTE model, which is in use by the military. It has an accompanying scheduling tool which has been validated in ground transportation studies. In terms of location on this grid, these models are somewhat easy to use. However, due to its predictive nature, they do not allow for great certainty that individual workers are fatigued while on duty and should probably not be the sole choice of technology for an organization. For these models to work, good data on work schedules, prior sleep, and other factors are needed. Sleep data for workers may be available in industries like aviation, but employers are likely to gather resistance in getting sleep data from other industry sectors if it's during off-duty hours.

Second are fitness-for-duty tests. These are technologies being used to assess the alertness of a worker just before their shift or prior to starting an extra period of work. Two common types of biological measures being assessed in these tests are cognitive functioning and pupillometry, or pupil behavior. Cognitive functioning is often measured through sustained attention tests. These tests collect data on reaction times and lapses in attention over a five-minute or longer period. One common and well-validated test is called the Psychomotor Vigilance Test, or the PVT test. The second type measure is pupillometry. It is the measurement of pupil size and reaction to flashes of high-intensity, bright light; a demonstrated biomarker of fatigue and a measure that really cannot be outsmarted or out-gamed.

The third group on our scale is task performance technologies. These technologies do not examine the worker's physiology or attention, but rather they measure the performance of the work task instead. They are primarily right now being used to measure driver behaviors. Some indicators of potential fatigue in driving include the lane deviation, larger steering wheel corrections, greater speed variability, and greater availability in distance with vehicles in front of them. Some of these are readily available in commercial vehicles. It is possible that drivers are more accepting of these devices than physiological measures as the focus of surveillance is on the task and not on the employee. There are, however, limitations to these systems, as they can easily be affected by non-normal road conditions like non-paved roads. These devices also provide real-time feedback, but the drivers may receive warnings when it's too late to implement some type of fatigue mitigation. Also, the equipment needs to be hardwired into the vehicle and can be easily disconnected. Both the worker monitoring and task performance technologies have options for real-time audio or visual feedback. The feedback can be given to the driver and also to an offsite safety manager. This

brings with it a whole other set of benefits and challenges, including concerns about data privacy and potential liability concerns for employers.

The fourth broad group is worker-monitoring technologies. The same cognitive and pupil behavior tests used during fitness-for-duty can also be used throughout work shifts to detect fatigue. These tests may be disruptive for workflow because they would require the user to stop working to do the test. Most of the technologies in this group, however, refer to passive and continuous monitoring capabilities for the worker while they're on duty. As passive technologies, they don't require extra effort by the user. So worker monitoring technologies use a variety of physiological measures to passively identify fatigue. A tool for measuring brain activity or the electroencephalograph, commonly known as EEG, has been acclaimed as one of the most successful methods of detecting high fatigue levels, although less successful in identifying lower levels of fatigue. In lab settings, trained personnel will apply electrodes to the scalp to interpret results. And as you can imagine, this is not very practical for a workplace. Portable devices that do not require a scalp preparation are now commercially available. These devices detect brainwaves through headbands or headsets which can be worn as-is or affixed to a baseball cap. Posture or head-nodding technologies detect the posture changes that accompany fatigue, such as head-nodding, as the neck muscles relax. Generally, they come in the size and shape of a hearing aid, which is worn behind the ear. These devices are cheap and relatively nonintrusive; however, they are a late-warning device as they can only detect fatigue at around the point of sleep onset or when a fatigue-related incident is already likely to have occurred. At this stage, some argue that they are not sensitive enough for use in the road transport industry.

A third group is the ocular measures or eye behavior. The eyes and eyelids can provide significant information about alertness. Example measures include the duration and rate of blinks and also a similar measure, examining the percent of eyelid closure, often called PERCLOS. The technology used to collect this data are infrared lights reflected off the retina and also cameras that can examine facial recognition features. Advantages of these devices are that they are relatively noninvasive. Some eye behavior devices are based on scientifically-validated measures in laboratory settings. But there is some difficulty in translation of them in the real world. For example, many of the devices using infrared reflectants are limited by factors like ambient light and the use of prescription glasses or sunglasses. Camera-based devices are also largely unable to adjust appropriately to nonstationary working conditions.

Galvanic Skin Response, or GSR, is another physiological measure forming the basis of new technologies. GSR is essentially described as the activation of sweat glands on the skin and has been demonstrated to increase with fatigue. However, GSR also varies in response to other influences such as stress, making it unclear if this measure is able to identify changes that are specific to fatigue. There are companies who are working on improving the technology and using clothing fibers and other wearables that may be able to detect fatigue. These technologies are all in the early stages of development and still need to be tested.

The last measure is heart rate variability, which has been shown to be effected by fatigue. However, much like GSR, this measure can vary based on a wide number of other factors like physical exertion and stress. At this point, the use of this measure in real-world settings for fatigue is possible but has challenges.

A fifth category is hybrid solutions. Given that fatigue is a multifaceted construct from a wide variety of factors and can result in a number of biological and performance deficits, it's most ideal to use multiple measurement methods. The use of several different forms of measurement can serve as a backup. If one measure fails, then another measure might be able to detect the fatigue. The few studies based on hybrid solutions have achieved more consistent and increased sensitivity and specificity outcomes. They can also include existing data sources for employers, which may keep cost down such as looking at working hours, overtime hours, etc. In our interviews with industry health and safety professionals, hybrid methods appear to have the most effectiveness, which, in part, is attributed to the fact that it is able to be tailored for the job task and the organization. The drawback, however, is that this type of solution can add layers of complexity.

Another emerging concern with fatigue detection technologies is the term fatigue "threshold." It's being used quite a bit these days, but we're not sure if there's a full understanding of what this means. It is quite easy to buy one of these monitors and when it beeps or flashes, to accept that there is a high level of fatigue and then to do some type of mitigation. But it's a little more complicated than that. For example, if you're working and your sensor provides a reading—in this case, amber—what does it mean? If you were at a job which requires a great deal of precision and also exposes you to hazards with severe consequences, the best measure would likely be to discontinue the task for at least that day. But the same reading for someone in the role that requires less precision and where a fatigue-related incident would have little or no impact—like supervising a closed automated system—it may be safe to continue working for the rest of the day, but take precautions like more breaks or extra check-ins to ensure safety. This example brings to light how we need to frame sensor readings in the context of the work involved.

