School of Public Health

Identifying occupational hazards among healthcare workers in Australia and Bhutan

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Human Ethics The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research studies received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262) and the Research Ethics Board of Health, Bhutan: Approval numbers HRE2018-0778, HRE2019-0079, HRE2019-0079-02 and REBH 2018/090.

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Abstract

Background

Healthcare workers are exposed to a wide range of hazards in their workplace. Although much work has been done on biological, psychosocial, and ergonomic hazards among healthcare workers, there is relatively very little research on chemical hazards, exposures to which have been associated with long-term adverse health effects. This is especially the case in low-and middle-income countries (LMICs) where occupational health is often a neglected public health issue and there are limited resources for the institution and implementation of occupational health and safety programs and for occupational health research.

The primary aim of this research project was to examine occupational exposures to chemical hazards among healthcare workers in Australia and Bhutan by (i) estimating the prevalence of exposure to occupational carcinogens, asthmagens and ototoxic agents, (ii) identifying the main tasks related to such exposures, and (iii) determining which demographic and occupational characteristics are associated with these exposures. The secondary aims were i) to synthesize the available research on occupational hazards that healthcare workers are exposed to in LMICs and ii) to compare OccIDEAS, the exposure assessment method used in this research project, with a traditional exposure assessment method, the Job Exposure Matrix (JEM) in the assessment of exposure to asthmagens in a high-income country and a LMIC.

Methods

Occupational exposure to chemicals among healthcare workers in Australia was investigated by analysing data from three population-based cross-sectional studies on occupational exposures to carcinogens, asthmagens and ototoxic agents conducted in Australia in 2011, 2014, and 2016, respectively.

For assessing exposure to chemicals among healthcare workers in Bhutan, a questionnaire was first adapted and tested in a pilot study among 30 healthcare workers at baseline and at 10-14 days. This questionnaire was then used to conduct a cross-sectional study among 370 healthcare workers in three hospitals in Bhutan.

For the secondary aims of the research project, i) a systematic scoping review was conducted to identify occupational hazards among healthcare workers in LMICs and to synthesize the literature, and ii) agreement between assessment of occupational asthmagen exposures in

healthcare workers in Australia and Bhutan using OccIDEAS and an occupational asthma-specific JEM (OAsJEM) was estimated.

Results

The scoping review found that healthcare workers in LMICs were exposed to a wide range of occupational hazards and that the implementation of risk reduction strategies was suboptimal, mainly due to resource limitations. Research on occupational hazards among healthcare workers in LMICs had increased considerably in the last decade, however, most of the studies were on biological hazards (48%), and research on other types of hazards was minimal in comparison (Chapter 3).

The Australian cross-sectional studies were described in detail in Chapter 4. The results of these studies showed that the prevalence of exposure to at least one asthmagen, carcinogen, and ototoxic agent among healthcare workers was 92.3%, 50.7%, and 44.6%, respectively. The most common chemical exposures were to: 1) cleaning and sterilising agents in the asthmagen group; 2) polycyclic aromatic hydrocarbons (PAHs) in the carcinogen group; and 3) toluene and p-xylene among ototoxic agents. Exposure varied by occupation, with exposure to carcinogens and ototoxic agents highest among personal carers and exposure to carcinogens most likely among nursing professionals and health and welfare support workers (Chapter 5).

The results of the pilot study showed that the adapted questionnaire was reliable and appropriate for assessing occupational chemical exposures among healthcare workers in Bhutan (Chapter 6).

The results of the Bhutanese cross-sectional survey showed that the prevalence of exposure to at least one asthmagen, carcinogen, and ototoxic agent was 98.7%, 28.1%, and 7.6%, respectively; and was 6.2% for anaesthetic gases and 2.2% for antineoplastic drugs. The most common exposures were to latex in the asthmagens group; formaldehyde in the carcinogens group; and p-xylene among ototoxic agents. Exposure varied by occupation group, with other health professionals and technicians most likely to be to be exposed to asthmagens and ototoxic agents, and nurses most likely to be exposed to asthmagens (Chapter 7).

There was poor to fair agreement in the assessment of exposure to asthmagens in healthcare workers between the two methods. OccIDEAS identified exposures to more agents than the OAsJEM, including agents that were less common, and also appeared to be more appropriate for evaluating cross-country exposures to asthmagens in healthcare workers (Chapter 8).

Conclusions

This thesis has made a significant and original contribution to understanding the epidemiology of occupational chemical hazard exposure among healthcare workers in Australia, a high-income country and Bhutan, a LMIC. A substantial proportion of healthcare workers in both countries were exposed to asthmagens, carcinogens and ototoxic agents, with exposure to asthmagens being the most common (>90% in both countries). The prevalence of exposure to many of the chemicals assessed was higher in Bhutan than in Australia. The findings also show distinctive exposure profiles for each country, with the main tasks and agents leading to exposures and occupation groups at risk for exposure being different in the two countries. This research provides information that can be beneficial in formulating policies and implementing control measures to protect healthcare workers.

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List of papers as part of the thesis

The following four papers were produced as part of the thesis. The papers were published in peer-reviewed international journals.

Paper 1: Exposure to occupational hazards among healthcare workers in low- and middle-income countries: A scoping review (Chapter 3)

Rai R, El-Zaemey S, Dorji N, Rai, BD, Fritschi L. Exposure to occupational hazards among healthcare workers in low- and middle-income countries: A scoping review. International Journal of Environmental Research and Public Health. 2021; 18(5):2603. DOI: 10.3390/ijerph18052603

Paper 2: The estimated prevalence of exposure to carcinogens, asthmagens, and ototoxic agents among healthcare workers in Australia (Chapter 5)

Rai R, Fritschi L, Carey RN, Lewkowski K, Glass DC, Dorji N, El-Zaemey S. The estimated prevalence of exposure to carcinogens, asthmagens, and ototoxic agents among healthcare workers in Australia. American Journal of Industrial Medicine. 2020; 63(7) 624-633. DOI: 10.1002/ajim.23108

Paper 3: Reliability and validity of an adapted questionnaire assessing occupational exposures to hazardous chemicals among health care workers in Bhutan (Chapter 6)

Rai R, El-Zaemey S, Dorji N, Fritschi L. Reliability and validity of an adapted questionnaire assessing occupational exposures to hazardous chemicals among health care workers in Bhutan. International Journal of Occupational and Environmental Medicine 2020; 11:128-139. DOI: 10.34172/ijoem.2020.1878

Paper 4: Occupational exposures to hazardous chemicals and agents among healthcare workers in Bhutan (Chapter 7)

Rai R, El-Zaemey S, Dorji N, Fritschi L. Occupational exposures to hazardous chemicals and agents among healthcare workers in Bhutan. American Journal of Industrial Medicine. 2020; 63(12):1109-15. DOI: 10.1002/ajim.23192

Authors’ contribution to the papers in this thesis

Paper 1: Exposure to occupational hazards among healthcare workers in low- and middle-income countries: A scoping review (Chapter 3)

Rajni Rai developed the search strategy; screened, extracted and analysed the data; and prepared the manuscript. Sonia El-Zaemey, Nidup Dorji, Bir Doj Rai and Lin Fritschi contributed to the development of the search strategy, screening and extracting the data, and manuscript revision.

Paper 2: The estimated prevalence of exposure to carcinogens, asthmagens, and ototoxic agents among healthcare workers in Australia (Chapter 5)

Rajni Rai prepared the manuscript and analysed the data; Lin Fritschi designed and supervised the original studies from which the data were obtained, supervised the data analysis and contributed to manuscript revision; Sonia El-Zaemey, Renee C. Carey, Kate Lewkowski, Deborah C. Glass, and Nidup Dorji contributed to the design of study and manuscript revision.

Paper 3: Reliability and validity of an adapted questionnaire assessing occupational exposures to hazardous chemicals among health care workers in Bhutan (Chapter 6)

Rajni Rai designed the study; collected, managed and analysed the data; interpreted the results and prepared the manuscript under direct supervision of Lin Fritschi. Sonia El-Zaemey and Nidup Dorji contributed to the design of the study and manuscript revision.

Paper 4: Occupational exposures to hazardous chemicals and agents among healthcare workers in Bhutan (Chapter 7)

Rajni Rai designed the study; collected, managed and analysed the data; interpreted the results and prepared the manuscript under direct supervision of Lin Fritschi. Sonia El-Zaemey and Nidup Dorji contributed to the design of the study and manuscript revision

Author’s note

This thesis is presented as a hybrid thesis and includes papers that have been published. As each chapter is a standalone manuscript there is some repetition that is unavoidable in the thesis, particularly in the description of the background and methodology. Keeping this in consideration, efforts have been made to reduce repetition especially in the literature review and general discussion. A short introduction is presented in the beginning of each chapter to link the individual chapters into a cohesive body of work. In addition, the reference lists have been removed from each chapter and have been presented together as a single list at the end of the thesis to increase cohesiveness.

Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
AOR	Adjusted Odds Ratio
AWES	Australian Work Exposure Studies
BSC	Biological Safety Cabinet
CI	Confidence Interval
HBV	Hepatitis B Virus
HIV	Human Immunodeficiency Virus
IARC	International Agency for Research on Cancer
JEM	Job Exposure Matrix
LMIC	Low and Middle Income Country
LTBI	Latent Tuberculosis Infection
OPA	Ortho-phthalaldehyde
OR	Odds Ratio
OSH	Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
NIOSH	National Institute for Occupational Safety and Health
PAHs	Polycyclic Aromatic Hydrocarbons
PEP	Post Exposure Prophylaxis
PPE	Personal Protective Equipment
RR	Relative Risk
QAC	Quaternary Ammonium Compounds
SED	Smoke Evacuation Device
TLV	Threshold Limit Value

UK	United Kingdom
US	United States
WAGs	Waste Anaesthetic Gases
WHO	World Health Organization

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Chapter 1 : Introduction

This chapter presents the background and the rationale for conducting this PhD research project, states the aims and provides an overview of the chapters of the thesis.

1.1 Background

The healthcare environment is well-known as a potential source of harm to patients through exposure to infectious agents, hazardous drugs and treatments, and the concern for patient safety remains paramount within the healthcare sector.[1] However, the risk that this same environment poses to the workers working there is not as widely recognised and is often neglected. According to the 2006 report of the World Health Organization (WHO), there were an estimated 56 million healthcare workers worldwide comprising 13% of the global workforce.[2] The demand for healthcare workers is expected to increase to meet the health needs of the rapidly-aging global population. With such a large proportion of healthcare workers potentially exposed to workplace hazards, there is a considerable magnitude of risk that needs to be addressed and mitigated.

Healthcare workers are exposed to a wide range of occupational hazards: biological, chemical, psychosocial and ergonomic hazards. The occupational risks of exposure to infectious agents such as tuberculosis, Hepatitis B, HIV, and influenza among healthcare workers have been a primary focus of research and safety programs.[1] Musculoskeletal disorders and injuries as well as psychosocial hazards such as stress, burn-out and workplace violence are also well-recognised occupational hazards among healthcare workers with a considerable body of literature investigating these hazards.[3-5] However, the fact that healthcare workers are exposed to hazardous chemicals linked to chronic diseases similar to those found in blue collar industries is less apparent, and hence has not received as much attention as the other types of hazards.[1, 6]

Several chemicals used in the healthcare settings have been linked to long-term adverse health effects. There is evidence showing a higher incidence of certain occupationally-related cancers such as hematological, breast and skin cancers among nurses.[7, 8] Formaldehyde, ethylene oxide and antineoplastic agents have been associated with cancers such haematological, breast and nasopharyngeal cancers.[9-11] Previous studies have shown healthcare workers to be an at-risk population for occupational asthma.[12] Exposure to various cleaning and disinfecting chemicals as well as latex used in gloves have shown associations with an increased risk of occupational asthma among healthcare workers.[13, 14] Healthcare workers are also exposed to chemicals such as xylene and toluene that have the potential to cause auditory damage.[15]

Safety standards and guidelines have been recommended to reduce exposure to workplace hazardous chemicals.[16] However, control measures are not universally implemented and exposures remain relatively prevalent.[17] There are not many population-based studies that have examined the prevalence and circumstances of such exposures among healthcare workers. The published studies have mainly investigated exposure to cleaning and disinfecting agents and have reported a high prevalence for such exposures.[13, 18] The only large population-based study conducted in Australia that examined occupational exposure to chemicals among healthcare workers reported that 46% were dermally exposed to chemicals; 33% had airborne exposures to combustion products, and 21% were exposed to industrial and medical gases and fumes.[19] This study however, examined exposures to only a limited number of hazardous agents in the healthcare sector as a whole, without examining circumstances leading to such exposures and the differences in exposures among the various occupational groups within the healthcare sector. Although healthcare workers are exposed to ototoxic chemicals, such exposures have not been examined in this occupation group.

In Low and Middle Income Countries (LMICs), the challenges of tackling the dual burden of diseases often result in the majority of resources being allocated to the control of communicable diseases and in the improvement of maternal and child health.[20] Thus, occupational health and safety is not regarded as a priority public health problem and the control of occupational exposures together with the development of research and safety programs receive little or no funding. As such, there is relatively limited research on occupational hazards among healthcare workers in LMICs and the published literature so far has mainly focused on biological, ergonomic and psychosocial hazards, with exposure to chemical hazards receiving scant attention.[1, 21]

In 2007, the WHO endorsed the Global Plan of Action on Worker's Health in a bid to promote occupational health and urged member states to provide essential occupational health services for the primary prevention of work-related diseases and injuries.[22] However, the ongoing COVID-19 pandemic has revealed that the workplace protection of healthcare workers is not adequate even in resource-rich countries, with 35,000 healthcare workers being infected with the virus globally as of 21 April, 2020.[23, 24] This raises the question regarding the level of protection available to healthcare workers, especially from workplace hazards such as exposure to chemicals which is not as well-recognised as exposure to infectious agents.

1.2 Aims and Outline of the Thesis

For any occupational safety and prevention program to be effective in implementing measures to control hazards, it is imperative to first identify the potential hazards, assess the magnitude of the exposures and determine the at-risk populations. Therefore, the primary aim of this research program was to examine occupational exposures to chemical hazards among healthcare workers in Australia and Bhutan by (i) estimating the prevalence of exposure to occupational carcinogens, asthmagens and ototoxic agents, (ii) identifying the main tasks related to such exposures, and (iii) determining which demographic and occupational characteristics are associated with these exposures. The secondary aims were i) to synthesize the available literature on occupational hazards that healthcare workers are exposed to in LMICs and ii) to compare OccIDEAS, the exposure assessment method used in this research project, with a traditional exposure assessment method, the Job Exposure Matrix (JEM) in the assessment of exposure to asthmagens in a high-income country and a LMIC.

In total, this thesis comprises of nine chapters (including this introductory chapter), which are summarised below:

Chapter 2 is a literature review on the chemical hazards that healthcare workers are exposed to in their workplace. It presents a description of the chemical hazards and the available control measures. A summary of the exposure assessment measures used to assess hazardous exposures in epidemiological studies is also provided.

Chapter 3 (published paper) is a systematic scoping review that synthesizes the available research on occupational hazards among healthcare workers in LMICs and identifies research gaps.

Chapter 4 presents a brief description of the Australian Work Exposure Studies (AWES) that were conducted to assess exposures to carcinogens, asthmagens and ototoxic agents. The data for chapters 5 and 8 were obtained from these studies.

Chapter 5 presents a published paper that examines occupational exposures to carcinogens, asthmagens and ototoxic agents among healthcare workers in Australia.

Chapter 6 presents a published paper that reports the findings of a pilot study conducted in Bhutan. In this study, a questionnaire was adapted from one developed by the National Institute for Occupational Safety and Health (NIOSH) and was tested for reliability and face validity.

Chapter 7 presents the findings of a cross-sectional survey conducted using the adapted questionnaire to assess exposures to carcinogens, asthmagens, and ototoxic agents among healthcare workers in Bhutan. The findings were published as a short report and these published findings, as well as some additional analyses, are presented in this chapter.

Chapter 8 is the final study of this thesis. This study estimated the agreement between assessment of occupational asthmagen exposures in healthcare workers in Australia and Bhutan using algorithms based on task-based questionnaires (OccIDEAS) and an occupational asthma-specific JEM (OAsJEM).

Chapter 9 is the conclusion of the thesis and provides a general discussion on the results and relevance of the findings, and describes the limitations and implications for future research and policy.

Chapter 2 : Chemical hazards in the healthcare environment

This chapter presents a review of the literature on the major chemical hazards that healthcare workers are exposed to in their workplace. It begins with the description of the various hazards and a discussion of measures to control these hazards. The chapter concludes with a description of the different methods used to assess chemical exposures in epidemiological studies.

2.1 Chemical hazards among healthcare workers

Healthcare workers are at an increased risk of long-term adverse health outcomes such as cancer and asthma due to exposure to hazardous agents in the workplace. Previous studies have shown an excess of certain cancers that were suspected to be occupationally-related such as breast cancer and leukaemia among nurses.[7, 8] A Danish study of healthcare workers found male physicians had twice the expected risk of brain cancer, and dental practitioners, female physicians and nurses were at an increased risk of skin melanoma.[25] Healthcare workers are also known to be an at-risk population for occupational asthma. A study conducted in the United States (US) reported that healthcare workers had one of the highest prevalences of asthma (12.6%) among all occupation groups.[26] Recent studies have estimated the prevalence of new-onset asthma among healthcare workers to be 6 to 10%.[18, 27-29] Various chemicals used in healthcare settings have been linked to these chronic health outcomes and are described below.

2.1.1 Natural rubber latex

Healthcare workers are exposed to latex mainly through the use of latex gloves. Latex is a recognised allergen and latex allergy is an important occupational health concern in healthcare workers.[30] Exposure to latex allergens via skin contact, inhalation or ingestion can induce an immune response that can lead to symptoms ranging from minor skin irritation to more severe reactions such as anaphylaxis and asthma.

