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Review

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Review

Creating a Future for Occupational Health

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Abstract

Objectives: Economic, social, technical, and political drivers are fundamentally changing the nature of work and work environments, with profound implications for the field of occupational health. Nevertheless, researchers and practitioners entering the field are largely being trained to assess and control exposures using approaches developed under old models of work and risks.

Methods: A speaker series and symposium were organized to broadly explore current challenges and future directions for the occupational health field. Broad themes identified throughout these discussions are characterized and discussed to highlight important future directions of occupational health.

Findings: Despite the relatively diverse group of presenters and topics addressed, some important cross-cutting themes emerged. Changes in work organization and the resulting insecurity and precarious employment arrangements change the nature of risk to a large fraction of the workforce. Workforce demographics are changing, and economic disparities among working groups are growing. Globalization exacerbates the 'race to the bottom' for cheap labor, poor regulatory oversight, and limited labor rights. Largely, as a result of these phenomena, the historical distinction between work and non-work exposures has become largely artificial and less useful in understanding risks and developing effective public health intervention models. Additional changes related to climate change, governmental and regulatory limitations, and inadequate surveillance systems challenge and frustrate occupational health progress, while new biomedical and information technologies expand the opportunities for understanding and intervening to improve worker health.

Conclusion: The ideas and evidences discussed during this project suggest that occupational health training, professional practice, and research evolve towards a more holistic, public health-oriented model of worker health. This will require engagement with a wide network of stakeholders. Research and training portfolios need to be broadened to better align with the current realities of work and health and to prepare practitioners for the changing array of occupational health challenges.

Keywords: health status disparities; occupational health

Introduction

The occupational health and safety field is in the midst of a significant transformation. Many researchers and practitioners entered the field during the 1970s, an era in which the Occupational Safety and Health Act was enacted, the labor movement was strong, and environmental and women's rights movements were on the rise. Since this time, economic globalization, technological innovation, economic transformation, and a waning labor movement, among other trends, have fundamentally altered the landscape for occupational health.

In developed economies, the use of a number of highly toxic or carcinogenic industrial materials has been reduced, workplace exposures have diminished, and reported injury rates have gone steadily down (Creely *et al.*, 2007; Bureau of Labor Statistics, 2014b). Yet in the USA alone, there are ~4500 deaths and 3 million injuries and illnesses recorded annually on legally mandated logs in the workplace (Bureau of Labor Statistics, 2014a, 2014c). The economic costs of these occupational injuries are substantial (Leigh, 2011), and mostly borne by injured workers, their families, and taxpayer-supported programs (OSHA, 2015). However, it is well understood that reported occupational injuries and illnesses represent only a fraction of the true number (Azaroff *et al.*, 2002; Spieler and Wagner, 2014). While estimating the burden of work-related injuries and illness is challenging due to multifactorial etiologies, latency, and underreporting, the impact of work-related psychosocial factors that can influence health or the contribution of working conditions to widening health disparities is even less well understood (Clougherty *et al.*, 2010; Burgard and Lin, 2013).

Further, programs in industrial hygiene, occupational medicine, and occupational health nursing around the USA have experienced a decline in program funding and are attracting a decreasing number of supporting faculty (McAdams *et al.*, 2011). These programs require updating of curriculum and research portfolios to stay current and responsive to the interests of students and needs of the workplace, as well as to remain competitive for increasingly restricted funding. There is also indication that the effectiveness of traditional regulatory approaches has declined over time (Gray and Mendeloff, 2005), suggesting that alternative strategies to control hazards need to be proposed, investigated, and evaluated. Despite recognition of these trends, researchers and practitioners entering the field are largely trained to assess and control exposures using approaches developed under old models of work, which may not adequately address health hazards in the workplace of the present and future.

The Future of Occupational Health Project

The 'Future of Occupational Health' Project was developed by faculty and students of Department of Environmental and Occupational Health Sciences at the University of Washington to address these trends and to explore how macro-level changes may affect occupational health and safety research and practice. Further, we sought to understand if traditional approaches to assessing and controlling risks in the workplace being taught to trainees are out of date or even obsolete.