There are several main points to keep in mind when establishing a fatigue threshold. First, fatigue exists on a continuum. There's no set cut point. Also, a warning from a sensor technology should be interpreted in relation to the job task. What we're managing is fatigue risk, which is the combination of the likelihood of an event and the severity of the consequence. And the resulting fatigue mitigation strategy should reflect these factors. Ms. Retzer cautions using fatigue-detection devices as the primary or sole fatigue mitigation strategy and encourages using them as part of a Fatigue Risk Management System, or FRMS. These are data-driven and flexible systems for managing fatigue in the workplace. It's rooted in the idea that in our 24/7 society, no system of work is without fatigue-related risk. FRMS is considered a risk-based approach and is more holistic as compared to the more traditional hours of service. Hours-of-service regulations are helpful in that they limit the time awake that is required for work and ensure opportunities for sleep. However, hours of service do not typically take into account the other multitude of factors leading to fatigue like we've talked about in this forum. They also don't consider non-work-related activities such as commuting or the wide, individual differences in the need for sleep, rest, and recovery. The latest FRMS programs tend to have a blend or a hybrid model that contains elements of hours of work as a baseline and then additional risk-based strategies. It also reflects the need for multiple layers of defensive strategies, much like Reason's Swiss cheese model and accident causation where each strategy is likely to have holes. An FRMS typically includes predictive controls to lessen the likelihood of fatigue, proactive controls to respond during operations, and reactive controls that lead to enhanced management through the investigation of fatigue-related incidents. It also

acknowledges that there is a shared responsibility between employers and employees to manage fatigue-related risk.

There are many configurations of an FRMS. Although they seem to differ slightly, they can be described generally as having these six components. Briefly, they contain policies and procedures which outline the commitment to address fatigue and the backbone of the operational procedures to address the issue. Second, roles and responsibilities of both management and employees in the FRMS. The risk assessment and management component includes review of actual hours worked versus scheduled work, sleep patterns, symptom checklist for recognition of fatigue, and incident reporting. Data collected from technologies could be a part of this component. Training and educational programs that promote knowledge about risks, causes and consequences of fatigue, and how workers can manage fatigue—management can manage fatigue—and then controls and action plans that include a toolbox of methods on how to address fatigue and decision trees for supervisors and workers on how to handle identified fatigue. The exceedance of established thresholds for devices may be used in these decision trees. And then lastly, an audit and review component to keep reevaluating the system to ensure effectiveness.

There has been widespread implementation of FRMS' in large-scale, safety-critical industries like aviation and rail. It is now required by the Federal Aviation Administration for airline operations. In comparison to the use of Safety Management Systems, however, FRMS is still considered very recent in the last two decades. And much of the published literature is focused on the implementation of the systems. However, studies in a few industries have illustrated effectiveness of FRMS. One randomized trial of a Fatigue Risk Management program in firefighters showed that sleep and alertness were improved following implementation of the system, which included sleep health education, a workplace napping policy, and blackout blinds for sleeping quarters. Another study in a nurse population found decreased sleepiness following their program. And another nursing study, using interviews, suggested that fatigue countermeasures resulted in increased feelings of lifestyle control and restfulness. In the aviation industry, implementation of FRMS' provided controlled napping opportunities for pilots and resulted in decreased levels of in-flight fatigue and increased alertness.

The literature on implementation has highlighted the need for FRMS to be as closely integrated into preexisting Safety Management Systems as possible and to implement FRMS in organizations with a mature safety culture where the reporting of fatigue and fatigue-related incidents is likely to occur because there is trust. There is currently limited evidence of a positive impact on lagging safety outcome measures. Future research needs to track key leading and lagging safety metrics from both the scientific and operational perspective. Potential challenges with implementing FRMS include the complexity and cost, in particular for smaller organizations or ones that do not typically deal with shiftwork or irregular working hours. These companies will likely need an off-the-shelf, simple system in order to use it.

There are several key NIOSH activities related to fatigue-detecting technologies and FRMS. Three centers at NIOSH have combined efforts to begin to share information about fatigue detection. The Center for Work and Fatigue Research, the Center for Motor Vehicle Safety, and the Center for Direct Reading and Sensor Technologies are conducting interviews with industry experts, doing a literature review, and publishing a

series of blogs and other products about the selection and use of these technologies. Sleep measures are currently being collected in three different NIOSH studies with taxi and for-hire drivers, nurses, and law enforcement. These data are being collected in conjunction with the evaluation of fatigue awareness training. All of these worker groups struggle with either unpredictable or long working hours. Actigraphy watches will collect sleep hours, waking time, and sleep efficiency from workers.

The second project is focused on miners. Mining is especially susceptible to worker fatigue due to the combination of environmental factors known to induce fatigue such as dim lighting, high temperatures, loud noise, repetitive tasks, and shiftwork. The objective of this program is to develop evidence-based toolkits that will enable mines to sustainably measure fatigue, interpret the data, and select and implement appropriate interventions. And the final project addresses commercial vehicle operators and is an evaluation of the effectiveness and cost benefits of the North American Fatigue Management Program. The team will use technologies to detect fatigued driving events. The system will be an onboard camera system that uses machine learning. There will be an open bid to select the vendor for this study.

Technologies will undoubtedly play an increasing role in the future of fatigue management, both in work vehicles but also at worksites. As this use increases, NIOSH and other organizations will want to place emphasis on the need for the validation of these devices and ensure there are well-defined criteria for validation. Validation, of course, ensures the device measures what it purports to measure. A second component of validation is how well the selected measure being collected with the device actually predicts or detects fatigue. Lagging indicators also need to be collected and evaluated with implementation of these devices, like fatigue-related incidents, crashes, and lost-time injuries.

Because there is no one measure that is perfect, valid, and easy to collect in the real-world environment, technologies will ideally be paired with other sources of data to increase the likelihood of an accurate assessment of fatigue. For example, a slow eyelid droop alongside a driver's lane departures and a previous work schedule with limited rest periods may be a strong indicator of likely fatigue when combined rather than with one individual measure by itself. We also want to consider the weight and strength of these individual pieces of information to assess risk and what actions should be taken. A third consideration is to provide caution that these technologies cannot be the sole approach for managing fatigue. Companies that have heavily invested in a technology may be tempted to over-rely on the data or trust less the workers' feedback on their own state of fatigue or alertness. Workers themselves may over-rely on a trusted device to warn them of potential fatigue rather than maintaining awareness of their own feelings of drowsiness. If the device fails, the results could be catastrophic. The ability of an organization to incorporate the device's data into their FRMS and also their larger SMS in place is critical to the sustainability of the technology in an organization. And finally, many technologies are being validated in lab conditions, but few have been successfully applied in real-world settings. For example, technologies that are collecting brainwave activity but with limited success in the real-world setting.

Ms. Retzer raised two questions to the board:

- 1) First, with this influx of new technologies available on the market, what can NIOSH do to promote their effective use within this holistic approach of FRMS?

- 2) Given the limited company resources and the complex efforts needed for FRMS, how can NIOSH help employers and workers develop this approach?

Discussion

Mr. Morrison asked Ms. Retzer to speak about the labor management connection, since the technology can feel like “Big Brother” and worker buy-in is needed to implement any kind of program.