The institution of universal precautions in 1987 lead to the widespread use of powdered latex gloves among healthcare workers with a resultant increase in the incidence of latex allergy.[31] Epidemiological studies conducted in the 1990s reported an increasing prevalence of latex sensitization among healthcare workers, with studies reporting rates of >10%.[32-34] In 1997, the NIOSH published an alert on the rise in latex allergies among healthcare workers and recommended the development and implementation of policies to control latex such as the use of low-protein, powder-free or non-latex gloves.[31]

Following the institution of preventive measures, studies reported a decrease in latex-related symptoms among healthcare workers in the early 2000s.[14, 34, 35] A systematic review published in 2006 reported a 4.3% prevalence of latex allergy in healthcare workers.[36] A study conducted in the United Kingdom (UK) reported a decline in the annual notifications of latex-related occupational asthma among healthcare workers from 1996 onwards.[37] An analysis of time-trends in the incidence of occupational asthma in France found that the incidence in healthcare workers decreased in the years 2001to 2009, partly due to a reduction of latex-related asthma.[38]

2.1.2 Cleaning, disinfecting and sterilising agents

To comply with infection control standards to prevent hospital-acquired infections, healthcare organisations have strict protocols for maintaining cleanliness and for the sterilisation of medical equipment.[39] This requires the extensive use of cleaning and sterilising chemicals resulting in a high risk of potential workplace exposures to multiple chemicals among healthcare workers.

Declos et al[18] classified cleaning and disinfecting agents in healthcare settings into three main groups: building surface cleaners, instrument disinfecting agents, and agents used in patient care.

2.1.2.1 General surface cleaners

General cleaning and disinfecting agents used in hospitals include chemicals such as bleach, chlorine, quaternary ammonium compounds (QACs) and phenols, which are used for cleaning of floors and other surfaces. In recent years, there is increasing evidence of occupational asthma associated with cleaning products in healthcare workers and these general surface cleaners have been the most frequently implicated agents, especially since the 2000s, with several studies reporting an increased risk with exposure to these agents.[18, 29, 37]

A study that analysed data from the Sentinel Event Notification Systems for Occupational Risks (SENSOR) Program found that 12% of occupational asthma cases were associated with the use of cleaning products, and nurses and nursing aides were the second largest occupational group who were at risk, after janitors.[40] Another study utilising data from the European Community Respiratory Health Survey (ECRHS II), reported that nurses who used bleach and/or ammonia were found to have a greater than twofold risk (RR = 2.16; 95% CI: 1.03 to 4.53) of new onset asthma as compared to the reference population.[28] In a study conducted in the US, exposure to bleach was independently associated with work-related asthma,[13] and a study from France showed that exposure to QACs significantly increased the risk of asthma and nasal symptoms among healthcare workers.[27]

In light of the growing evidence of these harmful effects, there have been initiatives for substitution with less toxic cleaning agents, including green cleaners.[16] However, there is currently no standard definition of green cleaners, with various organisations developing their own definition for certification.[39] There is also limited evidence regarding the efficacy of these products.

Preventative measures to control exposure to these agents include substitution with a less hazardous alternative where possible, using engineering controls such as local exhaust ventilation and using appropriate personal protective equipment (PPE).[41] Training of workers on the safe handling of these chemicals should also be carried out.

2.1.2.2 Instrument disinfecting agents

Chemicals used for disinfecting and sterilising medical instruments include but are not limited to glutaraldehyde, formaldehyde, ortho-phthalaldehyde (OPA), QACs and ethylene oxide.[16]

Glutaraldehyde is the most commonly used disinfectant and is used to sterilise heat-sensitive instruments (e.g., bronchoscopes, endoscopes, and dialysis equipment) and also as a fixative for x-ray films and electron microscopy. Exposure to glutaraldehyde through inhalation or skin contact can occur during activation of glutaraldehyde solutions or when equipment is manually processed in open containers in poorly ventilated conditions.[42] For occupational exposure standards of glutaraldehyde, the American Conference of Governmental Industrial Hygienists (ACGIH) and the UK Health and Safety Executive, currently recommends a Threshold Limit Value (TLV) of 0.05ppm in air, measured as a ceiling concentration and in Australia, the permissible exposure limit is 0.10ppm.[42, 43] In a study conducted in Australia among nurses engaged in endoscope disinfection, glutaraldehyde exposure levels were reported to be above the permissible exposure limits (levels reported were >0.15ppm).[44] Workplace glutaraldehyde exposure has been associated with respiratory symptoms including asthma in healthcare workers in a number of studies.[13, 45-47] OPA has been introduced as a safer alternative to glutaraldehyde and is increasingly being used in various countries because of the adverse respiratory outcomes reported with the use of glutaraldehyde.[48] However, there have been some reports linking OPA to asthma and dermatitis.[13, 49] The use of engineering controls such as automatic disinfection systems or local exhaust ventilation during manual disinfection together with proper work practices and the use of PPE are recommended to control exposures.[16]

Formaldehyde is used in healthcare settings for disinfection, and to fix, stain and preserve tissue samples and anatomical specimens.[16] Healthcare workers can be exposed to formaldehyde when preparing formalin solutions, disinfecting dialysis equipment or preparing tissue samples. The US Occupational Safety and Health Administration (OSHA) has set occupational exposure standards of a permissible exposure limit of 0.75 ppm for an eight hour time-weighted average exposure and a short-term exposure limit of 2ppm for formaldehyde.[50] Formaldehyde is a sensitizer and has been associated with asthma and asthma-like symptoms in studies carried out in healthcare workers.[46, 51] Arif et al[13] also reports that exposure to formaldehyde is associated with a significantly increased risk (AOR 2.66; 95% CI: 1.03 to 6.86) of work exacerbated asthma among healthcare workers. In addition to occupational asthma, there are concerns about the carcinogenicity of formaldehyde. Formaldehyde has been classified as carcinogenic to humans (Group 1) by the International Agency for Research on Cancer (IARC) based on evidence that it causes nasopharyngeal cancers and leukaemia.[52] In a recent review of available human data, Kwon et al[53] found a causal and significant dose-response relationship between formaldehyde exposure and nasopharyngeal cancer, lympho-hematopoietic malignancies and Hodgkin lymphoma. They also identified peak exposures as a potential risk factor for these cancers in occupational settings. Chemical substitution where feasible, effective ventilation, and proper work practices are recommended to control workplace exposures.[16]

Ethylene oxide is another chemical sterilant used for sterilising heat-sensitive medical equipment.[16] Ethylene oxide exposures occur mainly through inhalation and exposures have been linked with various adverse health outcomes. In a study among dental assistants, ethylene oxide exposures were associated with an increased risk of spontaneous abortion, premature and post-mature births (RR 2.5; 95% CI: 1.0–6.1).[54] The epidemiological evidence on ethylene oxide exposure and cancer risk is conflicting. Studies conducted in Sweden reported an increased risk of leukaemia and gastric cancer in ethylene oxide manufacturing workers and in those using it as a sterilant.[55, 56] Another study showed an increased breast cancer rate in female workers who were exposed to ethylene oxide.[57] However, other studies did not confirm these findings and concluded that the risk of cancer from occupational exposures to ethylene oxide was low.[10, 58] Despite the limited epidemiological evidence, the IARC has classified ethylene oxide as carcinogenic to humans based on findings from human cytogenetic studies.[59] Control measures include using a sterilizer with in-chamber aeration, isolation of the sterilizer to limit the exposures and good work practices.[60]

2.1.2.3 Agents used in patient care

Other cleaning and disinfecting agents used in healthcare settings include topical cleansers and antiseptics such as chlorhexidine, which are applied to patients' skin or used for hand hygiene.[18] There are a few studies that have examined chlorhexidine as a potential occupational allergen in healthcare workers. A small study conducted among healthcare workers in a district hospital in the UK reported four cases of symptoms of occupational allergy associated with the use of chlorhexidine hand wash.[61] Another study conducted in Denmark carried out skin tests among 104 healthcare workers to assess sensitization to chlorhexidine and asked about chlorhexidine allergy symptoms in 78 healthcare workers.[62] This study did not identify any chlorhexidine allergies among the included healthcare workers. However, a recent study conducted among 4055 nurses in the US found that increased frequencies of hand/arm hygiene were associated with poor control of asthma suggesting an adverse effect from the products used for these tasks.[63] The authors concluded that this was a potential risk factor for occupational asthma that warranted further research.

2.1.3 Antineoplastic agents

Antineoplastic agents used for cancer chemotherapy are known for inducing significant side-effects in patients.[64] In the 1970s, it was reported that these agents could also pose an occupational risk to healthcare workers.[65] Healthcare workers can be exposed to antineoplastic agents during the preparation and administration of these drugs or when they work in areas where these agents are being used through contact with contaminated work surfaces, equipment or clothing, drug vials, and patient secretions such as urine or faeces.[16, 66] The major routes of exposure are via skin absorption and inhalation. Evidence for occupational exposures have been documented from studies of workplace contamination with antineoplastic drugs[67, 68] and studies showing measurable amounts of drugs in the urine of healthcare workers indicating workplace exposures and the uptake of these drugs.[69, 70]

Guidelines and standards on the safe handling of antineoplastic drugs were published by organisations such as the NIOSH[65] and the WHO in the early 2000s.[71] However, despite efforts to reduce contamination in the workplace, there is evidence of continuing workplace exposures to antineoplastic drugs with studies showing that environmental contamination has not changed considerably in recent years,.[67, 72, 73]

A growing number of antineoplastic agents have been identified by the IARC as known or suspected human carcinogens.[74] Previous studies among healthcare workers handling antineoplastic agents have shown an increased risk of leukaemia (RR 10.65; 95% CI: 1.29 - 38.5) and breast cancer (RR = 1.83; 95% CI: 1.03 - 3.23).[11, 75] Occupational exposure to these agents have also been associated with an increased risk of congenital abnormalities, foetal loss, and impaired fertility among healthcare workers.[11, 76] A large study conducted in the US documented a two-fold increased risk of spontaneous abortions in nurses exposed to antineoplastic agents in the workplace.[77]

Engineering controls such as biological safety cabinets (BSCs) introduced in the 1980s for the preparation of antineoplastic agents substantially reduced workplace exposures.[16] More recently, closed drug transfer devices were introduced for the preparation and administration of antineoplastic drugs. Although there was a substantial reduction in occupational exposures with the introduction of these engineering controls, there is research suggesting that environmental contamination cannot be eliminated completely even when these controls are used.[68, 78, 79] Hence additional measures such as good workplace practices and the use of PPE together with engineering controls have been recommended.[65, 74]

2.1.4 Surgical smoke

Exposure to surgical smoke can occur in operating theatres during the thermal destruction of tissues from the use of electrocautery/diathermy, ultrasonic scalpels and laser devices.[80] A surgical smoke plume is generated during these processes, which comprises of 95% water and 5% cellular debris and combustion by-products.[81] This latter mixture contains biological and chemical hazards, and is responsible for the adverse effects of smoke.

Inhalation of surgical smoke has been associated with a variety of adverse health effects. Surgical smoke contains numerous hazardous compounds, the most prevalent of which are acrolein, benzene, fatty acids, formaldehyde, hydrocarbons, phenols, nitriles, polycyclic aromatic hydrocarbons (PAHs), toluene, ethylbenzene and xylene.[82] Many of these compounds are established carcinogens with well-defined occupational exposure standards.[83] Previous studies have shown that these compounds are routinely present in surgical smoke in concentrations exceeding the recommended exposure limits.[84, 85]

In addition, many of the by-products of the thermal destruction of tissue are respiratory irritants.[83] Studies carried out in animal models have shown that surgical smoke can cause chronic inflammatory responses leading to interstitial pneumonia, bronchiolitis, alveolar congestion, and emphysematous changes.[86, 87] Although these changes have only been demonstrated in animals, there is a potential for similar damage to be caused by surgical smoke in humans.

Surgical smoke is also known to have cytotoxic and mutagenic effects and studies have compared these effects to that of cigarette smoke.[88] One study reported that the mutagenic potency of the smoke condensate from the laser cauterization of 1gm of tissue was equivalent to that from three cigarettes and that from electric cauterization was equivalent to six cigarettes.[89] Based on these results, it was determined that the inhalation of surgical smoke from a single operation is roughly equivalent to smoking one packet of cigarettes. Another study reported that the average surgical smoke produced daily was equivalent to the mutagenicity of 27-30 cigarettes.[90]

The recommended control measures for surgical smoke include appropriate room ventilation, well-fitted face masks (e.g., N95 respirators) and smoke evacuation devices (SEDs).[80, 91] Of these, SEDs are considered to be the most effective and the NIOSH recommends that evacuation systems should be used during operations, especially in surgeries that might lead to high concentrations of surgical smoke.[92] SEDs should have capture velocities of 30 - 40m/min and the smoke collection nozzle should be kept 5cm from where the smoke plume is generated.[93]

2.1.5 Anaesthetic gases

Inhaled anaesthetics (halogenated agents such as halothane and nitrous oxide) are widely used in operating theatres, dental clinics and other procedure rooms.[16] Healthcare workers can be exposed to waste anaesthetic gases (WAGs) from leaks in the anaesthetic breathing circuit during the delivery of anaesthesia or from exhalation by patients who are recovering from anaesthesia.[94] Anaesthetists, surgeons, obstetricians, nurses and other operating room personnel are at risk of such exposures.

Several studies have shown that long-term exposures to WAGs, especially nitrous oxide and halogenated gases, lead to an increased risk of spontaneous abortions, congenital malformation, hepatic and renal diseases, genetic damage and cancers.[95-99] Some studies have reported no adverse effects from chronic low exposures.[100, 101] A number of reviews conducted on this topic concluded that there could be a risk of adverse effects if control measures are not used.[96, 102, 103] The OSHA recommends keeping WAG exposures to a minimum since the possibility of adverse health effects cannot be completely ruled out, especially for newer anaesthetics which have not been fully evaluated.[104]

Exposure to WAGs can be reduced by using engineering controls such as waste gas scavenging systems, key filler devices to fill vaporisers and dilution ventilation.[105] Appropriate work practices such as the use of close-system anaesthesia, starting the flow of anaesthesia after the application of mask or airway device and checking for leaks in the gas line are also recommended to control exposures.[106]

2.1.6 Laboratory and other chemicals

Healthcare workers working in laboratories handle various corrosive and toxic chemicals such as acids, dyes and solvents.[107] Organic solvents used in laboratories such xylene, toluene and styrene are known to cause auditory damage and can induce hearing loss, especially if exposed together with noise, which is another hazard that is prevalent in laboratories.[15, 108]

In addition to the above agents, there are several other chemicals used in healthcare settings that have been linked to asthma in healthcare workers. These include chemicals such as isocyanates used in orthopaedic clinics, acrylates used in dental clinics, inhaled medications such as pentamidine, antibiotics, as well as adhesives and adhesive removers.[12, 29]

2.2 Control measures to reduce occupational exposure to chemicals

Many of the controls used to reduce workplace exposure to chemicals in healthcare setting have been described above. Measures used for minimising worker exposure to hazardous chemicals follow the principles of primary prevention and the application of a hierarchical approach for control measures to reduce workplace hazards (Figure 2.1).[1, 16] According to this approach, controls are systematically applied in a decreasing order of efficacy as follows: elimination or substitution, engineering controls, administrative controls or work practices and PPE.[109] Substitution is the most important because it leads to the elimination of the hazard, as in the case of the substitution of latex gloves with non-latex gloves. If substitution is not possible, engineering controls are next in the hierarchy. Examples of engineering controls include gas scavenging systems for WAGs, closed systems used for antineoplastic drug administration and smoke evacuation systems to remove surgical smoke. The next in the hierarchy are administrative controls or work practices. Examples include checking for leaks in the anaesthesia machines to reduce WAGs, immediately cleaning any chemical spills, training and education. PPE is the last control in the hierarchy and examples include the use of masks, gloves and gowns to reduce exposures to glutaraldehyde or antineoplastic agents.

Engineering controls and some of the safer chemicals that can be used for substitution are often very costly. In resource-limited settings where these controls are not feasible, strict work practices and administrative controls (e.g., limiting personnel access to areas where there are hazards) together with the proper and consistent use of PPE can minimise exposures.[1] In such settings, an upside-down hierarchy has been suggested (Figure 2.1) to ensure that the health facility is responsible for applying all the control measure available to protect healthcare workers from these hazards, even in settings of resource constraints.

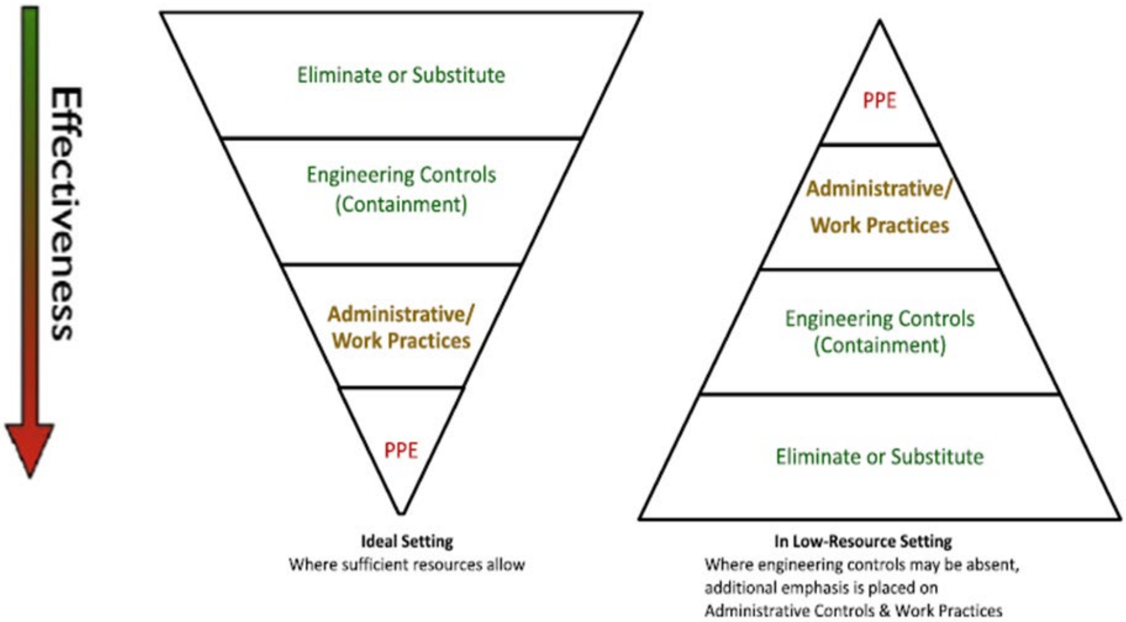

Figure 2.1 Hierarchy of controls (McDiarmid, 2014[1])

A recent large study conducted among healthcare workers in the US found that despite the long standing availability of safety guidelines, recommended practices were not always followed. This study reported that adherence to recommended safety guidelines was not universal, with a considerable proportion of healthcare workers not using the recommended control measures for protection from surgical smoke,[110] during the preparation and administration of antineoplastic agents,[17, 111] the use of chemical disinfectants,[112] and the administration of aerosolised medication.[113] For a safety program to be effective, not only should employers provide all available control measures, but equally important is that healthcare workers use these control measures consistently.