To aid this exploration, a series of speakers from different disciplines were invited to share perspectives on current challenges and future directions for the field. The speaker series culminated in a 2-day symposium exploring the future of occupational health practice, research, and policy. The content of the symposium was informed by the speaker series, keynote talks from highly regarded minds in the field, and input from a diverse group of ~150 symposium participants that included researchers, physicians, policymakers, students, practitioners, and others. Presenters covered a number of themes with implications for worker health and safety and the future of the field. The topics addressed included occupational injury and illness surveillance, work organization, globalization, well-being, emerging investigative technologies, policy, regulatory and voluntary approaches to control, climate change, and vulnerable worker populations. Notes were collected during presentations and discussions at each speaker session and throughout the symposium. These notes were periodically collated and presented to a steering committee charged with providing direction for the project for consideration and further discussion. The authors further distilled these materials and ideas to the most important outcomes, including cross-cutting themes discussed by many speakers and in many different contexts, and general directions for developing a new vision of occupational health, described herein. Ideas emerging from this project form the basis for a continuing discovery of key challenges within the field and future directions that will make the work relevant and effective in preventing the continuing burden of work-related injury and illness. The intent of this article is to report on these findings and to promote further discussion, planning, and innovation in research, training, practice, and policy initiatives related to the health of workers.

Summary of Outcomes and Emerging Cross-Cutting Themes

Through the speaker series, symposium, and resulting discussions, it became clear that the profound changes

in the nature of work and the understanding of worker health resulting from new economic, social, technical, and political forces necessitate a re-envisioning of occupational health. Despite the relatively diverse group of presenters and topics addressed in the speaker series and symposium, some important cross-cutting themes emerged from the discussions (see Table 1).

Work organization

The organization of work—especially the decreasing prevalence of stable long-term employer–employee relationships and the growing use of contract, contingent, part-time, and temporary work—emerges as a profound change affecting occupational health (Benach and Muntaner, 2007; Alterman *et al.*, 2013; Katz and Krueger, 2016). Such precarious employment arrangements have been associated with a variety of adverse physical health outcomes, including increased risk of occupational injuries, increased presenteeism (working while sick), reduced job satisfaction, worse self-reported health, and a number of mental health illnesses and disorders (Benach *et al.*, 2014). Adding to this view of precarious work is the expansion of subcontracting, global supply chains, and franchise business models, which have become the predominant system for lead brand companies, and described as the 'fissuring of the workplace' (Weil, 2014). Although precarious employment is not a new phenomenon, these large-scale shifts in workplace dynamics alter the landscape for the practice of occupational health professions in myriad ways.

The various forms of contract and contingent labor make identifying the employer responsible for working conditions less clear and more open to dispute. It means that workers likely have many different jobs and worksites (and employers and co-workers) over short periods of time and are thus less familiar with hazards in a particular site, as well as less accustomed to safe work practices and equipment. Likewise, temporary workers are more vulnerable to injury, and new workers are up to four times more likely to get injured in their first months on a job (Breslin and Smith, 2006; Smith *et al.*, 2010). Employers may feel they have less investment in particular employees and therefore spend less on occupational safety and health systems within a company, including training, mentoring, protective systems, and supportive supervision. These forces may also cause workers to be more reluctant to exercise their rights by either advocating for their own working conditions or refusing particularly hazardous work (Mayhew *et al.*, 1997; Aronsson, 1999). Regulatory agencies are also confronted with workers who are reluctant to speak out, and employers who shift hazards to suppliers and subcontractors, often out of reach for inspection and enforcement.

Changing demographics and vulnerable populations

The changing demographics of the workforce in age, gender, race and ethnicity, and particularly nativity (immigrant status) were identified as another large-scale shift occurring in recent decades. The increase in the number of women (Wagener *et al.*, 1997; Fullerton, 1999; Bureau of Labor Statistics, 2014d) and the aging (Hedge *et al.*, 2006; Toossi, 2012) of the workforce have been widely discussed previously, and shifts in race, ethnicity, and nativity are potentially related to globalization, discussed below. Immigrants are a growing part of the US labor force, making up over 16% (>23 million workers) of the total, compared to ~5% in 1970 (Singer, 2012; Mosisa, 2013). Many of these foreign-born workers earn less money than native workers (Mosisa, 2013) and work in high-risk industries, such as agriculture, healthcare, and construction, partly due to lower English-language ability and educational attainment (Orrenius and Zavodny, 2009). Consequently, these workers are more vulnerable to injury and death on the job (Loh and Richardson, 2004; Byler, 2013). Workers migrating from places with civil strife and/or who have risked their lives (and potentially those of their family) during migration may also have different expectations of safe working conditions (Whittaker, 2005). Further, workers who are members of racial or ethnic minorities, and/or are immigrants to the USA, may have less safety and health training, experience greater barriers (real or perceived) to occupational health services, may have less awareness of workers' compensation insurance programs, and may access and use occupational health services differently (Lashuay and Harrison, 2010; OSHA, 2015).