Ms. Retzer responded that she has had a lot of experience with this issue of worker acceptance in the larger scope of in-vehicle monitoring systems and any sort of systems monitoring the driver’s activities. There is a lot of hesitancy in tracking those behaviors when the workers are off duty, any kind of off-duty activities. But what she’s seen with success has been when the program is—it’s made very clear that the purpose is to protect the workers and when employers are clear that there’s not a punitive approach being used and that they’re not monitoring workers’ driving activities, other than to make sure that they’re driving safety. For examples, if cameras are being used, they’re not watching the driver unless there’s a critical incident that’s been captured and then that video is being examined for other things that the driver could adjust to be more safe.

This brings up the whole idea of the safety culture of the organization really needing to be mature enough that there is a level of trust there that the purpose is for safety and not Big Brother. Ms. Retzer has worked a lot in industry sectors that have very little union representation. She would like to be able to share a story of some success where unions had approved some type of device like this but is not aware of one. From experience of worker acceptance, it definitely relies on those workers understanding what the purpose of these devices are and they’re really hard for surveillance per se.

Dr. Wong agreed that it really takes fostering a safety culture that starts at leadership and building trust amongst all the workers. And that, of course, always takes time. One lesson learned is to start small. Start with small groups and show successes, and from that build momentum to accept this as being a safety measure and not a punitive measure.

Mr. Morrison also wanted to stress that sometimes some of these devices are really intriguing to especially engineers who run a lot of these businesses. And you have the shiny-new-toy phenomenon. He’s had situations where people have wanted to implement them without knowing ahead of time what they’re going to do with the data. In the models presented, knowing what to do with the data was an important part of it. It would be very valuable to give companies guidance on how to interpret it and what to do with it.

Dr. Reponen agreed guidance on the interpretation of the data would be very much needed.

Dr. Cox suggested a partial technical answer to at least the first question. Not an organizational answer about what can NIOSH do, but a technical answer to how can we combine the results of multiple detection technologies to best manage risk. The technical innovation, this probably comes up often in machine learning that you have a number of different predictors, more or less black-box methods like random forest and gradient-boosting machines and support-vector machines, have all these different predictors. And the

question rises how do you combine their results because they don't all give the same answer when you try to predict something?

A technical answer to that that's got some traction over the last maybe five years in machine learning, is to use a technique called super-learning where you treat the predictions as due variables and feed them into something like a decision tree growing algorithm. And if it's expensive to collect these measurements, you can also grow a tree that minimizes the total expected cost of collecting the measurements and then the cost of error if you fail to make that a correct decision. That technique, super-learning—where, again, super-learning just means you stack a number of different prediction technologies under a technique that combines them into a final decision tree, for example—that's pretty well-developed technology. Possibly it could be advantageous here for addressing not the organizational, but the technical question of when we have multiple techniques, how can we come up with something that's better than any of them?

A one-phrase answer to that is to just use off-the-shelf super-learning methods that are pretty well-developed. And that could help also address the second question, given the limited company resources, how do you get the most bang for your buck?

Dr. Reponen had a question on the privacy issues and how acceptable some of these are for the workers. For example, this brain activity; she wouldn't necessarily like to have somebody putting gadgets and measuring her brain activity.

Ms. Retzer Those devices, in theory in the lab, they're really good for identifying the cognitive facts of fatigue but, in the field, they require the headbands, the baseball caps, these extra apparel that the workers can use. And from the people that she's talked to that have piloted those devices, they've had difficulty in worker acceptance. It might work in a lab, but in the field—from a practicality perspective—that anything that a worker has to put on their bodies is going to be a challenge long term. The camera systems in the vehicles are much easier because they're already installed and the worker basically doesn't have to do anything. Cameras can be used for not just fatigue, but also seatbelt use and detect other risky behaviors. At least in a driving setting, cameras are a really good, useful tool. And facial recognition is just a way to detect eyelid closures and other things.

Dr. Wong drew on a NIOSH Science Blog that in development about implementation. First, as a health and safety professional, you do your research, you find fatigue-detection technology that's valid. But if the users don't accept it, then it doesn't work in your particular workplace or organization. It's about building a safety culture, even sharing the results with the workers so that they could see what it looks like. Some of these things that are measuring brainwave activity, you can show them the data and show them that it's not as intrusive as they think it might be and really create that dialogue between the workers and management and health and safety professionals to really find something that would work for their organization.

Ms. Doyle had comment along the lines of the question about union involvement. It's really important to have employees involved, to have an employee or several employees on the committee looking at these issues if an employer wants to bring it in to the workplace. Because she remembers back in the 80s when she worked in the surgical ICU and they had the MBAs come in and do those workflow studies. And they didn't

tell us ahead of time what was involved even the day of. They didn't want to interact with the ICU workers and tell them anything, so the ICU team was really resentful that these people were coming in, tracking every action that they took all day long, and they never got any feedback on what the results were. It's really important to have the employees part of this team that's looking at these technologies.

Ms. Retzer replied that a pilot that works directly with all effected parties needs to be part of any sort of implementation of these technologies and the development of any sort of policy associated with the technology should have the workers at the table; the line supervisors, all levels within the organization so that all those perspectives can be taken into account. Piloting is important, making sure it's really working and it is going to be acceptable.

COVID-19 and Workplace Fatigue: Lessons Learned and Mitigation Strategies

Presentation

Dr. Wong started by saying that we can't really have a discussion about workplace fatigue or even worker health and safety without discussing the events over the past year with the pandemic. She will share some of the lessons we have learned with regard to COVID-19 and workplace fatigue and considerations for mitigating workplace fatigue as we move forward. As you have heard, fatigue can stem from a number of different factors related to work, the individual, and life or lifestyles. Fatigue is actually more than sleepiness and its effects are more than falling asleep. And specifically with respect to COVID-19, it's important to remember that fatigue and mental health are closely related and fatigue is a symptom of mental health issues and it can exacerbate existing mental health issues. A lot has happened in the past year as we were navigating through one of the biggest global health crises in our lifetime. To ensure that health and well-being of Americans, there have been three notable events which impacted workplaces and the way we work. And the first was the declaration of COVID-19 as a national emergency on March 13th, 2020. The second was on May 14th when the CDC started rolling out guidelines for keeping communities safe and healthy using measures such as social distancing and wearing masks. This also included workplace guidelines provided by NIOSH. And the most recent event is the vaccine rollout program and momentum to regain a sense of normalcy again. So I'll be structuring this presentation around these events to illustrate what we've learned so far and what we need to consider as we move forward.