2.3 Exposure assessment methods in epidemiological studies

The accurate assessment of occupational exposures is crucial in examining the aetiology and burden of occupational diseases. However, exposure assessment in large population-based studies remains a challenge since direct quantitative measurements of exposures are often not feasible or are unavailable.[114] There are several methods to assess occupational exposure to chemicals in epidemiological studies such as self-reports of exposures, job exposure matrices (JEMs) and expert assessment.

In self-reports, exposure data (e.g., recall of exposure to a chemical) are generally provided by participants through a questionnaire or an interview. This method is easy to apply in large studies but is limited by reporting bias, which can result in exposure misclassification.[115]

A JEM is a cross-tabulation of job titles and agents with the cells in the matrix indicating the presence or absence of exposure to the agent in each job.[114] The advantage of the JEM is that it can be applied easily and rapidly in large studies in a transparent manner, thus saving time and resources. JEMs have frequently been used to assess exposure to occupational asthmagens and carcinogens in epidemiological studies.[116, 117] However, misclassification of exposures can occur with a JEM because all participants with the same job title are assigned the same exposure, irrespective of variations in tasks and work circumstances between participants.[118]

The expert assessment method is considered the most credible for assessment of exposures in epidemiological studies.[114] In this method, experts review detailed descriptions of tasks and work conditions on a case-by-case basis and assign exposures, thus capturing inter-individual exposure variations within a job and reducing exposure misclassification. However, the use of this method in large studies requires considerable resources in terms of time and money, and multiple experts may be needed if the study involves many agents.[118] In addition, the decision rules to assign exposures are not explicit and may vary from one expert to another, thus limiting the reproducibility of assessments.[119, 120]

In a bid to overcome some of the disadvantages of these traditional assessment methods, new exposure assessment methods have been developed in recent years.[118] These include the application of algorithms derived from experts to questionnaire responses and the use of historical exposure measurement data to create exposure estimates in JEMs. There is initial evidence indicating that these methods are as reliable as the traditional methods.[121]

OccIDEAS is an example of the newer methods. It is a web application based on the expert assessment method that uses algorithms to automatically assess occupational exposures.[122] It comprises of job modules specific for an occupation. These modules contain task modules with questions on particular tasks (e.g., using X-rays, sterilising equipment) that are linked to agents associated with the tasks. Based on the responses to the questions in the modules, algorithms that were developed by experts automatically assign the probability of exposures. However, the drawback of this method is that assessment is also based on questionnaire responses which are subject to recall bias and exposure misclassification. In addition, since it is not feasible to develop rules that cover all possible scenarios, this method may not be able to detect rare exposure circumstances.

2.4 Conclusion

Healthcare care workers are at risk of exposure to a wide range of chemicals and agents that are associated with chronic diseases such as asthma and cancer. Various control measures are available to protect healthcare workers from these hazards. However, these measures are not universally applied resulting in the continuation of workplace exposures to these chemicals.

Exposure assessment is very important in occupational epidemiological studies. Although there are several methods to obtain exposure assessments, no single assessment method is likely to be ideal for all study settings. While the expert assessment method is still considered the best available method, newer approaches are also increasingly important to reduce misclassification and to increase the efficiency and transparency of assessment of exposures in large epidemiological studies.

Chapter 3 : Exposure to occupational hazards among healthcare workers in low- and middle-income countries: A scoping review

In the previous chapter while reviewing the literature, I found that most of the occupational health literature on healthcare workers has originated in high-income countries. This chapter presents the findings of a systematic scoping review conducted to synthesize the available literature on occupational hazards among healthcare workers in LMICs and to identify any research gaps.

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Rai R, El-Zaemey S, Dorji N, Rai, BD, Fritschi L. Exposure to occupational hazards among healthcare workers in low- and middle-income countries: A scoping review. *International Journal of Environmental Research and Public Health*. 2021; 18(5):2603. doi.org/10.3390/ijerph18052603

In this chapter, the post-edited and reviewed version of the manuscript is presented. The publisher's version of the manuscript is presented in Appendix H.

3.1 Abstract

Background: Health care workers are exposed to numerous workplace hazards. The implementation of safety measures in high-income countries has largely mitigated these risks. However, in many low- and middle- income countries (LMICs), resources to institute safety measures are lacking, increasing the risk of occupational exposures to these hazards. The aim of this scoping review is to map and synthesize the available research on occupational hazards among health care workers in LMICs, identify research gaps and inform policy.

Methods: Searches for relevant articles were conducted in five electronic databases using a broad range of search terms. The inclusion criteria were: quantitative observational or experimental studies which examined exposure to one or more occupational hazards among health care workers in a LMIC; and the article was published in English in a peer-reviewed journal. A total of 99 studies met the inclusion criteria, and data were extracted from these studies.

Results: Large proportions of health care workers in LMICs were exposed to biological hazards (bloodborne pathogens, tuberculosis), psychosocial hazards (workplace violence, burnout, job dissatisfaction), ergonomic hazards (musculoskeletal complaints), and chemical hazards (exposure to latex and antineoplastic drugs). The implementation of risk reduction strategies was suboptimal. The majority of the literature was on biological hazards (48%), and research on other hazards was limited in comparison.

Conclusion: Occupational safety needs to become a priority public health issue to protect health care workers in LMICs. More research is needed to understand the magnitude of the problem in these countries.

3.2 Introduction

Healthcare workers are at potential risk of harm from exposure to numerous hazardous agents encountered in their workplace.[107] The most recent and visible example is the ongoing COVID-19 pandemic, which has showcased the vulnerability of healthcare workers and demonstrated the importance of ensuring their safety.[23]

In addition to exposures to emerging diseases, healthcare workers are routinely exposed to other infectious agents such as tuberculosis, influenza, HIV, and Hepatitis B, which have been the primary focus of research and safety programs.[1] Healthcare workers are also exposed to various chemical hazards and agents that have been linked to long-term adverse health effects. Chemicals used in healthcare settings such as ethylene oxide, formaldehyde, and antineoplastic drugs have been linked to cancers and adverse reproductive outcomes.[9-11] Exposure to latex and cleaning and disinfecting agents have been associated with occupational asthma among healthcare workers.[13, 14] Musculoskeletal disorders and injuries, and various psychosocial hazards such as workplace violence, stress, and burnout are other well-recognised occupational hazards among healthcare workers.[3-5]

Recognising these risks, safety measures and standards to protect healthcare workers have been instituted in high-income countries and have largely succeeded in mitigating these hazards.[16] However, in many low-and middle- income countries (LMICs) occupational health and safety is often neglected.[123] These deficiencies in occupational health have been attributed to a lack of political commitment, insufficient resources, poor data collection systems, and weak enforcement of regulations. Occupational health research has shown that providing a safe work environment increases organizational commitment and worker retention.[124] Poor working conditions and threats to health have been reported to contribute to problems in recruitment and retention of healthcare workers in LMICs, augmenting the issue of healthcare worker shortages in these countries.[125]

In order to institute any prevention and safety intervention, it is important to understand the magnitude of problem. The majority of the literature on occupational hazards in healthcare workers has originated in high-income countries, and research from LMICs on this topic is reported to be limited.[21] Findings from studies conducted in high-income countries cannot be generalised to LMICs because exposures in LMICs are likely to be different from high-income countries due to differences in legislation and regulations, health care systems, work practices and the availability of control measures. There is a need to determine the scope and volume of available research conducted on this topic in LMICs and to identify any research

gaps. Apart from a narrative literature review conducted in 2016, which was limited in scope and included only 46 studies, there are no other reviews available on this topic.[21]
Scoping reviews have been described by Arksey and O'Malley as those which: "aim to map rapidly the key concepts underpinning a research area and the main sources and types of evidence available, and can be undertaken as standalone projects in their own right, especially where an area is complex or has not been reviewed comprehensively before"[126]. A revised definition of scoping reviews was proposed by Daudt et al. as: "scoping studies aim to map the literature on a particular topic or research area and provide an opportunity to identify key concepts, gaps in literature; and types and sources of evidence to inform practice, policymaking, and research"[127]. Therefore, a scoping review was conducted to map and synthesize the available research on occupational hazards among healthcare workers in LMICs, to identify any research gaps and to inform policy to improve the safety of healthcare workers.

3.3 Methods

This review was conducted according to the methodological framework for scoping reviews outlined by Arksey and O'Malley[126], Levac et al.[128], Colquhan et al.[129], and The Joanna Briggs Institute.[130] It is reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR).[131] It was guided by the research question 'What is known from the existing literature about exposure to occupational hazards among healthcare workers in LMICs?'

3.3.1 Search strategy

The key terms relating to the research question were identified as follows: 'healthcare workers', 'health workers', 'health personnel', 'health professionals', 'nurses', 'doctors', 'laboratory workers' 'occupational hazards', 'occupational risks', 'occupational diseases', 'occupational health', 'occupational injuries', 'occupational accidents', 'low-and-middle income countries', 'low income countries', and 'developing countries'. The search strategy was developed by the research team in consultation with an academic librarian. Using these key terms and their associated mapped subject headings and MeSH terms, searches were conducted in the electronic databases MEDLINE, Scopus, CINAHL, Embase, and PsycINFO till 1st May, 2020 (Table 3.1 shows an example of the search conducted in Medline). Original peer-reviewed articles in the English language were the only limits applied to the searches to maintain a breadth of coverage. Bibliographies of the included studies were also checked to ensure that all relevant studies had been included in the review. Grey literature was not included.

Table 3.1 Search strategy for Medline (Ovid) (date of search: 01/05/2020)

#	Search terms	Results
1	Health personnel/ or allied health personnel/ or dental staff/ or dentists/ or medical laboratory personnel/ or medical staff/ or nurses/ or nursing staff/ or personnel, hospital/ or pharmacists/ or physical therapists/ or physicians/	247759
2	Healthcare worker.mp. or exp Health Personnel/	508882
3	Exp Health Personnel/	508239
4	Doctors.mp.	79077
5	Health worker.mp.	3624
6	Exp Nurses/	87604
7	Laboratory workers.mp.	872
8	Exp Developing Countries/	74246
9	Developing Countries/ or low income countries.mp.	78538
10	Developing Countries/ or middle income countries.mp.	86404
11	Low and middle income countries.mp.	15851
12	1 or 2 or 3 or 4 or 5 or 6 or 7	566760
13	8 or 9 or 10 or 11	90218
14	12 and 13	5552
15	Exp Occupational Health/	32933
16	Occupational Health/ or Workplace/ or Occupational Diseases/ or occupational hazards.mp. or Burnout, Professional/ or Occupational Exposure/	174709
17	Occupational Health/ or Occupational Diseases/ or occupational risks.mp. or Occupational Exposure/	150603
18	Exp Occupational Diseases/	130883
19	Accidents, Occupational/ or Occupational Diseases/ or Occupational Injuries/	99729
20	Occupational accidents.mp. or Accidents, Occupational/	17686
21	Occupation.mp. or Occupations/	49467
22	Workplace Violence/ or Workplace/ or workplace.mp.	48977
23	15 or 16 or 17 or 18 or 19 or 20 or 21 or 22	276420
24	14 and 23	173
25	Limit 24 to English language	170

3.3.2 Study selection

Studies were selected based on the following inclusion criteria: 1) participants were healthcare workers as classified by the World Health Organization (WHO),[132] 2) the study was conducted in a low- and middle (both lower and upper) income country as classified by the World Bank classification of countries, 2020,[133] 3) the study topic was on exposure to occupational hazards, 4) the type of study was a quantitative observational or experimental study, and 5) the article was published in English in a peer-reviewed journal. Studies were excluded if they were qualitative in design, case series or case reports, reviews, conference presentations or dissertations. The only exception to the application of the selection criteria was on studies on tuberculosis. For tuberculosis, since a systematic review on tuberculosis among healthcare workers in LMICs had been published in 2006,[134] only studies conducted after this period on this topic were included. Studies on night shift work were also excluded.

After removing duplicates, one reviewer (RR) assessed the articles by titles and abstracts and applied the inclusion and exclusion criteria to select the full-text articles to be retrieved. Any uncertainties related to study selection at this stage was discussed with the research team till a consensus was reached. Full-text articles were then screened independently by two reviewers (RR and SE-Z) to finalize their inclusion in the review. Any disagreements regarding the determination of study inclusion in the review at this stage was resolved by consulting a third reviewer (LF). Manual searches of the reference lists of included studies were also conducted.

3.3.3 Charting of the data

Data were extracted from the studies and charted on a table by one reviewer (RR). This included author, year of publication, country of study origin, aims, study population and sample size, study design and methodology, and key findings. A second reviewer (LF) then extracted data from ten randomly selected studies using the data charting form to ensure that the data extraction approach was consistent with the research question and study aims.

3.3.4 Collating and summarising the results

The study characteristics, which included year of publication, study design and methodology, location, participant characteristics, the topic researched, and the study outcomes, were first tabulated. This was done to provide a descriptive numerical summary of the studies included in the review. A thematic analysis was then carried out and the studies were sorted into occupational hazards groups based on the WHO classification of occupational hazards in healthcare workers.[135] These two steps assisted in identifying the dominant areas of research, their location and methodology and any research gaps. The findings are then described as a narrative review.

3.4 Results

The database searches identified 609 articles with a further 37 articles identified from a search of reference lists (Figure 3.1). After removing duplicates, 330 articles were screened by titles followed by abstract examinations of 141 articles. The review of abstracts resulted in 110 articles for full-text examination, of which 99 articles met the inclusion criteria and were included in the review.

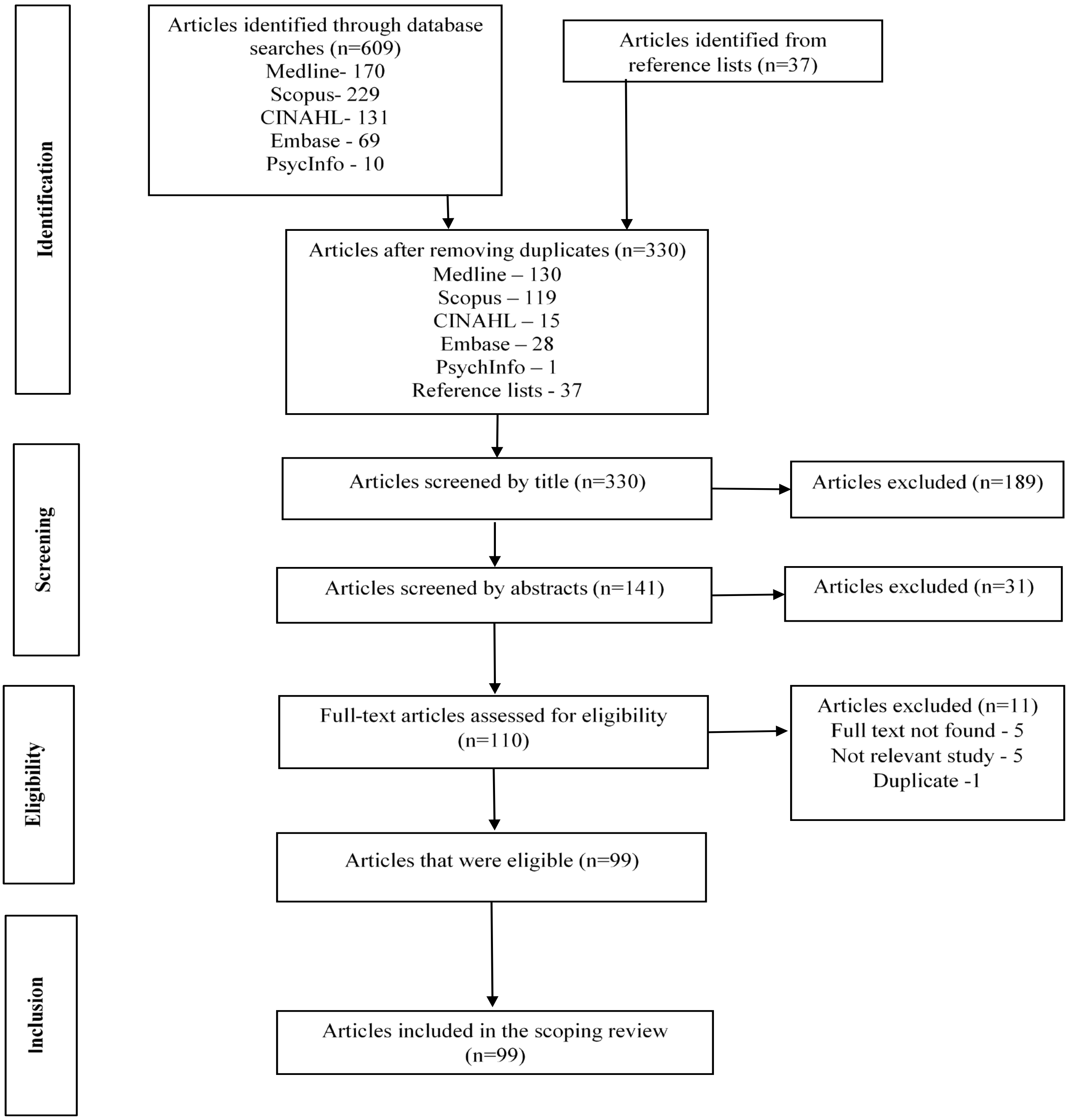

Figure 3.1 Flow chart illustrating the scoping review study selection process

The majority of the studies (34 of 99) were conducted in the Sub-Saharan African region (according to the World Bank regions), were cross-sectional in design (82) and participants were all healthcare occupations (51) (Figure 3.2). Fifty one studies were conducted in district/state hospitals and primary care centres, and 48 were conducted in tertiary care centres. The included studies were published after 1991, with six studies published in the

1990s, 31 studies published between 2001 and 2010, and 62 studies between 2011and 2020 (Figure 3.3).