Another profound shift in the labor force is the increasing prevalence of obesity, diabetes, and other chronic diseases among the US working population (Anderson and Horvath, 2004). The cost, in terms of both direct medical expenses and lost productivity, due to chronic disease in the working population is substantial and growing rapidly (Hertz *et al.*, 2004; DeVol *et al.*, 2007; Hammond and Levine, 2010; Breton *et al.*, 2013). These costs affect individuals, as well as their employers and the community at large, and suggest that a holistic approach to health in the workforce is needed.

Globalization

Globalization affects the movement of products, capital, and labor around the world. The competition for work that results can increase labor flexibility for employers but insecurity for workers, through limits on the exercise of labor rights (Benach *et al.*, 2007; Sparke, 2012). This occurs through corporate supply chains in which

Table 1. Identified emerging trends and challenges in worker health.

Cross-cutting themes	Resulting challenges
Changes in work organization	
• Transition from standard employer relationships (i.e. stable, long term) to contract, contingent, part-time, and generally precarious employment	• Employers may perceive less of an investment in a worker, spending fewer resources on training, mentorship, protective systems, and supportive supervision • Difficult to identify employer liability and responsibility for working conditions • Workers may frequently change jobs and worksites, reducing familiarity with relevant hazards, work practices, and equipment and limiting ability to perform employer- or place-based occupational epidemiology • Increased reluctance by workers to exercise rights • Reduced investment in occupational safety and health systems and in-house expertise
Changing demographics	
• Aging workforce	• Restriction of physical and mental abilities and increased presence of chronic disease
• More women in the workplace	• Potential for alteration of psychosocial dynamics of workplace and potential for discrimination, and increased importance of reproductive hazards and work/life balance
• Increasing diversity of workforce in terms of race, ethnicity, and nativity	• Potential for discrimination, increased vulnerability, weakened collective identity and/or bargaining power and related stress, and increased health disparities
• Increasing the presence of chronic disease in labor force	• Poor health is associated with reduction in hours of work, lower wage rates, early retirement, and disability transfer programs
Globalization	
• Development of corporate supply chains in which providers of goods and services outsource production to vendors on a global scale • Increase in labor migration and immigrant workers	• Demand for greater 'flexibility' of workforce, leading to increased precarity of US employment and pressure against labor organization • Emergence of post-industrial economies, shifting away from manufacturing towards service and transportation industries • 'Race to the bottom' for regulation and policies, including wages, benefits, environmental, and labor rights
Interaction of work and non-work factors	
• Acknowledgment that many factors contribute to health and safety of workers in addition to working conditions, including economic, social, and environmental conditions facing various worker populations	• Employment conditions are less 'place based', more dynamic, with higher frequency of job change • Assessing relevant factors impacting worker health, including community-based conditions • Understanding the role of work in supporting or compounding these other determinants of health
Global climate change	
• A changing climate, including rising temperatures, extreme heat, and weather events	• Increased risks to many workers, especially those working outdoors • Likely to increase the number of catastrophic weather events, requiring a greater number of high-risk tasks from first responders and clean-up/remediation efforts