The declaration of COVID-19 as a U.S. public health emergency altered the way we work and live almost immediately. There were many workers who were deemed essential services and faced seemingly insurmountable pressures to provide the necessities to keep our communities going. The ones that really come to mind include healthcare workers, transport or delivery drivers, and grocery clerks we have heard have worked long hours around the clock to meet rising demands. With the pandemic declaration, many workers faced sudden, major changes in their routine; living with uncertainty and worries about the situation, its duration, all of this contributing to daily stress. What also really became evident during this time

is the prevalence of stress-related sleep problems and those sensitive to sleep disruption are more likely to develop chronic insomnia. Insomnia is also a major risk factor for post-traumatic stress disorder when exposed to major a stressor. And thus, in turn, is associated with an increase of sleep disruption creating a spiral of stress, mental health issues, and sleep impairment. In studies immediately following the initial outbreak in Wuhan, China, found that those reporting greater fatigue and anxiety severity were more likely to experience insomnia. And symptoms of post-traumatic stress disorder were reported by 7% of residents just a of months after the COVID-19 outbreak.

n the U.S., other considerations related to fatigue had to do with isolation, particularly in areas where there were strict stay-at-home orders. Some people had less exposure to daylight, particularly those living in homes with small windows or without an outside area. Many people stopped exercising due to cancellation of regular sporting activities, restricted opportunities to leave the house, and having to juggle the requirements of work and childcare. Binge eating and other unhealthy behaviors are a natural reaction during times of stress and without a regular daily routine that is commonly dictated by work or school responsibilities, this can lead to sleep difficulties in addition to other health risks. And for some essential services, the addition of nightshift work was incorporated to meet rising demands, potentially increasing the risk for fatigue-related incidents for those who are unaccustomed to working off-hours.

We've learned that certain groups of workers have a higher risk for severe cases of COVID-19 requiring hospitalizations. Compared to nonessential workers, essential workers were 60% more likely to be hospitalized for COVID-19. Healthcare workers had the greatest risk at almost eight times likely to be hospitalized. And those in social care and transportation were twice as likely. A host of other factors that were significantly associated with increased risk for COVID-19 hospitalizations have been recorded. But what she really wanted to draw attention to were the occupational factors, specifically manual labor and nightshift work, which both increased risk. However, long work hours, defined as more than 40 or 45 hours per week, was not a significant factor, even though it might mean more exposure time. The finding that nightshifts was significant suggest that maybe factors associated with nightshift work such as circadian disruption, abnormal immune cell and cytokine levels, and disruption of melatonin production might be causal factors, increasing the risk for susceptibility and severity of COVID-19. But all of this warrants for the research, particularly with interaction effects between high-risk occupations and occupational factors. And this also suggests additional precautions may be needed for specific working groups and considerations for health communication strategies.

It can be agreed that healthcare workers are most likely to see the most traumatic effects of COVID-19 and have the most exposure to the SARS-CoV-2 virus with considerable and justifiable concern for their own health and safety. Studies on healthcare workers emanating from Wuhan, China, from the initial outbreak reported a surge of new cases of depression, anxiety, and insomnia. Other studies highlighted the prevalence of anxiety and stress and poor sleep, and also found a significant association between these variables. Other significant determinants for poor sleep and fatigue include exposure to COVID-19 patients, poor social support, and preexisting depression. And even in these early stages of the pandemic, studies also found that sleep quality decreased for most frontline workers during their shift and continued to deteriorate during and

after their post-shift isolation, raising concerns about the long-term effects on health and well-being of these workers with particular concern on the exacerbation of mental health issues.

We've heard about extreme pressures put on our supply chain as we see panic-buying of consumer goods such as toilet paper, hand sanitizer, and cleaning products. And all of these items are possible through our vast chain of trucking and delivery networks. In response to pandemic, truck drivers and support personnel were declared as essential critical infrastructure. And the Federal Motor Carrier Safety Administration also issued an emergency declaration relaxing the hours-of-service regulations for truck drivers transporting emergency or critical supplies. This included items such as allowing for extensions of their duty times and less time off between their haul schedules. However, this also restricted limitations such as motor carriers and drivers were not allowed to create situations where they were so fatigued that it impaired their ability to operate the rig safely.

So what do you think happened? Findings from a survey of truck drivers in the early stages of pandemic found that these loads shifted from long-haul deliveries to more short-haul deliveries as more emphasis was placed on regional distribution of critical supplies. These shorter-haul distances and lower-haul volumes meant that drivers were most likely getting paid less. With the decrease of traffic congestion, drivers were likely to push the speed limits in addition to their hours of service, but note, they did not violate the speed limits. Longer detention times and more time required to maintain proper hygiene practices meant that it added time to deliver goods. As drivers are paid by the load, this raised concerns that they were going to push the limits as much as they can. And with the closure of many businesses, it also limited the number of available places to pull over safely for rest stops. It's been suggested that these types of situations may ultimately create the incentive for drivers to operate longer, forego rest breaks, and park in unsafe or unsecure locations if they run out of available hours. And this raises considerable concerns about fatigue amongst those who are hauling essential goods in our supply chain.

This concern is not limited to commercial drivers. For other occupations which are paid by piecemeal, the pressure to compensate for economic gaps may create an incentive for workers to push their limits through work intensity or hours of work. Estimates show that up to 40% of workers have the privilege to work from home or remotely, although it's possible that the numbers could be much higher as flexible arrangement is materialized. A Gallup poll at the onset of the pandemic found that almost all of those working from home have said that COVID-19 caused a great deal or a fair amount of disruption in their lives. Many reported that they had children home from school and were dealing with issues regarding home schooling. There were reports of increases in daily stress and a lack of ability to balance work and life. There was concern that there was a gendered impact, that mothers may be more affected than fathers based on the existing distribution of childcare duties. Reports show that people were spending more time in meetings compared to prior to the pandemic and their time was also more fragmented to focus on work. For some, there was stress in learning how to use the new technology to work from home and some were experiencing workplace isolation. And as many of us have experienced, suddenly makeshift offices such as using dining room tables have cropped up to accommodate working from home. These may not always be the most ergonomically-friendly setups and often times small spaces used by a number of family members, making it difficult to concentrate when there's a constant noise in the background. And all of this contributes to stress and fatigue.

With the development of the CDC guidelines in May 2020, which included the NIOSH efforts for safe workplaces, many businesses and workers were trying to resume a regular routine within our confines of a new normal. What did that new normal mean for workplaces and work conditions? Following the declaration of the national emergency there is a devastating loss of jobs across the nation. The closure of many businesses led to financial instability and the highest unemployment rate since 1976. But since then the employment numbers have been steadily increasing, but we're still not quite near employment numbers from 2019. The Bureau of Labor Statistics and the International Labor Organization forecasts that the greatest job losses over the next 10 years will be in accommodation and food services, manufacturing, retail trade, and some public transport occupations. And the loss of income can be devastating. And a loss of employment also means there's a loss of employer-sponsored health insurance benefits, which is critical at this time. The Bureau of Labor Statistics has also reported that following the initial job losses in April, the uptick in employment was mostly amongst part-time workers who had preferred full-time employment but were working part time because either their hours were reduced or they were unable to find full-time jobs. Because of this, we may see more workers in multiple jobs for part of the gig economy to make ends meet, as someone had mentioned earlier today.

Again, the addition of overnight shifts amongst organizations to accommodate physical-distancing requirements while keeping up levels of production or service may increase the risk for fatigue-related incidents, particularly for those who are unaccustomed to working nonstandard schedules. We may see more organizations working with reduced staff and, in some cases, that might mean greater work intensity.