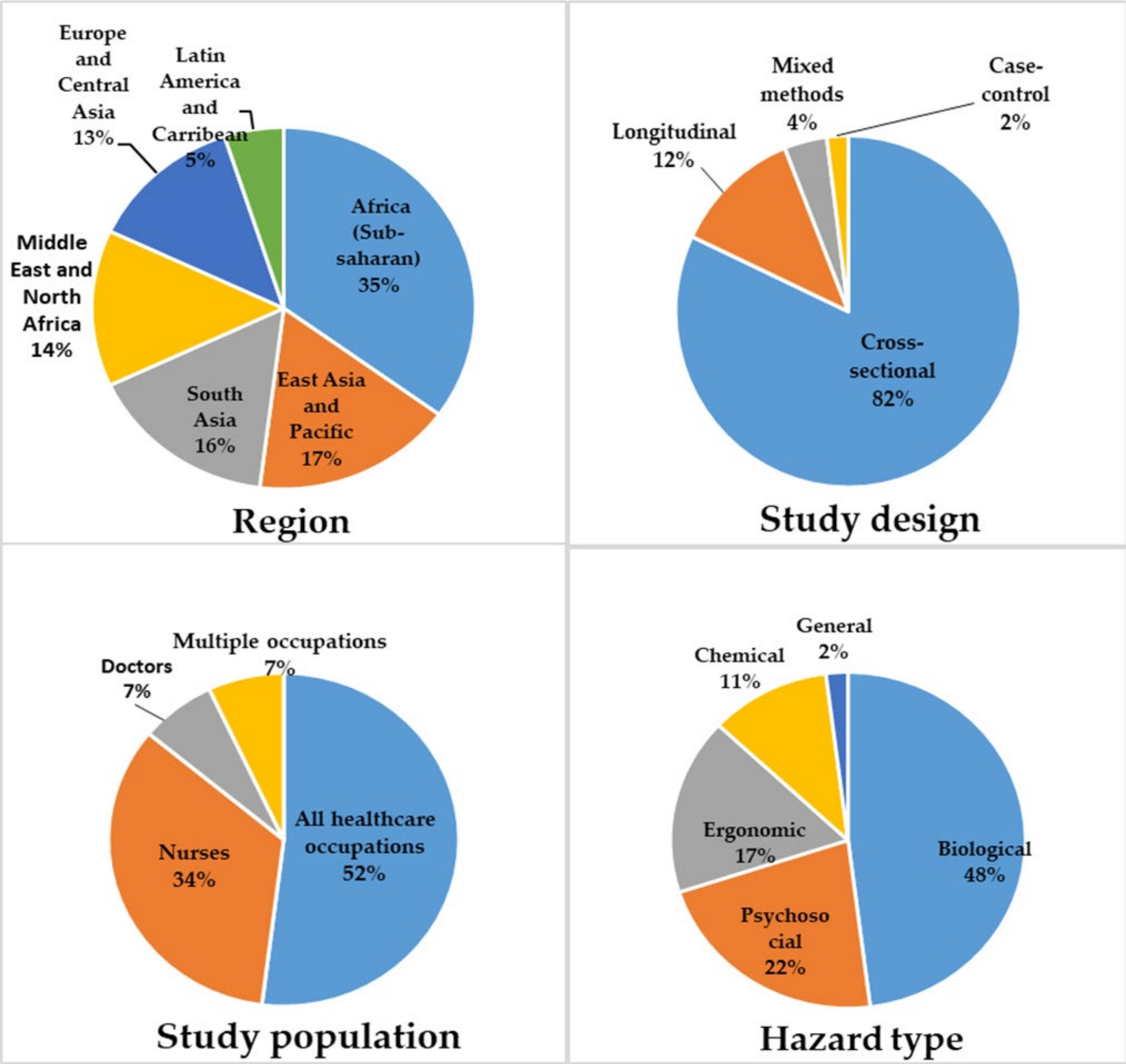

Figure 3.2 Characteristics of studies

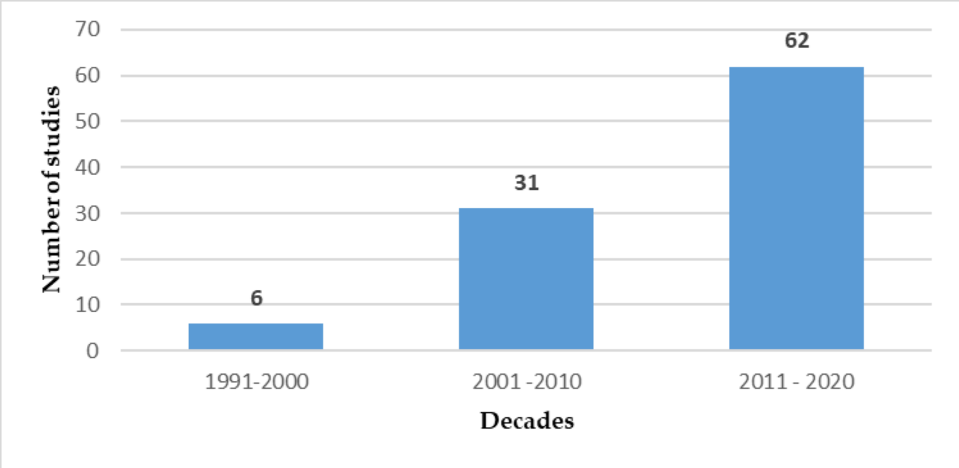

Figure 3.3 Number of studies by decade of publication

Almost half (47) the studies were on biological hazards, 22 studies were on psychosocial hazards, 17 were on ergonomic hazards, and 11 were on chemical hazards (Figure 3.2). In addition, there were two studies that investigated the different types of occupational hazards in general. Among the studies on biological hazards, the majority (38/47) examined exposure to blood borne pathogens and nine studies (after 2006) examined exposure to tuberculosis (Table 3.2). Among the studies on psychosocial hazards, 12 studies examined workplace violence and safety climate, six studies examined the prevalence of burnout and its risk factors and four studies examined work environment and job satisfaction (Table 3.3). The studies on ergonomic hazards mainly investigated the prevalence of musculoskeletal complaints and their risk factors (Table 3.4). Among the studies on chemical hazards, six studies examined exposure to latex and five examined exposure to antineoplastic drugs (Table 3.5).

Table 3.2 The characteristics of the studies (n=47) on exposure to biological hazards (arranged in chronological order according to the year of publication)

Authors	Year	Topic	Origin	Participants	Type of study	Methods	Findings
I. Bloodborne pathogens							
Cavalcante et al. [136]	1991	Occupational risk of acquiring HIV	Brazil	651 healthcare workers from a teaching hospital	Prospective	Healthcare workers who reported accidental exposures to infective material from AIDS patients to the Infection Control Committee (n=247) and those who had other risks of infection but no occupational exposures (n=404) were interviewed and blood was collected for HIV testing at baseline, 90, 180 and 360 days later (for healthcare workers who reported accidents)	247 healthcare workers reported 338 accidents and of these 115 were followed up for more than 6 months and 132 were lost to follow-up. None tested positive for HIV. 50% of exposures occurred through needlestick or sharp injuries, 22% through contact of blood on mucous membranes, 28% through exposures to urine, faeces or cerebrospinal fluid from AIDs patients. The highest frequencies of injuries were reported by nurses, followed by physicians, laundry and housekeeping personnel and laboratory workers. Of the 404 healthcare workers with no occupational exposures, 6 were positive and had confirmed risk factors for HIV transmission.
Adegboye et al. [137]	1994	Needlestick and sharp object injuries and accidents; awareness of the risk of occupational exposure to HIV	Nigeria	474 healthcare workers working in a University hospital complex, who were occupationally exposed to blood	Cross-sectional	Questionnaires on needle-stick and sharp injuries in the past year and on knowledge on HIV transmission	27% of healthcare workers reported at least one needle-stick injury in the past year. Circumstances resulting in needlestick injuries were unexpected patient movement (29%), handling or disposal of used needles (23%), needle recapping (18%), accidental stick by a colleague (18%), and needle disassembly (10%). 15% reported at least one sharp object injury in the past year and this most commonly involved broken glass from patient specimen containers (39%).The highest frequencies of injuries were reported by dental staff and surgeons. Almost all participants were aware of the risk of occupational exposure to HIV.

Olubuyide [138]	1996	Contact with HIV and Hepatitis B (HBV) positive patients and needlestick injuries	Nigeria	149 resident doctors in a teaching hospital in Nigeria	Cross-sectional	Questionnaire asking about contact with HIV/HBV patients, needlestick injuries, and precautions used. No time period was reported.	93% reported contact with HIV/HBV patients, 9% had needlestick injuries (presumably lifetime) and 54% used universal precautions when performing procedures.
Gumodoka et al. [139]	1997	Injuries and use of personal protective equipment (PPE) to protect from HIV	United Republic of Tanzania	403 healthcare workers from nine hospitals in the Mwanza region	Mixed methods	Questionnaires on the use of PPE and needlestick injuries and splashes. Observations and interviews were carried out in different sections of the hospitals to determine general hygiene practices.	Prick and splash incidents were reported frequently (at least 5 pinprick accidents and nine splashes per healthcare worker per year). The general hygiene measures to reduce the risk of HIV was not sufficient and PPE was not used consistently.
Khuri-Bulos et al. [140]	1997	Needlestick and sharp injuries	Jordan	248 healthcare workers working in a tertiary care hospital	Prospective	Surveillance of sharps injuries over a 3-year period. Healthcare workers who reported sharps injuries during this period completed a questionnaire. Serum samples were collected at baseline and 6 months later to be tested for Hepatitis B, C and HIV.	Over the 3-year period, 248 healthcare workers reported needlestick injuries. Highest frequencies were reported by nurses (34.6%). The total average annual rate was 82:1000 healthcare workers per year. Only a minority of healthcare workers submitted a serum sample.
Gounden and Moodley [141]	2000	Injuries and use of personal protective equipment to protect from HIV	South Africa	265 healthcare workers from a tertiary care hospital	Mix of retrospective and prospective	Healthcare workers were interviewed over a period of one year	13% reported accidental injuries with HIV positive patients. The highest frequencies of injuries were among registrars. Compliance with universal precautions was suboptimal. 48% of the participants on post exposure prophylaxis (PEP) did not complete their regimen; the side effects of PEP was reported as the main reason for discontinuation.

Phipps et al. [142]	2002	Needlestick injuries; and knowledge, attitudes and practices	China	441 nurses working in 3 tertiary care hospitals in Hunan Province	Cross-sectional	Questionnaire on needlestick injuries in the past year, Hepatitis B knowledge and immunization status, and work practices	82% of the nurses reported experiencing a needlestick injury in the past year. These injuries occurred most frequently when separating a needle and syringe, recapping a needle, transporting needles for disposal, and giving injections. Only 8% reported the injuries to an authority. The majority never wore gloves when drawing blood, giving an injection or starting an intravenous line. 29% were not vaccinated against Hepatitis B.
Talaat et al. [143]	2003	Needlestick injuries and Hepatitis B vaccination status	Egypt	1485 healthcare workers from health facilities in 2 governorates (Nile Delta and Upper Egypt)	Cross-sectional	Questionnaire on needle-stick injuries and Hepatitis B vaccination status	36.6% reported at least one needlestick injury in the past 3 months. Two-hand recapping was the most common behaviour associated with needlestick injury. 15.8% reported being fully vaccinated against Hepatitis B; vaccination rates were lowest among housekeeping personnel
Kermode et al. [144]	2005	Needlestick injuries	India	266 healthcare workers from 7 rural health settings (hospitals with attached community health projects) in north India	Cross-sectional	Questionnaire on needlestick or sharps injuries in the past week, past year, and over the working lifetime	63% reported at least 1 needlestick injury in the last year and 73% over their working lifetime. Doctors and nurses were more likely to be exposed than student nurses and laboratory workers.
Kermode et al. [145]	2005	Compliance with Universal precautions (UP)	India	266 healthcare workers from 7 rural health settings (hospitals with attached community health projects) in north India	Cross-sectional	Questionnaire on 12 behaviours related to the practice of UP	Compliance with UP was not optimal. Compliance with UP was associated with being in the job for a longer period, knowledge of bloodborne pathogen transmission, perceiving fewer barriers to safe practice and strong commitment to workplace safety climate
Nsubuga and Jaakkola [146]	2005	Needlestick and sharps injuries and risk factors	Uganda	526 midwives and nurses in a tertiary care hospital in Kampala	Cross-sectional	Questionnaire on needlestick injuries and risk factors	57% reported a needlestick injury in the last year and 82% in their entire career. The risk factors identified were lack of training, working for more than 40h/week, recapping needles, and not using gloves when handling needles. Lack of training was the strongest predictor.

Obi et al. [147]	2005	Needlestick injuries and splashes, and use of personal protective equipment (PPE)	Nigeria	264 surgeons from five tertiary health institutions in Southeast Nigeria	Cross-sectional	Questionnaire on needlestick injuries and splashes in the last 5 years, use of PPE, and attitudes towards care of HIV-infected patients	40.2% reported a needlestick injury and 26% reported blood splashes in the past five years. The highest frequencies were reported in resident surgeons. All wore protective aprons, 65.2% used double gloves and 30.3% used goggles during surgical procedures. 83% had some reservations about treating HIV-positive patients
Chelenyane and Endacott [148]	2006	Infection control practices	Botswana	22 healthcare workers from two referral hospitals emergency departments	Mixed methods	Questionnaire with multiple choice and open ended questions	Majority of participants reported compliance with universal precautions. Barriers to compliance were lack of appropriate facilities, shortage of equipment and materials, inadequate staffing, and lack of training programs.
Akinleye and Omokhodion [149]	2008	Needlestick injuries and work practices	Nigeria	270 primary healthcare workers from two urban and three rural local government areas	Cross-sectional	Questionnaire on needlestick injuries in the past year and work practices	32% reported a needlestick injury in the past year. Compliance with the use of gloves and hand washing were greater among rural than urban health workers.
Okeke et al. [150]	2008	Needlestick injuries and Hepatitis B vaccination status	Nigeria	346 medical students in a tertiary institute	Cross-sectional	Questionnaire on needlestick injuries and splashes, and Hepatitis B vaccination status	48% reported a previous needlestick injury and 27.7% reported being vaccinated against Hepatitis B.
Taegtmeyer et al. [151]	2008	Needlestick injuries (NSIs) and safety practices	Kenya	650 healthcare workers from 11 health facilities in Thika District	Prospective	Questionnaires and semi-structured interviews; together with an intervention of introduction of biosafety measures, vaccination, and post-exposure prophylaxis (PEP). Surveys were conducted at baseline and at one year.	The incidence of NSIs was 0.97 per healthcare worker per year. After the institution of biosafety measures, there was a significant reduction in injuries, an increase in the healthcare workers accessing HIV testing and in the uptake of hepatitis B vaccination uptake, but the uptake of PEP was low.

Chen et al. [152]	2009	Sharp object injuries	China	831 healthcare workers from 9 hospitals in Fujian, who worked in departments with a high risk of occupational exposures to blood.	Cross-sectional	Questionnaire on sharp object injuries in the past year	86.2% of the healthcare workers reported a sharps injury on the job and 71.3% said that it had occurred in the past year. Nurses reported the highest frequencies of injuries, followed by surgeons, anaesthetists, and laboratory workers. Disposable syringes caused most of the injuries.
Simon [153]	2009	Needlestick injuries	India	50 nurses in a super-speciality tertiary care hospital in Delhi	Cross-sectional	Questionnaire on needle-stick injuries, and knowledge and practices on needlestick injuries	70% had sustained a needlestick injury during their career, and of these the majority (71%) did not report it. There was a lack of awareness on prevention and management of NSIs.
Chakravarthy et al. [154]	2010	Sharps injuries, and blood and body fluid exposure incidents	India	265 healthcare workers who reported sharps injuries and accidental blood and body fluid exposures to the Infection Control committee of 4 tertiary referral hospitals	Retrospective review of data from sharp injury, and blood and body fluid exposure reports	Data were obtained from sharps injuries, and blood and body fluid exposures reports that were reported to the Infection Control Committees of the 4 hospitals. Data collection period ranged from 6 to 26 months.	243 sharps injuries and 22 incidents of blood and body fluids exposures were reported in the cumulated 50 months of study. The highest frequencies of injuries were reported by nurses and housekeeping staff. The majority of the injuries were caused by disposable needles.
Yacoub et al. [155]	2010	Needlestick injuries and Hepatitis B vaccination status	Syria	321 healthcare workers from three tertiary care hospitals in Aleppo	Cross-sectional	Questionnaire on needle-stick injuries and Hepatitis B vaccination status. Blood was collected to test for Hepatitis B (HBsAg)	76.6% reported at least one needlestick injury in the past year. Anaesthesiology technicians, doctors, nurses, and housekeeping had the greatest exposure risks. 56.1% reported being fully vaccinated against Hepatitis B; vaccination rates were lowest among housekeeping personnel. 2.8% tested positive for HBsAg.
Sangwan et al. [156]	2011	Needlestick injuries and splashes	India	70 healthcare workers in a tertiary care hospital	Cross-sectional	Questionnaire on needlestick injuries and splashes in the past year, and reasons for not using PPE	71.43% reported a needlestick injury in the past year. The most frequent reasons for not using PPE were in emergencies and other co-workers not using them. Only 34% reported that adequate PPE was always provided.

Irmak [157]	2012	Needlestick and sharps injuries	Turkey	143 nurses working patient care in a state hospital	Cross-sectional	Questionnaire on needl stick and sharps injuries in the past year	30.1% of the nurses reported at least one sharp object injury in the past year. The use of syringe needles was the most common cause of injury. 16.3% of the nurses were not wearing gloves when they sustained the injury.
Nasim et al. [158]	2012	Safe work practices and use of personal protective equipment	Pakistan	1782 laboratory technicians from public sector hospitals and private hospital laboratories throughout Pakistan	Cross-sectional	Questionnaire on safe and unsafe work practices, and the use of personal protective equipment	31.9% did not use any kind of personal protective equipment, 46% reported reusing syringes, 43.2% regularly recapped needles after use, 67.2% said that standard operating procedures were not available, and 84.2% had no formal biosafety training.
Omorogbe et al. [159]	2012	Injection safety practices and use of PPE	Nigeria	122 nurses from 6 mission hospitals in Benin city	Cross-sectional	Questionnaire adapted from the WHO injection safety assessment tool and observation of practices	55.8% reported recapping of needles and only 3.3% said that they regularly used gloves when giving injections.
Phillips et al. [160]	2012	Needlestick and sharps injuries	Zambia	442 healthcare workers from five health facilities in Lusaka and Livingstone	Cross-sectional	Questionnaire on needlestick and sharps injuries in the past year	The annual average sharps injury rate was 1.3 injuries/worker. The highest frequencies were reported by nurses and service workers. Syringe needles accounted for the majority of the injuries. 88% reported the availability of PPE, but only 8% were fully vaccinated against Hepatitis B.
Sethi et al. [161]	2012	Compliance with infection control practices	Uganda	183 healthcare workers from a referral hospital in Kampala	Cross-sectional	Questionnaire on hand hygiene, barrier protection, and contact precautions	68.9% reported using gloves as barrier protection. Universal precautions were not always followed. The reasons for suboptimal infection control practices were lack of time and lack of resources.
Abkar et al. [162]	2013	Unsafe injection practices	Yemen	127 healthcare workers from two hospitals and 6 rural health centres	Cross-sectional	Questionnaire and observation of injection practices	There were several unsafe practices, particularly the recapping of needles after use, which occurred in 61.1% and 36.8% of the observations in the hospitals and health centres, respectively.