Table 1. *Continued*

Cross-cutting themes	Resulting challenges
• Forcing large-scale sociotechnical and economic changes that are fundamentally altering the global economy	• Formation of new industries and workplaces (e.g. renewable energy production and sustainable agriculture) • Alteration of cultures in existing workplaces (e.g. altered hours for jobs that require working outdoors)
Decline in unionized workforce	
• Reduction in the number and percent of the workforce organized by labor unions	• Historically, labor unions have been an important force for advocating for improved working conditions, developing regulations, and providing security to workers
Federal funding and policy trends	
• Severe restriction of regulatory action	• Keeping standards consistent with current scientific understanding is limited • Emerging hazards may be difficult or impossible to regulate
• Declining funding for education and research	• Increasingly difficult to recruit and support students for the field, increasing the potential for a shortfall in competent professionals • Research activities are limited and faculty driven towards areas with more funding
Emerging technologies and data capabilities	
• Advancements in technology create new opportunities to collect and analyze worker exposure and health data	• Understanding the role of work-related factors in the integrated measures of effect (e.g. the exposome) requires incorporating workplace-specific measures of exposure • Translation of results into preventive interventions is further obscured by advanced methodologies
Contribution of work to health disparities	
• Widening socioeconomic status and health disparities are at least partially caused by, or mediated by, work conditions	• Work is an important contributor to health and well-being but may also be detrimental depending on workplace conditions. Both influences should be addressed within worker health models

providers of goods and services outsource production to vendor businesses on a global scale, and the resulting competition among vendors reinforces a 'race to the bottom' in terms of wages, workers' rights, and safety. Globalization also reinforces pressures towards deregulation. For instance, international trade agreements often include an attempt to harmonize regulations, which involves the direct reworking of national laws. As a result, laws and regulations set up to protect health and safety—for example reducing limits on the usage of dangerous pesticides or labeling requirements—may be superceded to encourage trade (Sparke, 2012). These anti-regulatory pressures affect the ability of governments to regulate the workplace (for example, by causing frequent shifting of worksites and/or reduced transparency and accountability along a supply chain) while also diminishing the significance of national agencies and rules.

Although our focus here is on working conditions in domestic and developed world workplaces, the devastating conditions and health and safety threats found in many developing economies are compelling for occupational health professionals. A number of factors within these economies—including use of child and forced labor, informal sector work, and a lack of corporate or governmental infrastructure—along with a shifting of hazardous operations to these unregulated markets, gives rise to a large toll of occupational health and injury burden (Benach *et al.*, 2007). While documentation of such conditions calls attention to many of these problems associated with global markets, models for effective intervention in such conditions are badly needed.

Blurring of lines between work and non-work risks

These new realities of the workplace coincide with another emerging theme: acknowledgement that workplace conditions contribute to, but do not solely determine, workers' health. Rather, the health of the workforce results from an interaction of work and non-work risk factors, which include everything from climate, to access to healthcare, to general legal and social conditions, and to genetic factors. Further, working conditions may influence behaviors and other risk factors traditionally thought to be beyond the purview of occupational health, for example stressful and demanding job characteristics leading to coping behaviors such as tobacco or alcohol consumption. Indeed, traditional occupational health paradigms—i.e. specific exposures leading to specific outcomes among specific work groups, and the near complete separation of work-related risks from non-work related risks—are less and less useful (Schulte *et al.*, 2012).

It is also important to recognize how the approach used in the occupational health paradigm differs from other aspects of public health, health promotion in particular. The occupational health model underscores the power dynamics in a particular environment as an important determinant of exposure and health and avoids seeing individual behavioral choices as the central determinant of change or effective point of intervention. Thus, the importance of worker participation and empowerment through training, collective bargaining, and workplace participation are key components of occupational health protection. While recognizing the blurring of the work and non-work influences on health, this importance of promoting worker agency in promoting a healthful environment should not be overshadowed by a focus on behavioral interventions.

Total Worker Health® (TWH), as proposed by the National Institute for Occupational Safety and Health (NIOSH), which aims to integrate occupational health and safety with workplace health promotion, overlaps with the idea that work and non-work related risks are important to worker health, and can be addressed by programs and policies within the workplace (Schill and Chosewood, 2013). However, perhaps belying its original intent, TWH interventions detailed in the literature to date have focused primarily on using the workplace to intervene on individual lifestyle derived risks (i.e. behavior-focused health promotion at the workplace) (Anger *et al.*, 2014; Feltner *et al.*, 2015). In response to this and other stakeholder concerns, NIOSH has recently refined the definition and agenda for the program (NIOSH, 2016) to better align with the concepts central to occupational health that identify the workplace itself, with its technical, structural, and social organizational characteristics, as a significant contributor to health and well-being of the workforce.

Other Trends Affecting Occupational Health

While the developments identified above emerged as arguably the most significant trends impacting the nature and organization of work, a number of additional social, political, and technical factors affecting working conditions and the health of workers also contribute to the changing scope of occupational health.