Among U.S. healthcare workers, there was about a 5% case fatality rate for COVID-19. Globally, a total of 153,000 healthcare workers were reported to have been infected with COVID-19, representing almost 4% of the total number of patients with COVID-19 worldwide. Additionally, for every 100 healthcare workers infected, there was one fatality. Comparatively in the U.S., almost 20% of COVID-19 patients had been identified as healthcare workers, but the fatality rate was half that of the global rate. And as you can see here from these heat maps—the blue representing infections, the red representing fatalities—the darker the shade, the higher the number of infections or fatalities. And in May of 2020 the U.S. had a pretty high prevalence of incidents and fatalities compared to the rest of the world. This perpetuated substantial reasons for stress, anxiety, and fatigue as the pandemic continued with no certain ending.

More studies and systematic reviews emerged during this period, some identifying determinants of workplace fatigue among healthcare workers. Studies from the U.S. and China from the first stages of this pandemic reported that limited resources, overwhelming workload, longer shifts, disruptions to sleep and to work-life balance. And some workers had opted not to live at home or, if they were living at home, some chose to separate themselves from the rest of the household to reduce potential exposure. Items like process inefficiencies, other occupational hazards, some organizations have mentioned an overall lack of preparedness and insufficient training. Again, there were concerns about financial instability. All of these factors were said to be significant contributors for an overall surge of new cases and exacerbation of existing mental health issues with ultimately effects on anxiety and insomnia. These factors are not limited to healthcare workers and perhaps we should also consider these as potential fatigue factors in other sectors.

This current phase that we're in now has been described as the vaccine rollout program and a period of either reclamation or rebuilding, with people eager to resume to some sort of normality with their lives. However, this is also a time to look back and think about the lessons learned and how we could be better prepared should something like this happen again. What can we do? First, we need to recognize that fatigue and stress go hand in hand, particularly these types of situations. A comprehensive Fatigue Risk Management plan is one effective method to manage fatigue and fatigue-related incidents. We found that good health and hygiene behaviors to control stress and boost immunity are critically important at these times. This includes strategies at personal and organizational levels, provision of psychological support systems. All of these measures have been shown to reduce workers' anxiety, depression, stress, and insomnia upon returning to work. An also effective messaging is important, which should be tailored to the audience and may include considerations for language level, translations, or use of infographics.

It looks like working from home may be here to stay for a little while, or at least some sort of hybrid situation. Tips for employers really center around communication, having a clear plan. Again, we're still in somewhat uncertain times so this includes basic engagement elements such as setting clear expectations, adjusting resources, and providing some flexibility if possible for those with dependents at home, helping workers feel connected and involved, and providing resources to help workers feel well-prepared to do their job. Again, whatever works for the organization that folks are in, but flexibility and creativity are needed to help everyone through these times. Consider redesigning tasks or shifting workloads that may not have been considered before. For workers, tips include setting physical and temporal boundaries to create a separation between work and home life. This would include regular breaks to walk around, stretch, get exposure to fresh air and natural, or watching manatee videos. Set aside, if you can, dedicated time without interruption and experts recommend two to three hours to concentrate on one task. Multitasking is difficult for the mind and can lead to fatigue and burnout.

Sleep is controlled by biological, social, and environmental regulators such as the light we're exposed to, mealtimes, exercise, and social events. When we stay indoors for a long period of time, we may lose a lot of these cues. Maintaining a regular routine will benefit a good night's sleep. We also find that in times of common stress it's normal for individuals to feel more of a need to communicate with each other, of course within safe confines. Social interaction always seems to diminish stress and studies have shown that social support further improves sleep quality.

The most salient lessons can be learned from the healthcare industry who have gathered some collective insights on what we can do in the next phase of rebuilding and how we can be better prepared for future crises. Previous data has reported that adverse psychological reactions among healthcare workers following the 2003 SARS outbreak with suggestions that it could have long-term, psychological implications and fatigue. And lessons learned from SARS and COVID-19 suggest that to prevent burnout, occupational stress, and fatigue include coordination of responses and sharing of information between and within local, state, and national levels. Other suggestions include structured training on large-scale disasters, increased staffing—whether it be temporary—to help us through these times, provision and easy access to mental health resources, and HR-adapted policies such as alternate paid-time-off options. It's been suggested that improving awareness of fatigue such as with wearable sensors or brief assessments and then communicating

this information to managers for timely intervention can reduce the risk for fatigue-related incidents and improve worker health and safety, and hopefully this will also help precipitate behavioral change. However, the integration of new technologies with current working conditions may present additional burden that requires further examination.

These are results from a really interesting path analysis with data collected from healthcare workers in Wuhan. The orange arrows represent a positive association, the blue arrows represent a negative association, and the weight of the line represents the strength of the association. So not surprisingly, high anxiety and high stress are associated with poor sleep quality, but greater self-efficacy equates to better sleep quality. What's really interesting to note is that with good social support, it reduced anxiety and stress and it fostered better self-efficacy with ultimate positive effects on sleep. This really starts at the leadership level at creating a good safety culture. Following this train of thought, a recent commentary published in the British Medical Journal stressed the importance of leadership to mitigate workplace fatigue in healthcare during these during these times. And this really means leadership that goes beyond mandated working hour limits and includes the identification, mitigation, and prevention of fatigue. And the authors of this commentary go on to suggest that ideas for a systems approach to managing fatigue in healthcare settings can be drawn from the same concepts outlined in Fatigue Risk Management Systems implemented in aviation. And this demonstrates that we can learn across from industries.

That being said, NIOSH has been busy developing a number of products to manage stress and fatigue during COVID-19 and these products are available in multiple languages. NIOSH has published several science blogs, one with tips for healthcare workers and employers on how to manage fatigue during emergency or disaster responses. And these are based on our recommendations from our online training products. Another blog post has tips to improve sleep during challenging times. And because stress and fatigue are so intertwined, a third post is dedicated to taking a holistic approach at managing stress and fatigue. The most recent was on COVID-19 and workplace fatigue from which this presentation was built upon. NIOSH has factsheets dedicated to coping with stress and building resilience. One aims specifically at healthcare personnel and first responders, another for all workers. And we also have a factsheet with tips on employers across all industries on managing fatigue.

NIOSH isn't quite done yet. The pandemic is not quite over and we still have several projects still being formed. And examples include those recently funded by the Disaster Science Responder Research just-in-time funding opportunity. This includes a project examining stress and fatigue amongst NIOSH responders during deployment and the residual effects after rolling off of deployment. Colleagues in the NIOSH Health Effects Laboratory Division have a longitudinal study to examine mental and physical health amongst well-established law enforcement cohort. Components of this study focus also on sleep and fatigue. And we are eagerly awaiting these studies. In the meantime, we're developing a Stress and Fatigue During Times of Emergencies webpage to house all our stress and fatigue resources in one place, making it easier to find. We have reached out to our colleagues across NIOSH and to external partnerships for resources that we can include on this page, which will be housed in our Center for Work and Fatigue Research website. And as an evergreen product that can fit in any crises—whether it be an individual, local, or national lever—we are also developing two short videos—one aimed at employers, the other for workers—at managing fatigue during

challenging times. We are also planning to have these available as downloadable podcasts to make it easier for people to obtain information.