Afridi et al. [163]	2013	Needlestick injuries, Hepatitis B vaccination status and infection control measures	Pakistan	497 healthcare workers from two tertiary care hospitals in Karachi	Cross-sectional	Questionnaire on needlestick injuries, Hepatitis B vaccination status and infection control measures	64% reported needlestick injuries during their career. Working for more than 5 years and working as a nurse were the factors associated with an increased risks. Injecting medicine, drawing blood, and two hand recapping of needles were the practices associated with needlestick injuries. 34% reported being vaccinated against Hepatitis B. Infection control measures were inadequate.
Rajkumari et al. [164]	2014	Needlestick injuries and splashes	India	356 healthcare workers who reported sharps injuries and splashes in a tertiary hospital in New Delhi	Prospective	Surveillance of sharps injuries over a 2 years 5 months period. Healthcare workers who reported sharps injuries during this period completed a questionnaire. Blood samples were collected at baseline and 6 months later to be tested for Hepatitis B, C and HIV.	Highest frequencies of sharps injuries were reported by doctors (36.2%), followed by nurses (14.6%) and hospital waste disposal staff (7.6%). There was no seroconversion among the exposed healthcare workers. The majority (85.1%) of the injuries reported were from sharps (as compared to splashes). Only 55.3% were using PPE during the time of exposure.
Bekele et al. [165]	2015	Needle-stick injury reporting and attitudes	Ethiopia	340 healthcare workers from four hospitals of Bale zone	Cross-sectional	Questionnaire on needle-stick injury reporting and attitudes	98.2% were aware of the risks of needle-stick injuries.58.7% of needle-stick injuries were not reported. The main reasons for not reporting were time constraints, sharps that caused the injury were not used by patients, the source patient did not have diseases of concern, and lack of knowledge of reporting.
Priya et al. [166]	2015	Needlestick injuries and splashes	India	105 healthcare workers who reported sharps injuries and accidental blood and body fluid exposures to the Anti-retroviral therapy centre of a tertiary care hospital	Retrospective review of data from sharp injury, and blood and body fluid exposure reports	Three years data were obtained from sharps injuries, and blood and body fluid exposures reports that were reported to the Anti-retroviral therapy centre of a tertiary care hospital	105 healthcare workers reported an occupational exposure to blood and body fluids. The highest frequencies were reported by interns. Needlestick injuries were the commonest type of exposure (85%), followed by mucous membrane splash (13%) and exposure on intact skin (2%). The practices that resulted in exposures were blood withdrawal (45.7%), during surgical procedures (24.7%) and disposal of sharps (23%).

Sabermoghaddam et al. [167]	2015	Needlestick injuries and splashes	Iran	371 healthcare workers from 6 government hospitals in the Northern Khorasan province	Cross-sectional	Questionnaire on needle-stick injuries and splashes in the past year	44% reported a sharp object injury and 31% reported contact with blood and body fluids in the past year. 91% reported always using a safety box to deposit used needles, 35.9% reported washing their hands before and after examining patients, 41.5% reported using gloves, 58% had attended training on safe handling of sharps. 52% of those who were injured did not report the injury.
Türe et al. [168]	2016	Needlestick injuries and splashes, and risk factors	Turkey	166 healthcare workers who reported sharps injuries and accidental blood and body fluid exposures to the Infection Control committee of a tertiary care hospital	Retrospective review of data from sharp injuries, and blood and body fluid exposure reports	Data were obtained from sharps injuries, and blood and body fluid exposure reports that were reported to the Infection Control Committee. Data collection period was from August 2011 to June 2013.	166 healthcare workers reported an occupational exposure to blood and body fluids. The occupational exposure incidence was 2.18 exposures/person-year. The highest frequencies of injuries were reported by nurses and cleaning staff. Having heavy workloads and long working hours increased the risk of exposures whereas increased work experience decreased the risk of exposures.
Konlan et al. [169]	2017	Hepatitis B vaccination status and practices to reduce occupational exposures	Ghana	108 nurses from two hospitals within the Tamale metropolis	Cross-sectional	Questionnaire on Hepatitis B vaccination status and practices to reduce occupational exposures to Hepatitis B	64.8% said that they reported occupational exposures to Hepatitis B. 33.3% reported receiving 3 doses of Hepatitis B vaccination. Compliance with precautions to reduce occupational exposures was suboptimal.
Matsubara et al. [170]	2017	Needlestick and sharps injuries and risk factors	Lao PDR	623 healthcare workers from 4 tertiary care hospitals in Vientiane Capital	Cross-sectional	Questionnaire on needlestick injuries over their entire career, and in the past 6 months, and injection practices based on the World Health Organization questionnaire on injection practices.	11.4% reported a needlestick injury in the past 6 months and 42.1% in their entire career. The highest frequencies were reported by surgeons, dentists and cleaners. The injuries were caused by percutaneous injections (17.9%), suturing needles (17.0%), intravenous line insertion (17.0%) , recapping needles (13.2%) , disposal (10.4%), and others (24.5%). Protective factors for needlestick injuries identified were adequate availability of needles and syringes, and adequate training.

Geberemariyam et al. [171]	2018	Needlestick injures and infection control practices	Ethiopia	648 health care workers with direct involvement in patient care in public healthcare facilities in one district	Cross-sectional	Questionnaire on needlestick injuries and infection control practices	Only 36.3% reported safe infection prevention practices. Life-time prevalence of needlesticks and blood or body fluid exposure 32.4% and 39.0%, respectively, with 24.8% of them having >1 injuries. Exposures occurred mostly during intravenous catheter insertion, suturing, and recapping of needles. Factors associated with better infection control practices were profession, service years, presence of infection prevention committee and guideline, and ever taking training.
Mandić et al. [172]	2018	Needlestick injuries and splashes	Serbia	5247 healthcare workers who routinely worked with blood from 17 general hospitals in Serbia	Cross-sectional	Questionnaire on needl stick injuries and splashes over their entire career and in the last year	39% reported an exposure to blood and body fluids in the past year and 66% over their entire career. The prevalence of needlestick injuries occurring in the last year was equal among genders, but it was more prevalent in women during the entire career. The highest frequencies were reported in nurses.
Hebo et al. [173]	2019	Exposure to blood and body fluids, practices of standard precautions and seroprevalance of Hepatitis B and C	Ethiopia	240 healthcare workers from Jimma University Medical Center	Cross-sectional	Questionnaires on exposure to blood and body fluids and use of standard precautions. Blood was collected and tested for Hepatitis B and C	60% reported being ever exposed and 43% reported exposure in the past year to blood and body fluids through accidental splashes and sharps injuries. 2.5% of the samples was positive for HBsAg and 0.42% for anti-HCV antibodies. Only 42.6% had good practices of standard precautions.
II. Tuberculosis (TB)							
Lien et al. [174]	2009	Prevalence of latent TB and risk factors	Vietnam	150 healthcare workers from a TB hospital and 150 from a non-TB hospital in Hanoi	Cross-sectional	Questionnaire on occupational history; Interferon-gamma release assay (IGRA), QuantiFERON-TB Gold In-Tube assay and one-and two-step Tuberculin skin tests (TSTs) for TB infection	Prevalence of TB infection was 47.3%, 61.1% and 66.3% as estimated by IGRA, one- and two-step TST, respectively. Working in a TB hospital, increasing age, lower education levels, and higher body mass index were associated with increased risk of IGRA positivity.

Mathew et al. [175]	2013	TB among healthcare workers	India	101 healthcare workers with TB (cases) and 101 without TB in a tertiary care hospital in Vellore	Nested case-control	Questionnaire on occupational history and non-occupational exposure to TB	Rate of active pulmonary TB was 314 per 100,000 person-years, which was 1.86 times higher than that of the general population. Body mass index < 19kg/m2, having frequent contact with patients, and working in the medical wards or microbiology laboratories were independently associated with increased risk of TB
Wei et al. [176]	2013	Prevalence of latent TB infection (LTBI)	China	210 healthcare workers in a chest hospital in Harbin	Prospective	Questionnaire on occupational history; participants were tested with two Interferon-gamma release assays (QuantiFERON-TB Gold In-Tube assay (GFT-GIT) and A.TB) and TST. Participants were observed for 2 years to check for the development of active tuberculosis.	Prevalence of LTBI was 76.5% by QFT-GIT, 65.7% by A.TB and 97.6% by TST, which was higher than that reported in the general population. Working as a nurse and age >30 years were independently associated with increased risk of LTBI.
Whitaker et al. [177]	2013	Prevalence and risk of latent TB infection (LTBI)	Georgia	319 healthcare workers in Georgia.	Prospective longitudinal	Questionnaire, and tests for LTBI using the TST and QuantiFERON-TB gold In-tube Assay (QFT-GIT). The tests were repeated 6-26 months after baseline	Prevalence at baseline was 67% by TST and 46% by QFT-GIT. Healthcare workers (HCWs) working in TB healthcare facilities had a higher prevalence of positive TST and QTF-GIT. Frequent contact with TB patients was associated with increased risk of QTF-GIT positivity only and increasing age was associated with increased risk of positivity of both tests. The conversions rates were high at 22.8/100 person-years (QTF-GIT) and 17.1/100 person-years (TST). Female HCWs had a decreased risk of TST conversion and older HCWs had an increased risk of QTF-GIT conversion

Tudor et al. [178]	2014	TB incidence and risk factors	South Africa	1313 healthcare workers from 3 district hospitals in KwaZulu-Natal	Retrospective	Occupational health medical records of 1313 healthcare workers were reviewed during the period of January 2006 and December 2010	The TB incidence rate was 1958/100,000 person-years, which was two-fold greater than in the general population. An increased incidence of TB was seen in those working in TB wards, paediatric wards, outpatient departments and stores/workshops. Healthcare workers living with HIV had a greater incidence of TB.
El-Sokkary et al. [179]	2015	Latent TB infection (LTBI) prevalence and risk factors	Egypt	132 healthcare workers from a chest Hospital in Zagazig city	Cross-sectional	Questionnaire and tests for LTBI using the TST and QuantiFERON-TB gold In-tube Assay (QFT-GIT).	Prevalence was 28.8% by QFT-GIT and 59.1% by TST. Being a nurse, working >10 years, smoking and diabetes were significantly associated with risk of LTBI
Tudor et al. [180]	2016	Occupational risk factors for TB	South Africa	145 healthcare workers (54 cases, 91 controls) from 3 district hospitals in KwaZulu-Natal	Case control	Cases were identified from the occupational health medical records between January 2006 and December 2010.	Healthcare workers with HIV and those who spent time working in areas with tuberculosis patients were at an increased risk of TB.
He et al. [181]	2017	Pulmonary tuberculosis status among healthcare workers as diagnosed with low-dose CT	China	1012 healthcare workers from the Beijing Chest Hospital	Retrospective	Health examination data of 1012 healthcare workers which included low-dose lung CT examinations from January 2012 to November 2015 were analysed	The incidence and prevalence rates of active TB were >2.8 times and >4.1 times greater than that of the general population of China. The majority (78.9%) of the healthcare workers with active TB worked in high-risk areas such as TB wards, outpatient clinics and radiology departments.
Erawati and Andriany [182]	2020	Latent TB infection (LTBI) prevalence and risk factors	Indonesia	195 healthcare workers from 34 primary health centres in Semarang	Cross-sectional	Questionnaire and tests for LTBI using QuantiFERON-TB gold In-tube Assay (QFT-GIT)	Prevalence of LTBI was 23.6%. Healthcare workers with comorbidities were at increased risk of LTBI

Notes: HIV- Human Immunodeficiency Virus, AIDS- Acquired Immunodeficiency Syndrome, HBV- Hepatitis B Virus, HCV- Hepatitis C Virus, PPE- Personal Protective Equipment, PEP- Post-exposure Prophylaxis, UP- Universal Precautions, NSI- NeedleStick Injury, HBsAg- Hepatitis B surface Antigen, TB- Tuberculosis, IGRA-Interferon-gamma Release Assays, TST- Tuberculin Skin Test, LTBI- Latent Tuberculosis Infection

Mixed methods studies refers to studies with qualitative and quantitative components.

Table 3.3 The characteristics of the studies (n=22) on exposure to psychosocial hazards (arranged in chronological order according to the year of publication).

Authors	Year	Topic	Origin	Participants	Type of study	Methods	Findings
I. Workplace violence							
Kisa et al. [183]	2002	Sexual harassment and work productivity	Turkey	215 nurses from two hospitals in Turkey	Cross-sectional	Questionnaires on sexual harassment and work performance	73% reported being sexually harassed. The main perpetrators were physicians and patients, and these incidents occurred more commonly in the in-patient clinics. 45% reported a decline in work productivity following the incidents.
Kamchuchat et al. [184]	2008	Workplace violence	Thailand	545 nurses working in a general hospital in southern Thailand	Mixed methods	Questionnaire modified from one developed by the Joint Program on Workplace Violence in the Health Sector and key informant interviews (n=17)	The 12-month prevalence was 38.9% for verbal abuse, 3.1% for physical abuse and 0.7% for sexual harassment. The main perpetrators of verbal and physical abuse were patients and their family, while co-workers were the main perpetrators for sexual harassment. Younger age and working in high-risk areas (out-patient unit, emergency units, operating theatre, medical and surgical units) were associated with an increased risk of violence.
Aydin et al. [185]	2009	Workplace violence	Turkey	522 general practitioners from 48 cities	Cross-sectional	Questionnaire on workplace violence	82.2% reported experiencing violence at work. Verbal abuse was the most common (89.3%), followed by physical violence (7.9%), economic (1.7%) and sexual violence (1.1%). Verbal and sexual violence was more common in women and physical and economic violence more common in men. Patients and their relatives was the most common source (91.1%).
Gimeno et al. [186]	2010	Prevalence of verbal abuse and its association with safety climate at work	Costa Rica	625 healthcare workers working in 10 public hospitals in Costa Rica	Cross-sectional	Questionnaires on safety climate and verbal abuse	83.9% of the participants reported low safety climate levels. Prevalence of verbal abuse from all sources was 78.2%, with the most common being abuse from co-workers and patients. The odds of experiencing verbal abused increased with lower levels of safety climate.

Atan et al. [187]	2012	Workplace violence	Turkey	441 nurses from 6 university hospitals	Cross-sectional	Questionnaires on workplace violence in the past year	60.8% reported some form of workplace violence, 59.4% verbal violence and 16.6% physical violence. The sources for verbal violence were patients (47.4%), visitors (39.5%), and health staff (10.7%) and for physical violence were patients (14.3%), visitors (5.0%) and health staff (0.5%). Of those who experienced violence, 42.9% reported a negative impact on their physical and/or psychological health and 42.9% reported a negative impact on work performance.
Khademloo et al. [188]	2013	Prevalence of physical and verbal abuse	Iran	271 nurses from 5 hospitals in the north of Iran	Cross-sectional	Questionnaire on physical and verbal abuse experienced in the last year (Staff Observation Scale Revised (SOAS-R))	95.9% reported verbal abuse; the sources were patients (30.3%), family members (53.4%), and co-workers (16.1%). 29.1% reported physical abuse; the sources were patients (44.3%) and family members (55.6%).
da Silva et al. [189]	2015	Workplace violence and its association with depression	Brazil	2940 primary healthcare workers from 66 health centres in Sao Paolo	Cross-sectional	Questionnaire on workplace violence (adapted from a WHO questionnaire on domestic violence), and depression and depressive symptoms (Brazilian version of the nine-item Patient Health Questionnaire)	The frequencies of violence experienced at work were: insults (44.9 %), witnessing violence (29.5 %), threats (24.8 %), and physical aggression (2.3 %). Exposure to violence was positively associated with depressive symptoms and probable major depression.
Baig et al. [190]	2018	Prevalence of workplace violence	Pakistan	822 healthcare workers from hospitals, nongovernment organizations and ambulance services in Karachi	Mixed methods	Questionnaires on workplace violence; and 42 in-depth interviews and 17 focus group discussions	33.5% had experienced violence in the past year. Verbal violence was more common (30.5%) than physical violence (14.6%). The main source was from people who accompanied patients (58.1%). The main perceived causes of violence were failure to meet the expectations of patients, communication gaps, poor quality of services, inadequate security in facilities, heavy workloads, and lack of training to respond to violence.

