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OCCUPATIONAL HEALTH (LT STAYNER AND P DEMERS, SECTION EDITORS)

Challenges and Opportunities for Occupational Epidemiology in the Twenty-first Century

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Abstract
Purpose of Review There are many opportunities and challenges for conducting occupational epidemiologic studies today. In this paper, we summarize the discussion of a symposium held at the Epidemiology in Occupational Health (EPICOH) conference, Chicago 2014, on challenges for occupational epidemiology in the twenty-first century.
Recent Findings The increasing number of publications and attendance at our conferences suggests that worldwide interest in occupational epidemiology has been growing. There are clearly abundant opportunities for new research in occupational epidemiology. Areas ripe for further work include developing improved methods for exposure assessment, statistical analysis, studying migrant workers and other vulnerable populations, the use of biomarkers, and new hazards. Several major challenges are also discussed such as the rapidly changing nature and location of work, lack of funding, and political/legal conflicts.
Summary As long as work exists there will be occupational diseases that demand our attention, and a need for epidemiologic studies designed to characterize these risks and to support the development of preventive strategies. Despite the challenges and given the important past contribution in this field, we are optimistic about the importance and continued vitality of the research field of occupational epidemiology.

Keywords Occupational · Epidemiology · Challenges · Opportunities

Introduction

This special issue of Current Environmental Health Reports is devoted to some of the key invited papers that were presented at the EPICOH (the epidemiology section of the International Commission on Occupational Health), that was held in

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Chicago from June 24-27, 2014. The theme of this meeting was *Challenges for Occupational Epidemiology in the twenty-first Century*. In this paper, we discuss not only the challenges but some of the opportunities that were discussed in a mini-symposium that we held on this topic at the conference.

Opportunities

There are clearly still abundant opportunities for research in occupational epidemiology. The continued need for research in our field is strongly supported by the sheer magnitude of the burden of occupational diseases as thoroughly described in one of the articles in this journal by Rushton [1]. It has been conservatively estimated that there are approximately one million deaths in 2015 due to 19 occupational causes in the Global Burden of Diseases, Injuries, and Risk Factors Study [2]. Disturbingly, the findings from this landmark report also suggest that the worldwide mortality rate from occupational diseases has actually increased over the past decade and the impact of many other hazards needs to be assessed.

There continues to be a substantial interest in epidemiologic research of occupational hazards throughout the world. Our EPICOH 2014 conference (the annual meeting organized by the epidemiology section of the International Commission on Occupational Health), drew over 400 attendants from 45 countries. The most recent EPICOH meeting in Barcelona set a new record for attendance of approximately 650 scientists. Over 40% of these attendees were new researchers in our field (i.e., students, postdocs, or assistant professors), which bodes well for the future of our field.

A literature search on Scopus for occupational epidemiology reveals that there has been substantial growth in the number of publications in our field over the past few decades (Fig. 1). However, the growth in publications has not been observed in all areas of research. A recently published review on trends in occupational cancer epidemiology, which was presented at EPICOH 2014, has revealed a sharp decline over the past decade [3]. The decline in publications on occupational cancer and the apparent increase in publications overall may be explained by a shift in our field from studies of cancer to studies of other outcomes. However, even within cancer there appears to be an increase in more sophisticated studies that include dose-response analyses and other methodological aspects.

Old and New Hazards

The dynamic nature of industrial and other work practices has and will always present new research opportunities for studying worker's health and safety. Indeed, our meeting included presentations on fairly recently identified occupational hazards such as an outbreak of kidney disease due to heat stress among sugarcane cutters in Central America [4]. An excess of heat stress-related kidney disease has also been reported around the world and may be one of the first epidemics to be due to global warming [5]. Another example is the continually evolving evidence of an increased risk of breast [6] and other cancers among night shift workers. Although there is conflicting evidence [7], these findings have immense public health implications as approximately 15 to 20% of the workforce in European countries and the USA is engaged in shiftwork [8], and most likely similar or higher percentages in the developing world.