Decline in organized labor

The reduction in the number and percent of the workforce organized by labor unions in the USA (Hirsch and Macpherson, 2014) has significant implications for occupational health practice and policy (Malinowski *et al.*, 2014; Hagedorn *et al.*, 2016). Labor unions have been an important force for health and safety laws and regulations, represented workers in advocating with employers for improving conditions, and provided workers the job security required to advocate on their own behalf. The decline of labor representation, especially in the private sector, reduces the impetus to public health action in the workplace. Although organized labor continues to play an important role in occupational health, other social movements and forms of worker organization may become increasingly important forums for workplace health and safety.

Federal funding and policy trends

The field has experienced restriction of regulatory action and funding for both education and research. The Occupational Safety and Health Administration (OSHA), the primary US regulatory agency for workplace health and safety, has produced a small number of new or revised health standards in its 46-year history. The recent promulgation of the first comprehensive standard for exposure to crystalline silica dust (OSHA, 2016), after at least 40 years of planning and failed attempts at regulation, is both a triumph and a stark lesson in the difficulty in regulating even well-recognized workplace hazards through the legal means available by OSHA, even when the evidence of risk is substantial. Alternative approaches—including publication of voluntary guidelines; public information campaigns about safe practices; as well as companies with records of violations and/or injuries and deaths among workers, and state and local standards and ordinances—have all proved to have potential, but cannot replace clear federal standards and enforcement.

Funding for occupational health research and teaching has continued to decline (McAdams *et al.*, 2011). This trend has forced many university-based researchers reliant on grant support to shift their focus to community environmental risks and away from workplace injury and illness, and also threatens a shortfall of competent professionals necessary to satisfy national demand for occupational health and safety services.

Global climate change

The rapidly changing global climate will affect workers and workplaces in myriad ways (Kiefer *et al.*, 2014). In addition to creating heightened heat-related risks to many workers, especially those working outdoors, climate change is likely to increase the number of catastrophic weather events, requiring a greater number of first responders and clean-up/remediation efforts, all of which may engender high-risk tasks. But global climate change is also forcing large-scale sociotechnical and economic changes that are fundamentally altering the global economy, producing new industries and workplaces (e.g. renewable energy production and sustainable agriculture), and profoundly changing cultures in existing workplaces (e.g. altered hours for jobs that require working outdoors, shifting of production to more hospitable locations).

Emerging technologies and data capabilities

Technological developments have created new opportunities to collect and analyze exposure and health data at multiple scales without necessarily making a clear distinction between risks at work and those outside work. Techniques such as metabolomics and proteomics permit collection of data on biological indicators of exposure and/or health conditions that can be compared among populations at risk. Likewise, low-cost sensors, distributed electronic sensing, and communication technologies (e.g. cell-phone-based applications) have the potential to identify risks and effects among large populations, both at work and at home (Weis *et al.*, 2005). The concept of the 'exposome', which aims to integrate the sum of lifetime exposures from all sources, is another direction promising a framework for environmental, including occupational, risks, as well as to characterize health disparities (Wild, 2012).

Additionally, new and improved methods and tools are becoming available to analyze exposure data (e.g. Geographical Information Systems, predictive risk assessment), and advances in information management and machine learning data analysis techniques are making it easier to collect and analyze large data sets from multiple linked sources (Brownstein *et al.*, 2009; Kamel Boulos *et al.*, 2011; Khoury and Ioannidis, 2014). These technological advances provide an opportunity for improved surveillance of workplace exposures and their resultant injuries and illnesses and promote the study of multiple environmental stressors in the totality of work and non-work environments a worker may occupy.

Elucidating the Contribution of Work to Health Disparities: Moving From 'Occupational Health' to 'Worker Health'

The trends in working conditions discussed earlier are also closely linked to a more general increase in disparities in both health and wealth. The enormous increase in income and wealth disparities between groups, especially in the US population, has been widely discussed (Saez, 2013). At the same time, the wide gulf in health, morbidity, and mortality between those in the top tier, and those struggling to survive, continues to increase (Kanjilal *et al.*, 2006; Singh and Siahpush, 2006). The link between socioeconomic status and health disparities is at least partially caused by, or mediated by, work conditions (Brand *et al.*, 2007). Thus, the future of occupational health requires that we engage in the larger context of social determinants of health, recognizing how the structure of employment contributes to the health of populations. This broadened view of occupational health also provides the opportunity for linking occupational health with the wider community interested in social determinants of health (Lipscomb *et al.*, 2006; Clougherty *et al.*, 2010; Burgard and Lin, 2013).