Zhao et al. [191]	2018	Prevalence of workplace violence and association with mental health	China	886 nurses from 8 tertiary hospitals in Heilongjiang Province	Cross-sectional	Questionnaires on workplace violence (Workplace Violence Scale), anxiety (Self-rating Anxiety Scale) and depression (Self-rating Depression Scale).	67.2% reported workplace violence. Workplace violence was positively associated with anxiety and depression. Service years played a moderating role in the relationship between workplace violence and anxiety, and gender played a moderating role in the association between workplace violence and depression.
Abate et al. [192]	2019	Workplace violence and associated factors	Ethiopia	435 healthcare workers from a tertiary care mental hospital in Addis Ababa	Cross-sectional	ILO/ICN/WHO/PSI Workplace Violence in the Health Sector Country Case Study Questionnaire.	62.1% reported verbal violence, 36.8% physical violence and 21.8% sexual harassment. Age>31 years and contact with patients were the associated factors
Yenealem et al. [193]	2019	Prevalence and risk factors for violence at work	Ethiopia	531 healthcare workers from Gondar city	Cross-sectional	Questionnaires adapted from the ILO/ICN/WHO/PSI Workplace Violence in the Health Sector Country Case Study Questionnaire.	58.2% reported experiencing some form of violence, of which 53.1% reported verbal abuse, 22% physical attacks, and 7.2% sexual harassment. Working in emergency departments, working in shifts, having less work experience and being a nurse was associated with an increased risk of violence.
Hacer and Ali [194]	2020	Workplace violence and its association with burnout	Turkey	310 physicians from Ordu province	Cross-sectional	Questionnaires on workplace violence and the Maslach Burnout Inventory	93.2% reported experiencing verbal violence, 86.1% psychological violence and 22.6% physical violence. The most common source of violence were patients and their relatives. Emotional exhaustion and depersonalization scores were significantly higher in those who had experienced violence.
II. Burnout							
Ashkar et al. [195]	2009	Prevalence of burnout	Lebanon	155 resident doctors from 2 tertiary care hospitals in Beirut	Cross-sectional	Questionnaires on occupational history and the Maslach Burnout Inventory for Health Service Workers	80% reported high levels of burnout in at least one domain. Prevalence according to subscales was: high levels of emotional exhaustion (EE)-67.7%, high depersonalisation (DP) scores-47.1% and low levels of personal accomplishment (PA)-23.9%. Working >80h/week, experiencing a major stress, getting >eight calls per month, and being female increased the risk of burnout

Ayala and Carnero [196]	2013	Demographic and occupational determinants of burnout	Peru	93 nurses working in acute and critical care departments in a referral military hospital in Lima	Cross-sectional	Questionnaires on occupational history and the Maslach Burnout Inventory	Higher emotional exhaustion scores were associated with having children and inversely associated with time working in the current department. Higher depersonalisation scores were associated with being single and working in the emergency room or intensive care unit. Higher personal achievement scores were associated with having children.
Zubairi and Noordin [197]	2016	Prevalence of burnout and risk factors	Pakistan	82 resident doctors working in a university hospital in Karachi	Cross-sectional	Questionnaires on occupational history and the Maslach Burnout Inventory	74.4% reported high levels of burnout on at least one subscale, and 12.2% reported burnout on all the three subscales. Prevalence according to subscales was: high levels of EE-60%, high DP scores-38% and low levels of PA-32%. Workload dissatisfaction, length of working hours, relationship with co-workers and lack of autonomy were associated with an increased risk of burnout
Colindres et al. [198]	2018	Association of psychosocial work environment, burnout and compliance with infection control measures	Ecuador	333 nurses in four acute care facilities in Ecuador	Cross-sectional	Questionnaires on effort-reward imbalance, burnout (Copenhagen Burnout Inventory scale) and infection control compliance (modified Johns Hopkins University School of Hygiene and Public Health Safety Climate Questionnaire)	21% of nurses experienced effort reward imbalance and 35.8% had work-related burnout. 44.2% reported adhering to infection control practices. Increased effort-reward imbalance was associated with an increased risk of burnout. Burnout was independently associated with decreased adherence to infection control practices.
Khan et al. [199]	2019	Job stress and burnout	Pakistan	447 anaesthesiologists from tertiary hospitals in Lahore and Karachi	Cross-sectional	Questionnaires on occupational history and the Maslach Burnout Inventory	39.4% showed moderate to high levels emotional exhaustion, 68.4% moderate to high levels of depersonalization, and 50.3% moderate to high levels of burnout in personal achievements. Working in Lahore, >2 nights on call per week, and>40 h/wk work inside the operating room were associated with burnout.

Mumbwe et al. [200]	2020	Prevalence of burnout	Zambia	160 anaesthesia providers (physicians and non-physicians) in Zambia	Cross-sectional	Questionnaires on occupational history and the Maslach Burnout Inventory	Burnout was seen in 51.3% of participants. Prevalence according to subscales was: high levels of EE-66.3%, high DP scores-45% and low levels of PA-23.8%. Not being a physician and not having the right team to work with were significantly associated with burnout.
III. Work environment and job satisfaction							
Li et al. [201]	2009	Psychosocial work environment and intention to leave	China	3088 nurses from 12 hospitals participated in the baseline study and 1521 in the one-year follow-up study	Longitudinal	Copenhagen Psychosocial Questionnaires	Prevalence of intention to leave was 16.26% at baseline and at one-year follow-up the incidence rate was 14.46%. Increased emotional demand, decreased workplace commitment, decreased meaning of work, and decreased job satisfaction were associated with intention to leave.
Ayamolowo et al. [202]	2013	Work environment and job satisfaction	Nigeria	161 nurses working in public primary healthcare facilities in Ekiti State	Cross-sectional	Questionnaires assessing work environment (adapted from the World Health Professions Alliance checklist on environment for healthcare professionals) and job satisfaction (Minnesota Satisfaction Questionnaire (MSQ)	44% of the nurses perceived their work environment to be of average quality and 31% as high quality. A majority (67.1%) of nurses reported low degrees of job satisfaction. There was a positive correlation between overall work environment and job satisfaction.
Ogunlade and Ogunfowokan. [203]	2014	Nurses' experiences and satisfaction with night shift work	Nigeria	186 nurses who did a roster including night shift in 2 tertiary hospitals in Ile-Ife	Cross-sectional	Questionnaires assessing experiences and satisfaction during night shift work	Overall, 55.4% were fairly satisfied with their night shifts as compared to 1.6% who were very satisfied and 43.0% who were satisfied. Inadequate staffing and equipment for protection from hazards were the factors that contributed to the low satisfaction with night shifts.
Ayalew and Workineh [204]	2019	Job satisfaction and associated factors	Ethiopia	220 nurses from public health facilities in Bahir Dar city	Cross-sectional	Questionnaire on job satisfaction using the Job satisfaction scale and Minnesota Questionnaire	43.6% were satisfied with their job. Advancement, recognition and work security were positively associated with job satisfaction

Note: Mixed methods studies refers to studies with qualitative and quantitative components.

Table 3.4 The characteristics of the studies (n=17) on exposure to ergonomic hazards (arranged in chronological order according to the year of publication).

Authors	Year	Topic	Origin	Participants	Type of study	Methods	Findings
Smith et al. [205]	2004	Musculoskeletal complaints (MSCs) and psychosocial risk factors	China	282 nurses from a tertiary care hospital in Shijiazhuang city	Cross-sectional	Standardized Nordic Questionnaire	Prevalence of MSCs in the past 12 months was 70%. The most common site was the lower back (56%) followed by the neck (45%), shoulder (40%) and upper back (37%). High mental pressure, limited work support and performing boring and tedious tasks were associated with increased risk of MSCs
Tezel [206]	2005	Musculoskeletal complaints (MSCs)	Turkey	120 nurses from 4 hospitals in Ezrurum	Cross-sectional	Standardized Nordic Questionnaire	90% reported at least one MSC in the past 6 months. Low back pain was the most common (69%), followed by neck (54%) and shoulder (46%) pain.
Fabunmi et al. [207]	2008	Prevalence of musculoskeletal disorders (MSD)	Nigeria	214 nurses in a university hospital in Ibadan	Cross-sectional	Standardized Nordic Questionnaire	90.7% reported experiencing MSDs in the past 12 months. Low back pain was the most common (78%). Job inexperience, volume and type of work were the predisposing factors.
de Castro et al. [208]	2009	Work-related injuries and back pain	Philippines	690 nurses from 13 regions of the Philippines who were attending the Philippines Nurses Association annual national convention	Cross-sectional	Questionnaires on work related injuries/illness, reporting behaviour, and safety concerns	38.6% reported experiencing at least one occupational injury/illness in the past year and 78.2% reported experiencing back pain. Most of the injuries were not reported. The most frequent safety concerns reported were stress and overwork.
Karahan et al. [209]	2009	Prevalence of low back pain and risk factors	Turkey	1600 healthcare workers from 6 hospitals in 4 Turkish cities	Cross-sectional	Questionnaires on back pain and occupational history	61.3% reported at least one occurrence of low back pain within the last 12 months. Age, female gender, smoking, occupation as a nurse, work stress and heavy lifting were associated with increased risks.
Mehrdad et al. [210]	2010	Musculoskeletal symptoms and association with psychosocial factors	Iran	317 nurses from the Emam hospital in Tehran	Cross-sectional	Standardized Nordic Questionnaire and General Nordic questionnaire on psychosocial work environment	95% reported complaints in at least one body site in the past 12 months. Low back was the most common site (73.2%). Higher levels of stress was associated with increased risk of musculoskeletal complaints

Tinubu et al. [211]	2010	Work-related musculoskeletal disorders (WMSDs) and risk factors	Nigeria	128 nurses from 3 hospitals in Ibidan	Cross-sectional	Standardized Nordic Questionnaire	78% reported WMSDs in at least one body site in the past 12 months. WMSDs occurred mostly in low back (44.1%), neck (28.0%), and knees (22.4%). Working in the same position for long periods, lifting/transferring patients, bending or twisting, and handling many patients were the commonest risk factors.
Arsalani et al. [212]	2014	Prevalence of musculoskeletal disorders (MSD) and risk factors	Iran	520 nurses working in 10 university hospitals in Tehran	Cross-sectional	Standardized Nordic Questionnaire and psychosocial working conditions from the Copenhagen Psychosocial Questionnaire	88% reported experiencing MSDs in the past 12 months, with the most common body regions being the lower back (65.3%), knees (56.2%) and neck (49.8%). Physical and psychosocial work demands and low control over their work, which lead to work-related stress, increased the risk of MSDs. Participants also reported inflexible work schedule, poor quality of devices for transferring patients, overexertion and job dissatisfaction.
Barzideh et al. [213]	2014	Prevalence of musculoskeletal disorders (MSD) and risk factors	Iran	385 nurses working in 14 educational hospitals	Cross-sectional	Standardized Nordic questionnaire and Job Content Questionnaire	89.9% reported experiencing MSDs in the last 12 months. Lower back pain was the most common (61.8%). High psychological and physical job demands and low decision latitude were associated with increased risks.
Munabi et al. [214]	2014	Prevalence of musculoskeletal disorders (MSD) and risk factors	Uganda	741 nurses from 5 hospitals in Uganda	Cross-sectional	Questionnaire adapted from the Standardized Nordic and standardized Dutch Musculoskeletal questionnaires	80.8% had experienced MSDs in the last 12 months. Low back pain was the most common (61.9%). Working in a bent or twisted position, mental exhaustion and being absent from work for more than 6 months were associated with an increased risk.
Yasobant and Rajkumar [215]	2014	Work-related musculoskeletal disorders (WMSDs), and risk factors	India	140 healthcare workers from a tertiary care hospital in Chennai	Cross-sectional	Standardized Nordic musculoskeletal questionnaire	50.7% reported symptoms in at least one body site in the past 12 months. Low back was the most common site (45.7%). Working in the same position for long periods, working in awkward and cramped positions, and performing repetitive tasks were the commonest risk factors

Abaraogu et al. [216]	2017	Work-related musculoskeletal disorders (WMSDs) and job stress	Nigeria	126 physiotherapists from hospitals in five states	Cross-sectional	Standardized Nordic musculoskeletal Questionnaire and Job Content Questionnaire	82.1% reported symptoms in at least one body site in the last 12 months. Low back was the most common site (57.8%). There were high levels of stress in most of the job dimensions. However, no specific domains of job stress dimensions were associated with WMSDs.
Amin et al. [217]	2018	Prevalence of self-perceived emotional distress and musculoskeletal disorders (MSD)	Malaysia	376 nurses working in public hospitals in the Klang valley	Cross-sectional	Standardized Nordic musculoskeletal questionnaire and short version of the Depression, Anxiety, and Stress Scale	73.1% had experienced MSDs in the last 12 months and neck was the most common site (48.9%). 75% reported emotional distress. Stress and anxiety were significantly associated with an increased risk of MSDs.
Dlungwane et al. [218]	2018	Low back pain and risk factors	South Africa	242 nurses from a regional hospital in KwaZulu- Natal	Cross-sectional	Questionnaire on back pain and risk factors	The point prevalence of low back pain was 59%. Frequent bending, maintaining prolonged positions and transferring patients were the risk factors
Ike and Olawumi [219]	2018	Back pain and risk factors	Nigeria	228 nurses working in a medical centre in Abeokuta	Cross-sectional	Questionnaire on back pain and risk factors	The point prevalence of back pain was 39%. Maintaining a particular position for long periods and lifting patients were common risk factors
Luan et al. [220]	2018	Prevalence of musculoskeletal disorders (MSD) and risk factors	Vietnam	1179 nurses working in 15 district hospitals in Haiphong	Cross-sectional	Standardized Nordic Questionnaire	74.7% reported symptoms of MSDs in the last 12 months. Low back and neck were the most common sites (44.4% and 44.1%). Age, history of musculoskeletal disease, anxiety and absenteeism in the workplace were risk factors
Dong et al. [221]	2019	Prevalence of musculoskeletal disorders (MSD) and risk factors	China	14,720 healthcare workers from 8 tertiary hospitals in Shandong Province	Cross-sectional	Questionnaire incorporating the Standardized Nordic Musculoskeletal and the Dutch Musculoskeletal Questionnaires	91.2% reported symptoms in at least one body site in the last 12 months. Low back was the most common site (72.8%). MSDs were associated with increased work load, psychological fatigue, mental stress and certain ergonomic factors (bending, twisting)

Table 3.5 The characteristics of the studies (n=11) on exposure to chemical hazards and occupational hazards in general (n=2) (arranged in chronological order according to the year of publication).

Authors	Year	Topic	Origin	Participants	Type of study	Methods	Findings
I. Chemical hazards							
Baykal et al. [222]	2009	Working conditions and safe handling practices of antineoplastic drugs	Turkey	171 nurses who worked in oncology units and administered antineoplastic drugs in nine hospitals in Istanbul	Cross-sectional	Questionnaires on working conditions and safe handling practices of antineoplastic drugs were distributed	94.7% of the nurses reported wearing gloves, 89.5% wore masks, 52.0% wore gowns and 18.7% wore goggles. 40.4% reported preparing drugs in a biological safety cabinet, 37.4% said that they prepared the drugs in the nurses' office and 15.8% said that they prepared the drugs in a room that was also used for other purposes such as meals.
Agrawal et al. [223]	2010	Exposure to latex and latex allergy	India	163 dental professionals working in Udaipur city	Cross-sectional	Questionnaires on latex glove use and symptoms of latex allergy	16% reported allergy symptoms to latex gloves. 81.6% wore gloves for >5 hours a day. The number of years of latex gloves use was significantly associated with allergic symptoms.
Amarasekera et al. [224]	2010	Exposure to latex and latex allergy	Sri-Lanka	325 healthcare workers in a tertiary care hospital	Cross-sectional	Questionnaires latex gloves use and symptoms of latex allergy	16.3% reported latex allergy symptoms. 49.2% wore gloves for >1 hour a day and 44.2% handled other rubber products at work. Longer duration of working as a healthcare worker and using gloves for >1 hour/day were the risk factors associated with allergic symptoms.
Phaswana and Naidoo [225]	2013	Prevalence of latex sensitization and allergy with the use of hypoallergenic powder and lightly powdered latex gloves	South Africa	501 healthcare workers (337 who used latex gloves and 164 administration staff who did not use latex gloves) in a tertiary care hospital in KwaZulu-Natal	Cross-sectional	Questionnaires on latex glove use and symptoms of latex allergy. Skin prick tests were conducted for latex sensitization	Prevalence of latex sensitisation and allergy in exposed workers was 7.1% and 5.9%, respectively; and in unexposed workers it was 3.1% and 1.8%. Work-related allergy symptoms were significantly higher in exposed workers. A dose-response relationship was observed for powdered latex gloves.

Supapvanich et al. [226]	2013	Exposure to latex and latex allergy	Thailand	899 nurses from three hospitals in Thailand	Cross-sectional	Questionnaires on respiratory and dermal symptoms that were attributed to latex gloves use	18% reported symptoms attributable to latex gloves use. Dermal symptoms were more frequently reported, particularly itchy skin and rash. Using >15 pairs of powdered latex gloves/day, using chlorhexidine and being an operating theatre nurse were the risk factors associated dermal symptoms.
Köse et al. [227]	2014	Exposure to latex and latex sensitization	Turkey	1115 healthcare workers from an education and research hospital in Izmir	Cross-sectional	Questionnaires on latex gloves use and symptoms of latex allergy. Blood was tested for latex-specific IgE levels	Prevalence of latex sensitization was 4.2%. Latex allergy was more common in nurses
Supapvanich et al. [228]	2014	Exposure to latex and latex sensitization	Thailand	363 nurses from two tertiary hospitals in Southern Thailand	Cross-sectional	Questionnaires on use of latex gloves and symptoms related to latex use. Latex sensitization was confirmed by detecting anti-latex IgE antibodies using a solid phase immunoassay	The prevalence of latex sensitization was 4.4%. The prevalence of latex sensitization was higher in hospitals where gloves with higher protein levels were used.
Abbasi et al. [229]	2016	Safe handling practices of antineoplastic drugs	Iran	86 nurses who worked in oncology units and administered antineoplastic drugs from six centres of chemotherapy in Shiraz	Cross-sectional	Questionnaires on the safe handling practices were distributed. Observation of work practices were done using a check list	Only about half of the nurses used personal protective equipment (PPE) during the administration of the drugs, and only about 5% used PPE during the administration and disposal of the drugs. Biological safety cabinets were used in all the hospitals and clinics included in the study.
Elshaer [230]	2017	Adherence to control measures used for handling of antineoplastic drugs	Egypt	54 nurses and clinical pharmacists who were exposed to ADs and 54 who were not exposed, working in oncology centres in Alexandria city.	Cross-sectional	Questionnaires on adverse health effects and control measures were distributed. Nurses and clinical pharmacists who were exposed to ADs were compared to those who were not exposed.	Biological safety cabinets and ventilation devices were used by pharmacists but not by nurses. Significantly higher percentages of pharmacists reported safe handling practices and the use of PPE as compared to nurses. There was no medical surveillance program in the workplace.