We still don't know the full effects of COVID-19, but being better prepared and identifying lessons learned as we put this period behind us will help us be better prepared for future crises. Fatigue is more than hours of work and sleep and I'm sure we can add more factors which can contribute to workplace fatigue as we learn more. The key message is that managing fatigue requires a holistic approach, which starts at recognizing the major sources so that targeted effective mitigation strategies can be implemented. We need to think about things like work intensification, changes in work arrangements such as multiple jobs, as was mentioned earlier, and how we structure job tasks. Over a year after the declaration of a national emergency, we are still in uncharted territories with uncertainty at how COVID will change our futures. We don't know the long-term physical effects of this disease, although studies are starting to report long-term damage to neurological, pulmonary, and respiratory systems. And all of this may affect people's abilities to work if they've had the disease. What is also very apparent is that there will be long-term mental health concerns that need to be addressed and all of this will have long-term impacts on fatigue.

Dr. Wong had two questions for the board:

- 1) Any thoughts on what else we could do during this time of rebuilding to address workplace fatigue?
- 2) How can we gauge the effectiveness of our products and activities and ensure that we're reaching the right audiences?

Discussion

Dr. Demian had a question about long-term care facilities. In a good year, in a non-COVID year, that is a workplace that is rampant with fatigue and prone to injuries and psychological stress. And yet it's very difficult to reach out or reach in and promote education regarding self-efficacy, stress management, even PPE. Are there any studies or intervention that NIOSH is involved in with nursing homes specifically?

Dr. Wong is not aware of, at this point, any studies in long-term care facilities.

Dr. Cox suggested using causal discovery methods to try to find out from data how the arrows should be oriented in the model Dr. Wong presented.

Dr. Reponen asked whether anyone think of anything else that should be added to the model.

Dr. Wong pointed out that the issue of multiple jobs is not on here yet. It's something on the forefront of her mind that she would like to look at a bit more closely. She's hoping that we can do that with some of the national surveys, which should have enough study power to look at any significant differences.

Dr. LeMasters suggested adding exercise.

Dr. Wong pointed out that this model was adapted from a study that was published in 2011, so there are a number of different factors that have not been included in this that could be added.

Dr. Cox suggested adding anxiety.

Mr. Foley added that it's important to distinguish between precarious work that occurs without any official or legal employment arrangement and situations where there's a direct employer or at least a staffing agency involved where there is some sort of legal employment arrangement. Because if we're talking about support or countermeasures that employers might take to assist workers to combat fatigue, there's a big difference if there's no actual legal employer covering the worker. This would include self-employed workers too. Dr. Wong's point about including multiple jobs is really important though. There's a lot of stress introduced when workers are constantly having to think about the next job that they've got to find. Looking for work is always stressful, it's especially stressful when you're employed as well as looking for the next job.

Dr. Schenker thought workplace precariousness summarizes that and agreed with its importance. And that includes a range of factors: documentation status, job security, etc.

Dr. Reponen pointed out there's a variable for working arrangement and asked whether that covers all of those that were just discussed.

Dr. Wong believed it did. In the broader terms used currently, that definitely envelopes the items that were discussed today.

Dr. Graham suggested adding housing arrangements, for example, if you're homeless, renting or in a home that you own.

Dr. Wong agreed and expanded it to high-rent status, as we're seeing in some cities. Low rent occupancy is driven also by high rent prices.

Dr. Barton asked a clarifying question about education – would that encompass education not only for helping with fatigue, but also education as it relates to the processes that are going on right now? She's referring to mixed messages and the fact that many don't really trust the messages that they're getting from the government. She suggested that education really should encompass not just directives or ideas on how to reduce fatigue, but also on whatever the issue is that's going on that's causing the situation.

Dr. Wong agreed completely and felt that these are great lessons we're learning as we're moving along. This has been a very unprecedented time and the information that's been shared continues to evolve. It's added to some confusion.

Dr. Olszewsky added to what Dr. Barton said about education, since a lot of parents are being homeschool teachers through this pandemic and they're carrying multiple roles. She would add dependency care beyond children, to include aging parents and extended families.

Dr. Wong hasn't seen any studies related to other dependency care, but Dr. Olszewski is absolutely correct. She hopes we're going to see more as we emerge from this period and as the scientists comb through all the data. Also, not only taking care of the older generations, but possibly taking care of people who are sick with COVID.

Dr. Barton pointed out that some of the factors that you have on here also are some of the social determinants for people who have worse outcomes from COVID. It's interesting that that kind of merges into this picture as well.

Global Perspectives on Workplace Fatigue and Fatigue Risk Management

Presentation

Dr. Popkin started by saying we face a radically changed world made even more complicated by the pandemic and its impact on job losses. We just heard about increased numbers of workers in the largely unregulated gig economy, which we just talked about too. And by evolving technology and automation.

The problem is not just for high-income countries. This stretches around the world and extends to and exacerbated in low- and middle-income countries. We want to suggest up front that we focus more of our efforts on solutions that are applicable in all countries and in all settings, many of whom are suffering with fatigue levels hard to imagine in the United States. We feel it's our ethical responsibility to do so.

As we've heard, human fatigue is complex. We do not know all the interactions and triggers. Our research tends to be siloed and specific and does not immediately lend itself to systems thinking and effective approaches to addressing it. Most importantly, we cannot regulate off-time or people's wish to survive or make a better life for themselves. We cannot regulate healthcare. The jobs of the future require skills that are directly targeted by fatigue. The impact of fatigue is most likely to grow worse.

But even after 50 years of research, we are still not cracking this nut. Even with the newest countermeasures, laws, fatigue risk management approaches, sleepiness remains a national safety and health issue. In some, we believe that the last century of scientific research has given incredible breakthroughs in our understanding of sleep and fatigue management. We also believe all too often our system fails to deliver those breakthroughs to workers at the critical moments when their safety, well-being, and health is most likely to be compromised. The next step is to find simple-to-understand solutions scalable to company size and lives. A goal should be to develop a pathway to allow this happen, research-to-practice impact, and to do so we need to build up this important scaffolding.

We are not really sure how we get to effective, simple, scalable solutions. There is work to be done to figure that one out. Playing the devil's advocate for this quote about work schedules that focus on how opportunities for sleep requires consideration of many factors and is unique to each country, industry, and workplace. We believe that it is perhaps nearly impossible in the current environment and culture to achieve this because it really comes down to the job, the situation, the person, and their values. The question is how do we move the needle so fatigue impairment becomes as socially awkward and unpalatable as drinking in the workplace?