To accomplish this, the definition of 'occupational health' needs to expand to include a wider range of work conditions that are health supportive or potentially damaging to health and worker well-being. For instance, well-being in the workplace has been proposed as a more comprehensive goal for occupational health, going well beyond physical health or lack of disease (Schulte and Vainio, 2010; Schulte *et al.*, 2015). While well-being includes physically safe and healthful conditions, it also includes environmental factors affecting mental health and features social support, autonomy, and self-determination in a more aspirational concept of holistic health. Because these broader constructs of worker well-being are beyond our current industrial, regulatory, and health delivery paradigm, we will need to research on all aspects of a health and well-being-supportive workplace. The broad themes emerging from the Future of Occupational Health project provide an opportunity to redefine occupational health with a population-based model that moves from a focus on the workplace towards a focus on working populations—thus, 'worker health' instead

of 'occupational health'. In this more public health-oriented approach, the health of specific populations of workers (and their families and communities) can be addressed in a more holistic way, integrating physical and psychosocial health parameters and exposures that occur at work with non-work conditions that may arise at least partially from employment conditions.

Future Directions for Worker Health

A number of general directions are proposed for developing a new vision of worker health, including:

- engaging those outside the field about work-related health issues;
- expanding academic research portfolios; and
- development of improved, more broadly defined training for the professions in work and health.

Engaging others in work-related health issues

To ensure that future worker health research, educational, and service activities are able to address emerging trends discussed herein, it is critical to engage a network of leaders interested in the intersection of work and health. Thus, rather than seeing occupational health as a narrow technical field, we need to redraw the lines of interest across academic disciplines, business, labor and community interests, and from key governmental agencies. This engagement allows the field to better connect relevant communities of interest to practitioners in occupational health, to identify and pursue new areas for collaboration, to develop new models of workplace and community intervention, and to reach high-risk worker populations.

Developing interdisciplinary networks across academic disciplines

It is critical that universities with worker health programs seek opportunities to develop academic collaborations for interdisciplinary teaching and research on work-related determinants of health. This will require engagement and building relationships with faculty that have expertise in social sciences, labor studies, business, economics, policy and political science, employment and human relations law, and occupational psychology. Within traditional public health disciplines, researchers in social epidemiology, health disparities, and health promotion fields are critical to understanding the impact of work on health.

Engaging state and local government

The limitations of the OSHA law for effectively controlling workplace risks, even in traditional 'Standard Employment Relationship'-type contexts, are well known, and the impact of OSHA into the new forms of work organization is even more limited. Thus, while OSHA plays a critical role in defining a minimum set of criteria for a safe workplace, local and state governments provide significant opportunity for leading development of policy and shifting standards to address emerging challenges facing workers and their health. Universities and research institutions should therefore continue to seek opportunities to engage with practitioners involved in compliance, enforcement, and policy at state and local agencies.

Engaging community-based and labor organizations

In exploring new models of health and safety intervention, the potential of community-based organizations, in addition to labor unions, as a locus to supply worker health resources should be developed. Opportunities abound to engage with workers through groups such as community centers, health clinics, faith-based organizations, national consulates, organizations that serve specific communities or industries, and worker centers, many of which have an interest in taking on worker health and safety issues. Development of these networks could help foster internships and other training opportunities for students and collaborative research projects, and by doing so, enhance the idea that the workplace is a primary determinant of health.