Alehashem and Baniasadi [231]	2018	Safe-handling practices of antineoplastic drugs and control measures	Iran	14 oncology healthcare workers filled 224 questionnaires in a tertiary care centre	Cross-sectional	7-8 healthcare workers worked in the Oncology ward every day. They filled the questionnaire on safe handling practices for six weeks or 30 working days	20.56% reported carrying out drug preparations without any personal protective equipment. All preparations of antineoplastic drugs were reported to be done in a biological safety cabinet.
Bayraktar-Ekincioglu et al. [232]	2018	Practices and safety measures when handling antineoplastic drugs	Turkey	40 hospital pharmacists who handled chemotherapy from Turkey	Cross-sectional	Questionnaires on chemotherapy drug preparation processes and knowledge on the safety measures	The majority (42.5%) reported using automated chemotherapy units and 30% prepared the drugs manually. The reported practices were not always consistent with published recommendations: use of double glove (63.6%), glasses (62.2%), hair cap (66.7%), foot covers (32.3%), masks (89.1%), coat (92.1%), closed-system drug transfer set (70.6%), and biological safety cabinet (91.7%).
II. Occupational hazards (general)							
Aluko et al. [233]	2016	Compliance with control measures	Nigeria	290 healthcare workers in Osun state	Cross-sectional	Questionnaires on knowledge on occupational hazards and their control practices	Participants were knowledgeable about the various types of occupational hazards (biological, chemical, physical, and ergonomic). Regarding control practices, 96.2 % wore gloves and 77.2 practiced correct body posturing during clinical procedures, 93.8% reported safe disposals, and 62.4% were immunized against Hepatitis B. Only 52.1 % always complied with standard procedures and the main reasons for non-compliance were lack of safety equipment and time constrains.

Tait et al. [234]	2018	Biological, chemical, and physical hazards in medical laboratories	Kenya	204 laboratory workers in 108 medical laboratories in Kajiado county	Cross-sectional	Questionnaires on biological, chemical and physical hazards	65.6% were exposed to 1+ biological hazard, 38.2% handled un-labelled and un-marked chemicals; and 49.5% reported laboratory equipment dangerously placed. There were a large number of other risks. Strong correlations between protective measures within individuals. Control measures reported were occupational health and safety training and supervising staff (98%), proper medical waste containers (92.6%), first aid safety equipment (36.8%), chemical hygiene plans (25%) and chemical hoods (19.1%).

Note: PPE- Personal Protective Equipment

3.5 Discussion

This study aimed to map and synthesize the available research on occupational hazards among healthcare workers in LMICs. The research conducted on this topic is quite substantial as evidenced by the 99 articles included in this review. However, half of these studies were on biological hazards, and research on the other types of hazards was minimal in comparison. The findings of this review also show that research on occupational hazards in LMICs has increased considerably in the last decade, perhaps indicating an increasing recognition of occupational health and safety of healthcare workers in these countries.

3.5.1 Biological hazards

3.5.1.1 Blood-borne pathogens

The majority of the literature on biological hazards was on the occupational transmission of blood-borne pathogens, such as Hepatitis B, HIV, and Hepatitis C, through needle stick/sharps injuries and splash accidents. Healthcare workers from LMICs are at increased risk of transmission of blood-borne pathogens because of the high population prevalence of these diseases and the fact that safety measures to reduce these risks are inadequate.[235]

The prevalence of needle stick injuries was variably reported in the studies included in this review, with some studies reporting prevalence in the past year, some over the entire career and a few reporting it in the past 3 months, 6 months and 5 years. The prevalence of needle stick injuries in the past year was reported in 12 studies and showed a wide variation, ranging from 27% in a study conducted in Nigeria to 82% in a study conducted in China.[137, 142, 144, 146, 149, 152, 155-157, 167, 172, 173] The prevalence of needle stick injuries over the entire career was reported in nine studies and ranged from 32.4% in a study conducted in Ethiopia to 86.2% in a study from China.[144, 146, 152, 153, 163, 170-173] The incidence of needle stick injuries was reported in two studies. A study conducted in Kenya reported an incidence rate of 0.97 needle stick injuries per healthcare worker per year [151] and a study from Turkey reported an incidence of 2.18 exposures/person-years.[168]

Needle stick injuries were more common than accidental splashes,[147, 154, 164, 166, 167] and syringes caused most of the needle stick injuries.[152, 154, 157, 160] The highest frequencies of injuries were reported by nurses, doctors (mainly surgeons and interns), dental personnel, and cleaners.[136, 137, 140, 141, 152, 154, 155, 157, 160, 164, 166, 168, 170, 172] The risk factors for injuries were lack of training, heavy workloads, long working hours, not using gloves, recapping of needles, and using syringes frequently.[146, 152, 157, 160, 168]

Various risk reduction strategies have been recommended to decrease occupational exposures to blood-borne pathogens, such as the use of standard precautions, vaccination against Hepatitis B, and post-exposure prophylaxis (PEP) for Hepatitis B and HIV.[236] Compliance with standard precautions for infection control was suboptimal as reported in a number of studies from various countries.[138, 139, 141, 142, 145, 147, 156-159, 161, 163, 167, 169, 173, 233, 234] Barriers to compliance reported were shortage of equipment, inadequate staffing, and lack of training.[148] Unsafe injection practices such as recapping of needles and reusing syringes were also prevalent.[137, 143, 158, 159, 162, 163] Most of the needle stick injuries were not reported and treated.[142, 153, 165, 167] There were seven studies that reported on Hepatitis B vaccination status. The vaccination status (completed 3 doses of vaccine) was low in most of the studies ranging from 8% to 56.1%,[143, 150, 155, 160, 163, 169] except for a study conducted in China (71%).[142] Among all healthcare workers, vaccination rates were lowest in housekeeping personnel.[143, 155] There were only three studies that examined post-exposure prophylaxis for HIV and these studies reported a low uptake of PEP by healthcare workers and that almost half of those who started PEP discontinued the treatment due to side effects of the drugs.[136, 141, 151] There were no studies reporting the use of HBV immunoglobulin for post-exposure prophylaxis for HBV infection, which could be due to its unavailability in LMICs.[143]

Taken together, the findings of this review show that needle stick and splash injuries are prevalent in LMICs and risk reduction strategies to protect healthcare workers from these infections are suboptimal.

3.5.1.2 Tuberculosis

A systematic review on tuberculosis among healthcare workers in LMICs published in 2006 reported a high occupational risk of tuberculosis, with a latent tuberculosis infection (LTBI) prevalence of 54% (range 33% to 79%), an incidence of 0.5% to14.3% per year, and an attributable risk due to nosocomial exposure from 25 to 5,361 per100,000 per year.[134] As with transmission of blood-borne infections, healthcare workers in LMICs are at an increased risk of exposure to tuberculosis due to high population tuberculosis rates and limited resources to institute control practices.[237] As compared to high-income countries where there are strict infection control practices to protect healthcare workers, even basic infection control strategies to reduce transmission in healthcare facilities in LMICs are lacking and tuberculosis control is mainly focused on case detection and treatment.[237, 238]

This present review included studies conducted after 2006, and found that occupational tuberculosis transmission is still a significant problem in LMICs. The prevalence of LTBI as reported by five studies in this review ranged from 23.6% to 76.5% when assessed using interferon-gamma release assays (IGRAs), and from 59.1% to 97.6% when assessed with Tuberculin skin tests (TSTs).[174, 176, 177, 179, 182] IGRAs are newer tests that use antigens that are more specific and hence are less likely to be affected by previous BCG vaccination status and non-tuberculosis mycobacteria infection, which are the drawbacks of TSTs.[238] In the systematic review, only one study had used IGRAs to detect LTBI prevalence. There was one study in this present review that reported the incidence rates of LTBI test conversion, a prospective study conducted in Georgia from 2009 to 2011, which reported conversion rates of 17.1 per 100 person-years for TST and 22.8 per 100 person years for IGRAs.[177]

There were four studies examining active tuberculosis among healthcare workers in this review.[175, 178, 180, 181] A study conducted in India reported a pulmonary tuberculosis incidence rate of 314 per 100,000 person-years among healthcare workers and that this was 1.86 times higher than that of the general population.[175] Another study conducted in South Africa reported a tuberculosis incidence rate of 1985 per 100,000 person-years among healthcare workers, which was double the incidence of tuberculosis in the general population.[178] A study conducted in China used low-dose lung CT examinations to detect active tuberculosis, and reported that the incidence and prevalence rates of active tuberculosis in healthcare workers were >2.8 times and >4.1 times greater than that of the general population, respectively.[181]

The risk factors for acquiring tuberculosis identified in this review were working in high-risk areas (tuberculosis facilities/wards, medical wards, outpatient departments, microbiology laboratories, radiology departments), belonging to certain occupation groups (nurses, microbiology laboratory technicians, and radiology technicians), working for >10 years, increasing age, and having co-morbidities such as diabetes and HIV.[174-182]

In summary, the prevalence and incidence of LTBI in healthcare workers in LMICs is very high and active tuberculosis among healthcare workers is approximately two times higher than that of the general population.

3.5.2 Psychosocial hazards

3.5.2.1 Workplace violence

The majority of studies on psychosocial hazards in this review was on workplace violence. Workplace violence has been reported as a significant problem in the healthcare sector throughout the world.[5] In this review, the prevalence of experiencing some form of violence in the workplace was high and ranged from 60.8% to 82.2%.[185, 187, 191] The prevalence varied depending on the specific type of violence measured (e.g., physical, verbal, sexual). Verbal abuse was the most common type of violence experienced by healthcare workers, with a prevalence ranging from 30.5% to 95.9%.[184-190, 192-194] The prevalence of physical abuse ranged from 2.3% to 36.8%[184, 185, 187-190, 192-194] and that of sexual harassment ranged from 0.7% to 21.8%.[184, 185, 192, 193] Patients and their families were the most commonly reported perpetrators of verbal and physical abuse, while co-workers and patients were the most commonly reported perpetrators of sexual harassment.[183-188, 190, 194] The risk factors for workplace violence identified in this review were working in certain high-risk areas (out-patient departments, emergency departments, operation theatres and in-patient clinics), lower safety climate levels at work, working in shifts, having heavy workloads and younger age.[183, 184, 186, 190, 193]

Being a victim of workplace violence can result in a range of negative consequences (psychological, physical, emotional, social, work functioning, quality of care, and financial).[239] Five studies included in this review reported on the consequences and associations of workplace violence.[183, 187, 189, 191, 194] Three studies reported on psychological consequences, where exposure to workplace violence was associated with anxiety, depressive symptoms and major depression, and burnout.[189, 191, 194] Two studies reported on work functioning consequences and found that almost half (42.9% and 45%) of the participants who experienced workplace violence reported a decline in work productivity.[183, 187]

3.5.2.2 Burnout

Burnout, as described by Maslach et al,[240] comprises of three dimensions: emotional exhaustion, depersonalization, and low personal accomplishment. Healthcare workers are known to be at an increased risk of burnout due to the inherent nature of their job which exposes them to high levels of emotional and psychological stress.[4] Burnout has been found to be associated with absenteeism, high turnover rates, low morale, and decrease in the quality of care.

Four of the six studies included in this review examined burnout among doctors (residents and anaesthesiologists)[195, 197, 199, 200] and two studies examined it in acute and critical care nurses.[196 198]These studies reported a high prevalence of burnout. The prevalence of high levels of burnout in at least one dimension ranged from 51.3% to 80%.[195, 197, 200] Emotional exhaustion, depersonalization, and low personal accomplishment prevalence ranged from 39.4% to 67.7%, 38% to 68.4%, and 23.8% to 50.3%, respectively.[195, 197, 199, 200] The work-related risk factors for burnout identified in this review were long working hours, experiencing a major stress at work, not having the right team to work with, lack of autonomy at work, and negative psychosocial work environments (as measured by perceived effort-reward imbalance). Personal risk factors were reported by only two studies and these included female gender, being single and having children.[195, 196] Only one study reported on the consequences of burnout and this study found that burnout was independently associated with decreased adherence to infection control practices.[198]

3.5.2.3 Work environment and job satisfaction

Two studies included in this review examined job satisfaction and work environment among nurses and reported that more than fifty percent of the nurses (56.4% to 67.1%) were not satisfied with their jobs and only 31% perceived their work environment to be of high quality.[202, 204] Advancement in the job, recognition, work security and a good work environment were the factors that were reported to be positively associated with job satisfaction. One study examining nurses' satisfaction with night shift work reported that only 43% of these nurses were satisfied with their night shifts, and the factors associated with the low levels of satisfaction were inadequate staffing and inadequate equipment for protection from hazards.[203] A longitudinal study conducted in China examined psychosocial work environment and intention to leave among nurses and reported a 16.3% prevalence of intention to leave and an incidence rate of 14.5%.[201] Increased emotional demands, decreased workplace commitment, decreased meaning of work and decreased job satisfaction were the factors reported to be associated with intention to leave.

The delivery of quality health care depends largely on the quality of staff delivering these services.[241] Satisfied workers are known to be more efficient and productive, thus contributing to the provision of better quality services. Job dissatisfaction, on the other hand, is associated with absenteeism and higher employee turnover rates. Providing a good work environment is a key factor in improving employee job satisfaction, organizational commitment and intention to remain.[124]

In summary, the prevalence of verbal and physical abuse, and burnout were reported as being extremely high in these studies. In addition, satisfaction with work was low. These factors impact on retention of healthcare workers which is particularly important in the context of LMICs since these countries already face a shortage of healthcare workers.[242]

3.5.3 Ergonomic hazards

Musculoskeletal disorders are a common cause for work-related disability and absenteeism, resulting in substantial financial consequences in the form of workers' compensation and medical expenditure.[243] Healthcare worker are at an increased risk of musculoskeletal disorders and there is an extensive body of literature from high-income countries examining these disorders among different occupation groups within the healthcare sector (nurses, surgeons, physical therapists, dentists).[3, 244-246]

The studies on ergonomic hazards included in this review examined prevalence and risk factors of musculoskeletal disorders among healthcare workers. Thirteen studies examined musculoskeletal disorders using the Nordic Musculoskeletal questionnaire, mainly among nurses (10/13 studies),[205-207, 210-217, 220, 221] and four studies examined only low back pain.[208, 209, 218, 219] The prevalence of musculoskeletal complaints in at least one body site in the past twelve months was reported in 12 studies and ranged from 50.7% to 95.0%. The most commonly reported body site for these complaints was the lower back (35.3% to 78.2%). The prevalence reported for the other regions of the body ranged from 28% to 49.8% for the neck, 23.5% to 52.1% for the shoulders, 20.7% to 54% for the upper back and 11% to 68.7% for the knees. There was only one study that examined work-related injuries, in which 38.6% of the nurses in the study reported experiencing at least one work-related injury in the past twelve months.[208]

The occupational physical risk factors for musculoskeletal complaints identified in this review were working in the same position for prolonged periods, working in a bent or twisted position, lifting and transferring patients, handling many patients, and performing repetitive tasks.[211, 214, 215, 221] The occupational psychosocial risk factors for musculoskeletal complaints identified were high levels of stress, anxiety, mental exhaustion, limited support in the workplace, low decision latitude, increased work load, monotonous work, job inexperience, and absenteeism.[205, 207, 210, 213, 217, 220, 221]

In summary, there were few studies of musculoskeletal disorders among LMIC healthcare workers and they found a very high prevalence of musculoskeletal complaints in at least one body site. There was a lack of studies on work-related injuries.

3.5.4 Chemical hazards

The studies on chemical hazards in this review mainly examined exposure to latex and latex allergy. Three studies examined the prevalence of latex allergy symptoms among healthcare workers and reported a prevalence ranging from 16% to 18%.[223, 224, 226] The occupational risk factors for latex allergy reported in these studies were the number of years using latex gloves, using latex gloves for >1hour per day, using >15 pairs of powdered gloves per day, longer duration of working as a healthcare worker, using chlorhexidine and working as an operation theatre nurse. Two studies conducted in Turkey and Thailand examining the prevalence of latex sensitization by measuring latex-specific IgE antibody levels reported a prevalence of 4.2% and 4.4%, respectively, and that the prevalence was higher in hospitals where gloves with higher protein levels were used.[227, 228]

The use of less allergenic alternatives such as powder-free latex gloves and nitrile gloves has been recommended to control latex exposures among healthcare workers.[16] A study conducted in South Africa examined the prevalence of latex allergy and sensitization after the introduction of hypoallergenic powder-free and lightly powdered latex gloves.[225] The prevalence of latex allergy and sensitization reported in this study was 5.9% and 7.1%, respectively. The authors concluded that healthcare workers using hypoallergenic powder-free latex gloves were at risk of developing latex sensitization and recommended that a cost-effective alternative that eliminated latex from the healthcare environment was required in resource-poor countries.

Five studies included in this review examined exposure to antineoplastic drugs, mainly safe handling practices, and reported that adherence to control measures was suboptimal. A study conducted in Egypt reported a lack of medical surveillance programs and training, inadequate handling practices, and low usage of personal protective equipment [230]. Two studies conducted in Turkey found that only about 40% of participants used biological safety cabinets and that personal protective equipment was not used consistently [222, 232]. Two studies conducted in Iran reported that antineoplastic drug handling practices were not always consistent with published recommendations [229, 231].

Few studies have been conducted on the many chemical hazards in healthcare work. The only studies which could be found examined exposure to latex and antineoplastic drugs and there were no studies on other chemicals such as cleaning products, disinfectants and diathermy smoke.

Healthcare workers can also be exposed to physical hazards such as radiation, noise, and slips and falls [16]. However, this review did not identify any studies on exposure to these types of hazards from LMICs.

3.5.5 Implications

This scoping review has revealed that healthcare workers in LMICs are exposed to a wide range of occupational hazards and that risk reduction strategies and safety measures are inadequately implemented, mainly due to equipment and human resource limitations. To protect healthcare workers in these countries, first and foremost, occupational health and safety needs to be prioritised. This requires political commitment from governments to increase investments in occupational health and safety programs. Also, although development and public health agencies have promoted the importance of healthcare workers by including the healthcare workforce as an essential component of sustainable development, these agencies have focussed mainly on increasing the numbers and competency of healthcare workers.[247] There is a need for these agencies to equally address the underlying reasons for healthcare workers' migration, death and illness in LMICs and to advocate for the provision of safer workplaces for healthcare workers in these countries.

It is encouraging that research on occupational hazards among healthcare workers in LMICs has increased considerably in the past decade. However, the majority of the studies in this review were cross-sectional and some of them were of low quality (quality was not an exclusion criteria). In future, larger, more well-designed and prospective studies need to be conducted to make a convincing case for prioritising occupational health and safety of healthcare workers in these countries. In addition, the majority of the studies were on biological hazards and there were very few studies assessing exposure to chemical hazards. This is as expected since the risks from biological hazards are more apparent in LMICs where the population rates of infectious diseases are high. However, healthcare workers are also routinely exposed to chemicals that have been linked to chronic diseases such as cancer and asthma. More research is required in this area from LMICs.