A major influence of work schedules or regulations, which often get a lot of press, especially when tragedies occur. So let's consider them for a moment for moment levels and for multiple countries. There is a great variation from country to country and within countries from industry to the next. Gartner argues that this variation changes along two dimensions, the types of rules and the focus of the regulation. We believe that there's a third element, a culture or appetite for change. In Gartner's model, there are three basic types of rules there on the left-hand side, which may be used alone or together to formulate a set of regulation.

Prescriptive rules set limits on work hours, but can be easily circumvented and do not handle nuance well. Fatigue Risk Management Systems, which while including a lot of science, take a lot of resources to implement well, which is difficult for small businesses and therefore not easily scalable. And with process rules, bargaining depends on the outcome desired, often ending up the status quo when pitting dollars against long-term health and safety, vis-à-vis work schedules.

Driving the different rules are four primary focus areas which resonate differently between people and are related to culture and mindset. There on the right-hand side you have safety, impact of which is infrequently seen, we end up with the not-me mindset. Well-being, people are often willing to sacrifice weekends or sign up or be given overtime without understanding the demand characteristics being set up, where they're just trying to survive in this world. We have health, which, again, is hard to understand long-term risk or consequences so people just end up hoping for the best. And then you have income, which is easy to see the immediate harm or gratification and therefore gets the most attention.

There are other hidden factors at work too that come about when regulations and bargaining meet work schedules. The example is a 10-hour backwards-rotating shift schedule. It uses five teams and three overlapping 10-hour shifts. It's not that unusual and often is preferred due to the extended off periods.

Now, this is an example of how context is important. Here, income and cost can play a pivotal role in adoption depending on the conditions under which an employer has to pay overtime. As you know, in the United States certain categories of workers are required to receive overtime premium pay for work exceeding 40 hours a week. This schedule would require 20 hours of overtime pay every four weeks, while in Europe, hours can be averaged out over the entire work cycle with no additional cost burden.

Another important-but-hidden factor is health insurance, as seen here. In Europe, insurance can be paid by the day or hour, while in the United States, it is paid by the person leading to pressure to get the most out of an employee rather than adding additional staff. Not only are there tremendous variations in the types of rules and the focus of the regulations, but there are large variations across countries in the role that national, state, and local governing bodies, industries, and unions play in the final regulations, all adding additional levels of complexity and difficulty in implementation.

The regulatory chain is better represented as a triangle all meant to funnel down to protect the individual, but mostly without their input or specific needs or limitations considered. This might also be considered as a three-dimensional matrix: type of rule, originator of the rule, and outcome of the rule. Outcome of the rule is the culture piece or the lens where safety can be thought of as either supportive or diverting personal responsibility. With healthcare, its impacts may be socialized, especially long term, versus full-cost accounting including the impact of the implemented schedules.

Australia is one example of just how complex it can be to perform and implement regulation. In Australia, most regulatory approaches lie somewhere on a continuum where more traditional, prescriptive rulesets on one end to a fully-articulated risk-management systems on the other. The Labor Relations Fair Work Act of 2009 provides a framework where worktime up to 38 hours a week is considered ordinary hours. Any work over that period is considered additional hours and an employee cannot be required to work additional hours

unless it is reasonable to do so. What does “reasonable” mean here? it includes an employee’s personal circumstances and the needs of the workplace or enterprise. So it gets a little bit squishy. There’s also a duty-of-care and chain-of-responsibility rule. If the consigner, say, puts undue burden on the shipper and working time rules are not followed as a result, they can be held liable, at least in theory.

At the state level, we need to consider various workplace health and safety regulation which include an act which provides some general principles, a regulation which describes standards that must be met within the various codes of practice within an industry which gives practical guidance on how to satisfy the provision, satisfy the act in the regulations. And then finally at the bottom level there, we actually get to the industries and companies themselves, which ends up as an amalgam of standard hours that adhere to simple prescriptive rules, a basic fatigue management approach which has slightly more flexibility, flexible rulesets, and some standardized controls within an Advanced Fatigue Management system which operates fully outside prescriptive regulations using approved firm-specific, risk-based system.

In the end, what we have is the very precise rules that are difficult to implement and enforce and have not been validated as effective outside of being science-based. Rules need to be practical and context-sensitive, which together are hard to achieve. So back to the problem, rules being too blunt or too expensive or too hard to implement and no real evaluation of their efficacy.

So what to do? We believe a new approach is needed in the way workplaces and the overall population think about the importance of sleep. We need to influence the narrative. Social networks can be extraordinarily powerful here as documented by Damon Centola at the University of Pennsylvania. In 2010 in a science article, for example, Centola found that people are more likely to require new health practices while living in networks with dense clusters of connections; that is, when in close contact with people they already know well rather than a broad, disparate set of connections they might have, for example, in LinkedIn.

To change attitudes around sleep, we’re going to need to find the social networks in which employers and workers are involved. And we are going to need to bring them together using what are called egalitarian networks; that is, a focus on the issue, not positions.

What might these networks be? They could easily consist of industry groups sharing information on the economic advantages of a better-rested workforce. Or spouses on Facebook would gather to share concerns about their shift-working partners. This is preferred to a more-general network of friends. Also we’re going to need to identify the influences in those networks of employers and workers that can change attitudes around sleep. Here we don’t need individuals or companies who economically or socially dominate others, just ones who engender trust and respect. Also, messaging is incredibly nuanced. For example, we’ve seen in transportation that children who say, “Mom, Dad, I am worried when you drive while distracted” are much more likely to get their parents to change their behavior than children who simply say, “Mom, Dad, texting while driving is dangerous.” There are research and evaluation questions that need to be addressed here for sure, figure out how to start the change. Bottom line, though, is we need to identify these networks, their influencers, and the messages.

Once we have the employers and workers united around the idea of the benefits of restfulness, we're going to need to bring them together and other decision-makers within the egalitarian network which had been shown to cut down on polarization. For people from different backgrounds come and share views based on data, there needs to be trust. And as Centola found out, the tipping point is about 25%; roughly 25% of people need to take a stand before a large-scale social chain initiates.

So where does this leave NIOSH? We know it is difficult to reduce fatigue if it is perceived to cut into both company and workers' bottom line and it's inconvenient. Current regulatory systems help maintain this view. Yet increasingly, researchers are finding that there are net increases in productivity when fatigue in the workplace is reduced, safety benefits, and as people are living longer, those people should want those additional years to be healthy. This information is not being widely heard, understood, or valued at the moment. We propose that we need to facilitate behavioral change and populate current networks with companies and individuals from both the periphery open to these data in the center who are resistant to change. The more peripheral idea may finally make it past the major influencers who have been resisting this change. To do so, we need to engage the right networks, the right influencers, and with the right level of trust imbued.