Engaging industry in new models of worker health

Engaging employers in developing a more holistic approach to supporting the health and well-being of workers will require development, demonstration, and communication of models of the costs and benefits to the enterprise of alternative workplace policies. Such programs would include both traditional occupational health programs, and supportive safety and health climate approaches, but may also extend to health-supportive programs, pay and benefits, worker engagement, family leave policies, and other aspects of employment that affect health and well-being profitable. Studies to demonstrate how such programs affect productivity and profitability are key to promoting the adoption of such programs (Goetzel *et al.*, 2007; Loeppke *et al.*, 2009; Tompa *et al.*, 2009; Fabius *et al.*, 2013). Models for such worker health-supportive management policies are needed to demonstrate their effectiveness within different industrial sectors, alternative work organizational models, and should include metrics for both economic and health outcomes. New production technologies such as 'green' production, product life-cycle assessment, and other sustainability-related business practices, which consider worker health as a key outcome, are an additional direction for the development of healthy

communities (Schulte *et al.*, 2013). Well-designed intervention studies that test the effectiveness of such innovations are a key methodology required for building the evidence base to support these changes.

Aligning with current social movements

One key challenge to the field is the apparent absence within the public consciousness of the enormous burden workplace injuries, illnesses, and deaths pose to society (Leigh, 2011). A number of long standing and recent social movements, such as race equity, labor rights, environmentalism and sustainability, gender and sexual equity, immigrant rights, and economic and health disparities, have all garnered significant attention in recent years. By demonstrating the links between working conditions and health and placing them within these wider social movements, the worker health field could better demonstrate its relevance to social progress.

Broadening academic research and training portfolios

Academic programs will continue to evolve through faculty and staff hiring and retirement and through responses to perceived needs and funding opportunities. However, research institutions have the potential to make a much bigger impact on the future scientific basis and practice of worker health and to develop training programs that will support new directions and initiatives.

Integrating a broader concept of work-related exposures and risks

Whereas occupational health researchers and practitioners often focus on assessing physical risks in the workplace (e.g. work at height, chemical hazards), most are ill-equipped to evaluate psychosocial conditions of work that may contribute to health and or disease (e.g. job-related stress, harassment). These psychosocial exposures may be especially important for workers engaged in precarious employment where stress and economic impacts on health are potentially significant. Similarly, at-risk populations including immigrants, women, and racial or ethnic minorities may also be at risk for injury or illness due to general social conditions often ignored in biomedical and individually oriented theories of disease causation. Thus, research models should allow for more inclusive definitions of health and well-being when examining the role of work on health, including integrating multiple dimensions of exposure and embracing social determinist frameworks.

Estimating the burden of work on health and well-being

Traditional estimates of the burden of occupational disease rely on the prevalence of specific occupational exposures (e.g. noise, asbestos), models of population exposures, and risks associated with those exposures. If we are to move towards a more inclusive measure of health impacts of work-related factors, new multifactorial metrics that incorporate stress, social support (at and outside of work), ergonomics, physical activity, organizational factors, and so forth will be needed. Multilevel approaches to worker health studies may allow for identification of groups with similar working conditions, examine associations between working and living conditions and health, and provide a basis for preventative actions (Härenstam *et al.*, 2003; Schulte *et al.*, 2012; Goh *et al.*, 2015). Such models will have to include both the supportive and detrimental aspects of employment and work on health and well-being.

Leveraging new investigative technologies

The use of distributed sensor technologies for both health and exposure assessment supports the idea that exposure and effects occur both at work and outside work, and can affect whole communities. Additionally, limitations of coverage and cost faced by worker health researchers and practitioners in assessing exposure supports the need to move to low-cost, high-throughput samplers that integrate exposures over long time periods—even if this means decreased accuracy and sensitivity. The potential for 'big data' to demonstrate patterns of exposure, including the varied exposures that occur at work, and their relation to health, may produce meaningful associations. The various 'omics technologies that use biological indicators of exposure and effects will cut across specific occupations to understanding the totality of environmental exposure as experienced by individuals and their communities. Thus, all of the burgeoning technologies associated with distributed or population-based exposure and health effects have the potential to further our understanding of work factors and health, but only if the delineate work-related factors associated with differences observed within the data gathered.

Developing global health perspectives

The potential for work on effective monitoring and enforcement of labor and health standards throughout global supply chains is a potentially rich area for development within occupational health and public health programs. Although a number of important investigations have demonstrated both the potentials and limitations of voluntary supply chain regulation for improving working conditions (Locke, 2013), opportunities for building upon this work abound. Integration of a workplace perspective into the global health campaigns being conducted through many agencies, foundations, and

universities (especially schools of public health) could greatly enhance their effectiveness. Supply chain regulation is an important area for business strategies, and the field's involvement in such efforts could be fruitful. There may also be opportunity for training supply chain regulators in the recognition of occupational health and safety violations. Incorporating global health perspectives into occupational health can also drive domestically oriented research projects, including focusing on the special challenges facing high-risk immigrant and refugee worker populations within the USA.