It is not only new hazards, however, that demand our attention. We still lack a complete understanding of the risks

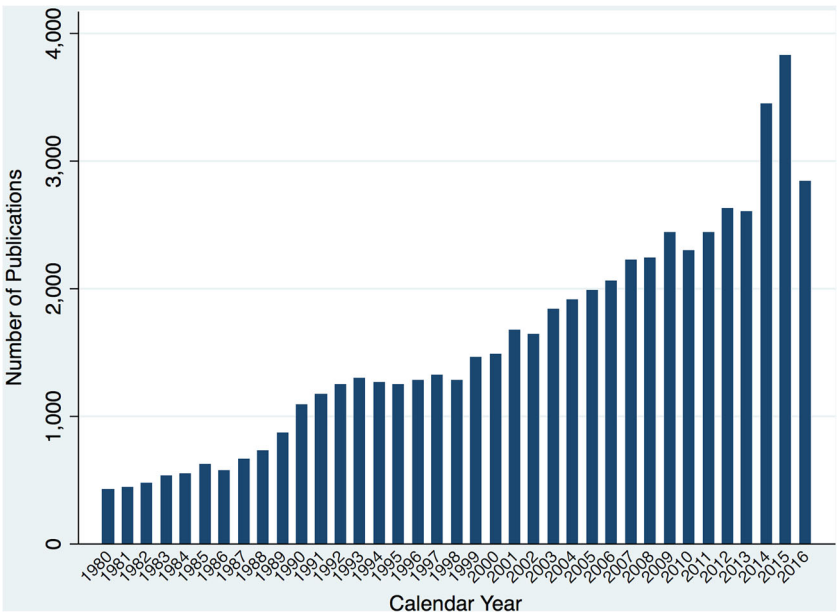

Fig. 1 Number of publications on occupational epidemiology by calendar year*. *Based on a Scopus search using the terms "industrial epidemiology" or "workplace epidemiology," or (occupational w/2 [epidemiology or medicine or noise or stress or diseases or exposure])

associated with most (if not all) of the workplace exposures that have been previously identified. For example, Ward et al. [9] conducted a review of 20 occupational exposures that have been classified as possibly (2b) or probably carcinogenic (2a) by the International Agency for Research on Cancer (IARC) with a view towards understanding research gaps that, if filled, might resolve these controversies. Some general themes that emerged from this review are the opportunities for improvements in study design, exposure assessment, and additional mechanistic data for these potentially carcinogenic agents. Additional research to fill the gaps in our understanding for other known occupational diseases is certainly at least as important as it is for cancer. The increasing number of women, minorities, and migrant workers engaged in the workforce raises questions of how the effects of known hazardous exposure might differ from the studies conducted in the past that predominantly included white male workers. Furthermore, increases in life expectancy have led many countries to enact policies to increase labor force participation among older workers and workers with pre-existing health conditions. There is a clear need for research on the effects of hazardous exposures on older workers, and for the developing strategies to support the ability to work for older workers.

Statistical Methods

Occupational epidemiology has always been at the forefront of the development of new statistical methods for the analysis of epidemiologic data. The first lifetable analyses of cohort mortality data were published in 1955 in the pioneering studies of asbestos workers by the late Sir Richard Doll [10]. One of the thorniest problems in occupational epidemiology has been dealing with the bias caused by the healthy worker survivor effect, which is a bias caused by the fact that healthy workers tend to remain in the workforce and thus tend to have higher duration of exposure than sick workers. This phenomenon was described over 100 years ago by Ogle [11]. Although Robins [12] first described an analytic approach to dealing with this issue, it is only very recently that practical methods for adjusting for this important source of bias have come to fore, which was the subject of several papers in our conference and of one of the papers in this special issue [13]. Development of new methods for causal analyses of epidemiologic data is rapidly evolving due in part to the advent of inexpensive and powerful computing resources. These advances will present researchers in our field with many opportunities for methodologic innovations in the future.