Fatigue maintains—remains—a public health issue, often manifesting itself in the workplace and is often worse for our most-vulnerable, lowest-paid workers. And this is true worldwide. We need to change the narrative from within as pressure from outside will not likely yield much more benefit. NIOSH could put a stake in the ground here, focusing on communications research as the means to inform and influence and tools to provide feedback to the different stakeholders that would amplify those messages. Social networks are already being used by billions of people worldwide. They could be the center of simple, scalable solutions here.

Discussion

Dr. Cox asked might there be a sort of prisoner's dilemma situation? Most retail stores are open on Sundays and stay open late during the holiday season. The incentive system is that nobody really wants to do it. It's like an arms race. Nobody wants to do it, but those who don't go out of business compared to those who do. You have to run as fast as you possibly can just to stay where you are. If everybody competes on long hours, then those who don't may go under. If that's true, this is not just an employer-specific challenge. It's more like an industry challenge. You would need coordinated action across multiple companies or multiple competitors possibly. There could be a sort of prisoner's-dilemma-type incentive issue.

And then techniques for overcoming that have been studied in very different context such as how to get people to chip in to fighting climate change when free riding is such a temptation? And there's been some work on how to do that that's based on concepts like if you don't cooperate by a certain time, then you lose the option of being one of the cooperators. There's stuff that game theorists and behavioral scientists have messed around with for climate change that tries to overcome free-rider and prisoner's-dilemma-type incentives. Perhaps some of those incentive considerations and coordination questions might be relevant for the culture change and behavior change here.

Dr. Popkin replied that it's not just about the work and being able to go to work on the weekends or overnight, but it's all these other pressures for one's time. And that's where it all comes together with the culture of how do we value our time? He spent a year in Finland in 1991 and it was very different there, where everything shut down on Sundays. Very few things were open and that was a cultural norm. That's been shifting over time, but it was very prevalent, and different from the United States where everything has to be more and more 24 hours. This is a megatrend that not one company or one even industry or sector can really attempt by itself. It's really a national or even maybe a world phenomenon now that needs to be considered.

Dr. Reponen added that she's from Finland originally. Everything shuts down in July. Pretty much everybody is on vacation except of course retailers and healthcare.

Dr. Schenker doesn't think industry agreements along those lines can work in this country. However, regulation can work. Except for the transportation industries, for the most part, there's very little fatigue-related regulation. That's a big part, a necessary part of the solution, frankly, that there probably isn't a lot of appetite for, but certainly wasn't in the previous administration. Maybe in the current situation, a little bit more appetite.

Dr. Popkin replied that with regulation, what you get is that immediate pushback where you're taking something away rather than giving something or protecting something. That's when you have to start changing the discourse about this. The National Sleep Foundation has been trying to change the conversation about this. You can put regulations in place, you can try to make them useful. But at the end of the day, if people can't work in one place then they'll work part time one place and part time another. They're still going to be prioritizing money over their long-term health.

Dr. Schenker said one of the questions has to do with the national versus state approaches and he would completely argue that national approaches are needed and that's where NIOSH can help. Regulation is an option if it's done correctly. It levels the playing field, not perfectly, but it says this applies to all industries so you don't get a competitive advantage if you start to break the rules. We're talking about things that have a national impact and it makes no sense to say you can have one standard in this state and another in another state and another in another state.

Dr. Popkin cautioned that if we make a national standard to level the playing field here, some of that work will be transferred overseas to people who are not going to be subjected to those rules or regulations. We've seen some of that with the mining or potentially with manufacturing.

Ms. Doyle said there are some companies that do close on Sunday. It's probably not because they're worried about worker fatigue. It's more for religious reasons, such as Chick-fil-A and Hobby Lobby. And it would be interesting to know the impact that has on their business. They seem to be very profitable.

Dr. Reponen asked whether one way to spur culture change might be to recruit the influencers in each of these industry sectors?

Dr. Popkin thought that would be a great research question. Centola is not the only person who's looking at this, so focusing in on the communications aspect. It's not his area of expertise per se, but it is others' and so

getting them involved to identify who those are, how to engage them. We did a little bit of that in the railroad industry over time. Back in the 1980s fatigue management, there was more about giving railroad engineers, for example, a training or a book and then holding them accountable for managing their fatigue. And over a long period with the regulator and with the unions and with management associations, we were able to build up a bolus of awareness and understanding around fatigue and why it's important. And over time we've started developing data too showing no benefits in fuel usage in driving a locomotive, for example, by having people who are not so tired. But it takes a very long time to really build that up, at least that's what we found.

Dr. Reponen asked the Board if they had any suggestions for collaborations with international agencies or other agencies that have not yet been mentioned?

Dr. Popkin confirmed that they were already working with the International Commission on Occupational Health Scientific Committee on Shiftwork and Working Time, which is called the Working Time Society as a shorthand.

Dr. Cox suggested developing an explicit strategy for coordinated culture change without heavy-handed regulations. It's like having people observe the same conventions in driving. It's good for everyone to have coordinated conventions.

Dr. Schenker added that we need to look at social media as a value, but not sufficient answer. It creates awareness, but it doesn't necessarily change behavior. And you need other approaches as well.

Public Comment

There were no oral comments.

The Public Safety Committee of the American Academy of Sleep Medicine submitted a letter to the docket. The authors were pleased to see a presentation Dr. Imelda Wong on COVID-19 and workplace fatigue on the agenda and emphasized how critically important this work is. They also provided a link to a tip sheet from the American Academy of Sleep Medicine with practical tips for healthcare providers on healthy sleep and managing fatigue.

Action Items

After deliberation, the Board identified five "action items" for NIOSH to seriously consider. These were not voted on.

- Pursue partnerships with National Sleep Foundation and COSH organizations (national, state, regional)
- Prioritize industries by the most severe problems (differentiate rate vs count). Develop 1-2 interventions and measure effectiveness. Learn from international researchers

- Strategy for coordinated culture change among workers and employers to promote sleep and rest
- Measuring impact – Focus on behavior change as an outcome. Awareness is nice to measure, but not adequate.
- Enhancing economic analyses
 - Cost-effectiveness analysis for fatigue-reducing strategies
 - Gaps – Make a business case for hiring additional staff rather than requiring workers to work long hours
 - Medical claims in addition to worker’s comp
 - Cost of malpractice (where applicable)
 - Employee turnover
- Consider adding variables to model: exercise, multiple jobs, precarious work, support for caregiving
 - Gaps - fatigue of new mothers in the workplace, perhaps it would be helpful to research whether on-site daycare (technology enhanced) would help well-being and increase productivity.
- Help companies get the most of limited resources using a machine learning technique called Super Learning to combine data from multiple devices is to grow a decision tree. Off the shelf super learning approaches are available.

Certification Statement

I hereby certify that, to the best of my knowledge and ability, the foregoing minutes of the September 29, 2020, meeting of the NIOSH Board of Scientific Counselors, CDC are accurate and complete.

_____*Tiina Reponen*_____

Tiina Reponen, PhD
Chair, NIOSH Board of Scientific Counselors

July 26, 2021_____

Date