Developing and improving curriculum

The jobs that graduates of occupational health programs are being prepared for may not reflect the jobs available in the future. Thus, revision of our current research and training portfolios are warranted to better align them with the current realities of work and health and to prepare graduate students leaving their training programs for the changing array of worker health challenges they will likely encounter.

Strengthening competencies of graduates

The skills needed among worker health professionals to effectively address the issues discussed above go beyond many of the traditional occupational health methods. There is no doubt that the skills for effective worker health practice include traditional occupational hygiene, medicine, nursing, epidemiology, toxicology, and engineering. But as we broaden our perspective, our research and professional communities will also need to understand more of the social sciences, management, business economics, and policy processes—particularly to address psychosocial factors and population health determinants of workers' health. Leadership, and the ability to effectively communicate to varied audiences, which are commonly identified by employers as a place where worker health curriculum needs improvement (McAdams *et al.*, 2011), will become even more valuable in the future. Related, cultural competencies will become increasingly important to working with vulnerable and immigrant populations, as well as community-based organizations and international occupational health work. Additionally, there is evidence that certain disciplines related to occupational health are facing a shortfall in sufficiently trained professionals, for instance in health physics and radiation protection (National Council on Radiation Protection and Measurements, 2013). Clearly, we cannot expect any one training program to be able to do all of this, but we need to define the array of skills needed and how best to form specialties, all with an ability to address work and health.

Incorporating broader social, political, and legal contexts

Issues emerging from the project suggest occupational health practitioners would benefit from an improved understanding of the social, political, and legal contexts affecting workers' health. This would involve incorporating teachings related to the social and economic context of work and work organization; impact of health on business sustainability, labor, and political movements and their impacts on work conditions; and the relationship between work and health disparities into existing classes, coursework, and seminars. Additionally, academic and research institutions could develop curriculum elements that enhance teaching and learning for students engaged in general public health and social science disciplines with interests in worker health (e.g. public affairs, social work, labor studies), including studying current and emerging public health regulatory policy and structures that incorporate working conditions as a significant component of health at the individual, community, and society levels.

Conclusion

Economic, social, technical, and political drivers are fundamentally changing the nature of work and work environments, with profound implications for occupational health priorities. Over the past several decades, significant improvements have been made to measureable workplace conditions in the USA and in many other societies around the world. Yet the overall burden of occupational injuries and illnesses remains unacceptably high.

Changes in work organization due to fissuring of organizations and the resulting insecurity and precarious employment arrangements change the nature of risk to a large fraction of the workforce. The workforce continues to diversify, as gender, age, race, nativity, and economic disparities among working groups are rapidly growing. Globalization exacerbates the 'race to the bottom' for cheap labor, poor regulatory oversight, and limited labor rights. These effects of globalization work both between countries and within the USA between localities competing for business investments.

Largely, as a result of these phenomena, the historical distinction between work and non-work exposures has become highly artificial and less useful in understanding risks or developing effective public health intervention models. Additional changes related to climate change, governmental and regulatory limitations, and inadequate surveillance systems challenge and frustrate occupational health progress, while new biomedical and information

technologies expand the opportunities for understanding and intervening to improve worker health.

It is incumbent upon worker health researchers, practitioners, and policymakers to identify new and creative approaches to workplace health and safety as a component of the changing workplace, economic, environmental, and public health priorities. The ideas and evidences discussed during this project suggest a reconceptualization of 'occupational health' towards a more comprehensive and public health-oriented model addressing 'worker health'. In doing so, we need to retain the central insight of occupational health, which identifies the structural work environment as the key focus for health intervention, through meaningful participation by workers in enhancing their working lives. Through the lens of worker health, we can integrate specific conditions found at the workplace, including traditional physical, chemical, and biological hazards and psychosocial stressors, with the economic and social conditions created for individuals and communities through work. This integrated approach more directly addresses the role of work and work conditions in public health, including those giving rise to stark health disparities throughout society, and offers the field a tremendous opportunity to increase its positive contribution in promoting health and well-being of communities locally, nationally, and globally.

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