Exposure Assessment

The accurate estimation of exposure to occupational hazards has been and remains one of the foremost challenges in conducting occupational epidemiologic studies. One might say that exposure assessment is the Achilles heel of many occupational studies. There were four sessions that included 22 oral presentations on this topic making it one of the extensively covered subjects at our conference. These papers covered a wide range of topics including classical measurement methods based on air monitoring and the development of job exposure matrices [14] to the use of novel methods such as using metagenomics to detect bacteria in animal slaughterhouses [15] and the use of machine learning methods to develop decision rules for exposure assessment [16]. There is a clear need for further research on improving exposure assessment methods for use in occupational epidemiology studies which is further discussed in the paper in this issue by Dopart and Friesen [17]. Exposure estimation facilitates exposure response analyses in epidemiological studies, which are crucial for risk assessments and for the derivation of health based exposure standards. Another area of interest is the use of biomarkers of exposure in relation to health outcomes (e.g., blood lead, serum PFOA). Such biomarkers may reflect internal dose and in some cases, may be preferable to measurements of external exposure. However, one problem is that they often reflect only recent exposure because of a short half-life. Another problem is that they may suffer from the problem of reverse causation, whereby the health effect in question causes a change in the level of the biomarker, rather than the other way around [18].

Molecular Epidemiology

There were very few abstracts submitted to our conference that involved the use of genetic or epigenetic markers. This is remarkable given the explosion of these methods in the medical sciences and in other areas of epidemiology. In part, this may reflect the difficulties of conducting this research in the work environment where concerns persist about the potential misuse of this information to discriminate against workers with genetic predisposition to the effects of occupational exposures. We organized a mini-symposium at the conference with the somewhat provocative title of "What Has Molecular Epidemiology Really Brought to Occupational Health". There were a number of examples of the usefulness of biomarkers presented in this mini-symposium such as the use of immunologic markers for studies of workers exposed to formaldehyde and trichloroethylene [19].

Challenges

The rapidly changing nature of work and industry presents particular challenges as well as opportunities for occupational epidemiology. The decline in heavy industry in industrialized countries has changed the nature of what occupational hazards we are able to study. Exposures to classical hazards such as

asbestos, nickel, cadmium, and radon have been dramatically reduced in most western industrialized countries making it more difficult to study these exposures. The rapid automation of many industries also makes it increasingly difficult to study the effects of remaining common industrial exposures on worker's health (e.g., welding fumes, lead, silica) due to there being too few workers involved. The labor unions based in heavy industry have declined in the USA from about 20% in 1983 to 11% in 2016 according to the Bureau of Labor Statistics [20]. Much of occupational epidemiology in industrialized countries has historically driven by pressure from the labor unions, now often absent.

The export of industries to countries with lower labor costs and often weaker regulations has been a common occurrence in recent decades. Migrant workers increasingly fill hazardous occupations in developed economies as discussed in the article in this issue by Moyce and Schenker [21]. Thus, studying workers has become somewhat of a moving target. Political instability and war is also increasing the numbers of displaced workers, who may present particular health concerns in the workplace due the trauma that they have experienced. Finally, many under developed countries lack the infrastructure for conducting epidemiologic research (e.g., mortality and cancer registries). Furthermore, in many developing countries, difficulties and barriers have been created by the industries that hamper occupational studies.

Funding

One of the most obvious challenges is a lack of funding from both the public and private sectors. Funding for extramural research by the National Institute for Occupational Safety and Health (NIOSH) was only US$21 million in 2015 (personal communication with Sarah Felknor NIOSH). This is far less than other research institutes in the USA such as the National Institute for Environmental Health Sciences (NIEHS) which awarded US$306 million in extramural grants in 2015 [22]. NIH does not provide estimates of funding for occupational health research, but it is undoubtedly a very small fraction of the US$32 billion that NIH invests annually in medical research. Prospects for funding for occupational epidemiology are scarcely better and perhaps even worse in the European Union (EU). The Horizon 2020 research initiative, which is the largest EU funding program ever offered in Europe, has no occupational health and safety research theme. To date, Horizon 2020 has not granted any awards to studying occupational health and safety issues, apart from some projects in which occupational risks are included to facilitate risk assessment for agents relevant for the general environment or consumers. In most EU member states, funding of occupational health and safety programs have been considerably reduced or programs have terminated. In Canada, there are no targeted research funds for occupational health from granting institutions, and the Canadian cancer Research Alliance estimated that occupational cancer represented 0.1% of funding from the 40 major funding institutions.

While more difficult to estimate, funding from the private sector for occupational epidemiology seems also to have dried up from its heyday in the late twentieth century when industry sponsored epidemiologic studies of workers in the rubber [23, 24], automobile [25], diatomaceous earth [26], asphalt [27], and electrical utilities industries [28]. These classic studies were in most cases based on a constructive tripartite partnership between industry, academia, and labor unions. The tripartite oversight of these studies resulted in them having substantial credibility for objectivity despite their funding source. Attendance by epidemiologists working for industry in our EPICOH conferences has been very low in recent years, which may simply be a reflection of reductions in the numbers of epidemiologists employed by industry. During the mid-90s, there were dozens of companies that had epidemiology units which sponsored studies and did their own internal studies. Today, most of these units have disappeared.

Political and Legal

Political and legal challenges to conducting occupational epidemiologic studies are nothing new to our field. Numerous conflicts with industry were documented in Alice Hamilton's autobiography "*Exploring the Dangerous Trades*" from her pioneering work during the 1940s [29]. A prominent recent example, which was discussed at our conference, is provided by studies of diesel exhaust exposure among miners and the risk of lung cancer that were recently completed by researchers at NIOSH and the National Cancer Institute (NCI) [30, 31]. These landmark studies, which provided strong evidence for an association between exposure to diesel exhaust and lung cancer, were highly influential in the classification of diesel exhaust as a Group 1 (known) human carcinogen by the International Agency for Research on Cancer (IARC) in 2012 [32]. The study was challenged by industry lawyers from the Mining Awareness Research Group (MARG) from its very inception in 1992 [33]. These legal maneuvers severely delayed the study which took over 20 years to complete. The industry lawyers even went so far as to send a letter to at least four science journals warning them that they risked unspecified consequences if they published the studies [34]. Several industry sponsored papers have been published questioning the conclusions drawn from the NCI/NIOSH studies [35–37] and presenting several re-analyses [38–40]. While the published papers and re-analyses raised the level of scientific discourse, the legal actions taken by the industry have resulted in significant delays in the conduct of this study and in the development of policies to address the hazards related to exposure to diesel exhaust.

The conflicts that arise from our research are not at all surprising since our findings may have great economic consequences, which naturally foster intense scientific debates and political/legal challenges. These conflicts may be particularly intense when litigation is involved. They may subside over time as scientific consensus is reached as it has for many occupational hazards such as those resulting from occupational exposures to asbestos, benzene, and lead.

Conclusion

Occupational epidemiology has played a major role in providing a safer workplace for many workers throughout the world. While changes are occurring, we remain extremely optimistic that research in occupational epidemiology will remain a vital and essential field. Participation in our EPICOH meetings has been growing and the contribution of our society to the literature and public health is inexorably rising. As long as work exists, there will be occupational diseases that demand our attention and a need for well-designed epidemiologic studies designed to characterize these hazards. Additional sources of funding need to be developed and legal/political barriers need to be reduced in order to continue the growth of this area of research which is so vitally important to the protection of worker's and the public's health.

Compliance with Ethical Standards

Conflict of Interest L.T. Stayner, J.J. Collins, Y.L. Guo, D. Heederik, M. Kogevinas, K. Steenland, C. Wesseling, and P.A. Demers declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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