3.5.6 Strengths and limitations of the review

To our knowledge, this review on exposure to occupational hazards among healthcare workers is the most comprehensive to date. It was based on a rigorous, systematic search strategy across five large databases with no date restrictions using strict methodological inclusion criteria.

Although this review has provided an overall synopsis of occupational hazards in healthcare workers in LMICs, there are some limitations to the study. First, the quality of the included studies was not assessed, so the review is inclusive of all articles irrespective of their quality.

Second, only articles published in English were included, which might have resulted in the omission of data published in other languages. Thirdly, there is a possibility that all data may not have been captured by the search strategy, particularly if the articles were published in journals not indexed in Medline. Lastly, this review also excluded night shift work, which is an important occupational risk for healthcare workers. Despite these limitations, this review provides a comprehensive overview of the hazards encountered in the workplace by healthcare workers in LMICs.

3.6 Conclusion

Large proportions of healthcare workers in LMICs are occupationally exposed to a wide range of hazards. Safety measures and risk reduction strategies in these countries are suboptimal, mainly due to resource limitations. Healthcare workers need to be protected from occupational hazards because these hazards have the potential to cause diseases and injuries and can adversely impact the retention of healthcare workers and the quality of care provided. Healthcare worker retention is of particular importance in LMICs since these countries already face a shortage of healthcare workers. Political commitment towards making occupational health and safety a priority public health issue is necessary to ensure the safety of healthcare workers in LMICs. Although research on occupational hazards among healthcare workers in these countries has increased considerably in the last decade, most of this work is on biological hazards. More research is needed on the other types of occupational hazards.

Chapter 4 : Australian Work Exposure Studies

My research included data from three Australian Work Exposure Studies (AWES) that were conducted prior to the commencement of my PhD project. This chapter provides a general overview of the methods of these studies. Further discussion of the research methods with reference to the aims of this PhD project is presented in Chapter 5.

4.1 Introduction

The Australian Work Exposure Studies (AWES) were three population-based cross-sectional telephones surveys conducted in 2011, 2014, and 2016, to determine the prevalence in the Australian working population of work-related exposures to carcinogens (AWES-Cancer), asthmagens (AWES-Asthma) and to noise and ototoxic agents (AWES-Hearing), respectively.[248-250]

In the AWES-Cancer study, exposures were assessed to 38 known or probable carcinogens, which were prioritised based on three criteria: the evidence of carcinogenicity (classified as group 1 or 2A) according to the International Agency for Research in Cancer (IARC), their use in occupational settings, and their use in Australian industries (Table 4.1). In the AWES-Asthma study, exposures were assessed to 27 asthmagen groups that were included from a comprehensive list of asthmagens[251] and based on three criteria: evidence indicating that the agent was an asthmagen, it was used in occupational settings, and was used in workplaces in Australia. In the AWES-Hearing study, in addition to noise, exposures were assessed to 10 ototoxic agents that were prioritised if they were ‘ototoxic’ and ‘possibly ototoxic’ as classified by the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) group,[252] if there was evidence (category 1 and 2) of ototoxicity to humans as classified by the Nordic Expert Group,[253] and if the agent had ‘good evidence’ of ototoxicity according to the EU-OSHA list.[254] There also had to be evidence indicating that the included agents had ototoxic effects at exposure levels near the relevant 8-hour time weighted average occupational exposure limits (TWA OEL) for Australia.

Table 4.1 The list of asthmagens, carcinogens, and ototoxic chemicals assessed in the three AWES studies

Asthmagens	Carcinogens	Ototoxic agents
Cleaning and sterilising agents	Shift work*	Toluene
Latex	Other PAHs[1]	p-xylene
Flowers	ETS[2]	Ethyl benzene
Pesticides	Diesel engine exhaust	n-hexane
Biological enzymes	Wood dust	Carbon monoxide
Bio-aerosols	Leather dust	Styrene
Arthropods	Asbestos	Mercury
Acrylates	Silica	Trichloroethylene
Ammonia	Artificial UV[3]	Lead
Aldehyde	Solar UV[3]	Carbon disulphide
Acids	Ionising radiation Lead	
Agents derived from animals	Radon-222 and its decay products	
Drugs	Acid mists	
Dyes	Acrylamide	
Epoxy	α-chlorinated toluene	
Food	Benzene	
Ethylene oxide	1,3-Butadiene	
Amines	PCB[4]	
Agents derived from fish/shellfish	Nitrosamines	
Isocyanates	Diethyl/ di-methyl sulphate	
Flour	Epichlorhydrin	
Wood	Ethylene oxide	
Agents derived from plants	Formaldehyde	
Solder	Glycidol	
Anhydrides	MbOCA[5]	
Other reactive chemicals	N-nitrosodimethylamine	
Metals	Ortho-toluidine	
	Tetrachloroethylene	
	Trichloroethylene	
	Styrene 7,8-oxide	
	Vinyl Chloride	
	Arsenic	
	Beryllium	
	Cadmium	
	Chromium VI compounds	
	Cobalt	
	Lead	
	Nickel	

*Exposed to any one or more shift work agents (light at night, phase shift, sleep disturbance, diet and chronodisruption, alcohol and chronodisruption, lack of physical activity, and vitamin D insufficiency),[1]Polycyclic Aromatic hydrocarbons; [2]Environmental tobacco smoke; [3]Ultraviolet radiation; [4]Polychlorinated biphenyls; [5]Methylene-bis (2-chloroaniline)

4.2 Study population

Participants were randomly selected from a list of Australian households provided by the same commercial sampling company in the AWES-Cancer and AWES-Asthma studies. Participants selected for the AWES-Cancer study were excluded during the selection of the AWES-Asthma study sample. In the AWES-Hearing study, a separate survey company (Sampleworx) supplied a list of telephone numbers from which the participants were randomly selected.

All Australian residents aged 18 to 64 years (65 years in the AWES-Cancer study) who were currently employed were eligible to participate in the studies. Ineligible participants were those with insufficient ability to speak English, those who were deaf, or those too ill to participate in the telephone interview.

In the AWES-Cancer study, a total of 19,896 households were contacted. There was no response from 2452 households (after 10 call attempts), 10485 households were considered ineligible and there were 1936 refusals. Interviews were completed by 5023 participants. The response fraction (completed interviews/eligible and unknown households) was 53% and the cooperation fraction (completed interviews/eligible households) was 72%.

In the AWES-Asthma study, calls were made to a total of 38,051 phone numbers. There was no response from 10,284 households (after 10 call attempts), 21,429 contacts were considered ineligible and there were 1318 refusals. Interviews were completed with 4878 participants. The response fraction (completed interviews/eligible and unknown households) was 29% and the cooperation fraction (completed interviews/eligible households) was 77%.

In the AWES-Hearing study, calls were made to a total of 128,418 telephone numbers. There was no response from 73,924 households (after 10 call attempts), 48,679 contacts were considered ineligible, 807 refused to participate and 17 had incomplete interviews. Completed interviews were obtained from 4991 participants. The cooperation fraction (completed interviews/eligible households) was 86.1%.

4.3 Data collection

In all the three studies, data were collected using computer-assisted telephone interviews. Verbal consent was obtained from all participants before the commencement of the interviews. Demographic information including gender, age, education, country of birth and residential postcodes were collected. Socioeconomic status and remoteness of residence were determined from the participants' postcodes by applying the Socioeconomic Indexes for Areas disadvantage score[255] and the Accessibility/Remoteness Index of Australia score.[256]

For the AWES-Cancer and AWES-Asthma studies, preliminary information on the participants' current job was first collected to establish whether their occupation corresponded to employment categories that were predetermined to be less likely to result in exposure. In the AWES-Cancer study, these categories were customer service workers, retail workers, white collar and clerical workers who were not required to travel as part of their jobs, carers, psychologists and social workers, correctional services workers, domestic cleaners, takeaway restaurant personnel who did not do cooking, primary school teachers, childcare workers, and high school teachers who did not teach arts, science or technical subjects. In the AWES-Asthma study, these occupations were retail workers not involved in food outlets, clerical workers, customer service personnel, data processors, bank or postal workers, flight attendants and pilots, and correctional service officers. Participants employed in these jobs were considered to be unexposed and the interview was terminated at this point.

For the remaining participants in the AWES-Asthma and AWES-Cancer studies and all participants in the AWES-Hearing study, additional information about their current job was obtained, which included job title, tasks carried out in the job, the industry they were employed in, the hours worked per week and the weeks worked per year. Based on this job information, interviewers assigned participants to one of the 52 job modules in OccIDEAS, which is a computer application that manages interviews and assesses exposures.[122] The job modules were developed individually for specific jobs where exposure to any of the carcinogens, asthmagens and ototoxic agents could occur. If a participant's job did not correspond to any of the 52 modules, a Generic module was assigned to gather information about the common tasks carried out in the job. Interviews were completed within 5 to 20 minutes, depending on the job of the participants and their responses to the questions.

After the data collection was completed, each job was coded according to the Australian and New Zealand Standard Classification of Occupations (ANZSCO).[257] These codes were then classified into 30, 24 and 43 occupational groups in the AWES-Cancer, AWES-Asthma and the AWES-Hearing studies, respectively, containing occupations that were broadly similar in terms of exposure to the relevant agents in each study.

4.4 Exposure assessment

Each job module in OccIDEAS contained questions about the work environment and on specific tasks carried out in the job that had been identified as potential determinants of exposure to carcinogens, asthmagens, and ototoxic agents based on published literature, expert knowledge and material data sheets. Information was also obtained on the frequency of the tasks, method used (e.g. sanding by hand or using a power sander) and the use of control measures (e.g., local exhaust ventilation, gloves, respiratory protection and other protective clothing) where appropriate. Questions were focused on current tasks carried out by the participants, for example, 'Do you clean out ash or scale from a furnace?' and 'Do you polish furniture?'

Based on the responses to the questions, algorithms were applied in OccIDEAS to automatically assign the likelihood of exposures ('probable low/medium/high', 'possible' or 'no' in AWES-Cancer and AWES-Hearing studies, and 'no/possible/probable' in the AWES-Asthma study). The rules in the algorithms are based on expert knowledge, evidence from literature and material data sheets on the determinants of exposure. The automatic assessments were reviewed by the research staff and alterations to the rules were made where appropriate or where indicated. These alterations with the new rules were then applied again to the assessments. All the 'possible' exposures were also reviewed and were categorised as exposed or not exposed using all the available information.

Chapter 5 : The estimated prevalence of exposure to carcinogens, asthmagens, and ototoxic agents among healthcare workers in Australia

This chapter presents the findings of the analyses of healthcare workers' data obtained from the three Australian Work Exposure Studies (AWES) to examine exposure to carcinogens, asthmagens and ototoxic agents.

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It has been published in the final form at: https://onlinelibrary.wiley.com/doi/full/10.1002/ajim.23108. This article may be used for non-commercial purposes in accordance with the Wiley Self-Archiving Policy [http://www.wileyauthors.com/self-archiving].

5.1 Abstract

Background: Healthcare workers are occupationally exposed to various hazardous chemicals and agents that can potentially result in long-term adverse health effects. These exposures have not been comprehensively examined at a population level. The aim of this study was to examine occupational exposures to a wide range of asthmagens, carcinogens, and ototoxic agents among healthcare workers in Australia.

Methods: Data were collected as part of the Australian Work Exposures Studies, which were computer-assisted telephone surveys conducted in 2011, 2014, and 2016 to assess the prevalence of occupational exposures to carcinogens, asthmagens, and ototoxic agents, respectively, among Australian workers. Using data on healthcare workers, prevalence of exposures to these agents were calculated and associations of demographic variables and occupation groups with exposure status were examined.

Results: The prevalence of exposure to at least one asthmagen, carcinogen, and ototoxic agent was 92.3%, 50.7%, and 44.6%, respectively. The most common exposures were to: 1) cleaning and sterilising agents in the asthmagen group; 2) shift work in the carcinogen group; and 3) toluene and p-xylene among ototoxic agents. Exposure varied by occupation, with exposure to carcinogens and ototoxic agents highest among personal carers and exposure to carcinogens most likely among nursing professionals and health and welfare support workers.

Conclusion: The results demonstrate that a substantial proportion of Australian healthcare workers are occupationally exposed to asthmagens, carcinogens, and ototoxic agents. These exposures are more common among certain occupational groups. The information provided by this study will be useful in prioritising and implementing control strategies.

5.2 Introduction

The healthcare environment as a potential source of harm to patients has given rise to the patient safety movement with a heightened public awareness on this topic.[1] However, less apparent are the risks and hazards that this same environment poses for the people who work there. The healthcare environment contains numerous hazardous chemicals similar to those found in 'blue collar' industries.[6] This is quite counter-intuitive since hospitals are often perceived as clean and safe, and this perception may be a reason why chemical hazards in the healthcare environment do not garner as much recognition as other types of hazards (e.g., psychological, biological). In its 2006 report, the World Health Organization estimated that there were 56 million healthcare workers worldwide, comprising 13% of the global workforce.[2] In Australia, the context of this study, the healthcare and social assistance industry has the highest number of employees (n=1,351,015) compared to any other sector, accounting for 12.6% the national working population.[258] With such a large proportion of the workforce being potentially exposed to healthcare workplace hazards, the magnitude of risk is substantial and needs to be addressed.

An excess of certain cancers (e.g., breast and skin cancers) due to occupational exposures has previously been reported in healthcare workers.[8, 259] Work-related or occupational asthma has also been shown to be prevalent among healthcare workers.[260] Various agents used in healthcare settings have been associated with these long-term adverse health effects. Chemicals such as formaldehyde and ethylene oxide, and drugs such as antineoplastic agents, have been linked to certain cancers such as breast, haematological, and nasopharyngeal cancers.[9-11] Several chemicals found in cleaning and disinfecting agents, as well as latex from gloves have shown an association with occupational asthma in healthcare workers.[14, 29] Exposure to ototoxic agents has not been specifically researched among healthcare workers. Although safety standards and programs have been recommended to reduce these hazards, implementation is not universal and exposures remain relatively prevalent.[16] There are not many population-based studies examining the prevalence and circumstances of these exposures among healthcare workers. The few published studies have mainly examined exposures to cleaning and disinfecting agents, and reported a high prevalence of these exposures.[13, 18] The only study conducted in Australia found that 46% of healthcare sector workers reported dermal exposures to chemicals; 33% reported airborne exposures to combustion products, and 21% reported exposure to industrial and medical gases and fumes.[19] However, this study did not examine the circumstances of such exposures and was quite limited in the number of agents investigated. In addition, only the industry as a whole was examined with no information on the occupation groups within the industry.

Using data from three nation-wide surveys conducted in Australia, the main aim of this study is to estimate the prevalence of exposure to asthmagens, carcinogens, and ototoxic agents among healthcare workers and identify the circumstances of such exposures. In addition, the study will also examine the association of demographic variables and occupation groups with these exposures.

5.3 Methods

5.3.1 Study population and data collection

This study uses data that were collected as part of the Australian Work Exposure Studies (AWES). These were three discrete cross-sectional studies conducted in 2011, 2014, and 2016, to examine the prevalence of work-related exposures among the Australian working population to carcinogens (AWES-Cancer), asthmagens (AWES-Asthma), and noise and ototoxic agents (AWES-Hearing), respectively.[248-250] For the AWES-Cancer and AWES-Asthma studies, participants were randomly selected from a list of Australian households supplied by the same commercial sampling firm. For the AWES-Asthma study, the firm was asked to exclude participants who had been selected for the AWES-Cancer study. For the AWES-Hearing study, participants were selected from a randomly generated list of telephone numbers provided by a different sample survey company (Sampleworx). Ethics approval for the original AWES studies and this analysis were obtained from Curtin University Human Research Ethics Committee (HRE2018-0778). Detailed methodologies of the studies have been described elsewhere.[248-250]

In brief, all Australian residents between the ages of 18 to 64 years (to 65 for cancer) who were currently employed and were able to complete a telephone interview in English were eligible to participate. Data were collected using computer-assisted telephone interviews. After a description of the study was provided, participants gave verbal consent before the questionnaire was commenced. Demographic information including age, gender, education level, country of birth, and residential postcodes were collected. Socio-economic status and remoteness of residence were derived from participants' postcodes using the Socio-economic Indexes for Areas disadvantage score[255] and the Accessibility /Remoteness Index of Australia, respectively.[256] Among those with known eligibility, the response rates for the AWES-Asthma, AWES-Cancer and AWES- Hearing studies were 79%, 72%, and 86%, respectively

5.3.2 Exposure assessment

For the studies of carcinogens and asthmagens, basic information on the participants' current job was first obtained to determine whether their occupation corresponded to categories of jobs that were not likely to be exposed to the agents, which was predetermined based on evidence from literature and expert opinion (e.g., retail workers and customer service workers for carcinogens, office and clerical workers for asthmagens). Participants who were employed in these categories were considered as unexposed and the interviews were terminated. For the rest of the participants and for all participants for the study of ototoxic agents, additional information about their current job was collected, including job title, main tasks performed in the job, employing industry, the hours worked in a week, and the weeks worked per year. Using this information, participants were assigned to one of 52 different job modules in OccIDEAS, which is a web-based tool that manages interviews and assesses exposures.[122] Each job module in OccIDEAS contains questions on specific tasks carried out in the job that have been identified as potential exposure determinants to asthmagens, carcinogens and ototoxic agents. Where appropriate, the job modules also included questions on control measures, such as the use of personal protective equipment.

The healthcare workers in this study were assigned job modules for healthcare workers, laboratory workers, cleaners, and office workers. These job modules include questions on various tasks carried out, such as during sterilisation, working in dental and general surgery (e.g., operating diathermy equipment, applying antiseptics, suturing), working in a laboratory (e.g., the use of various reagents and laboratory chemicals), general cleaning tasks, and about shift work. The questions in the job modules for healthcare workers examined exposures to 27 asthmagen groups, 33 carcinogens, and 10 ototoxic agents. Pre-determined algorithms in OccIDEAS were applied to determine the likelihood of exposures (no/possible/probable). The rules in the algorithms are based on occupational hygienists' knowledge of workplace exposures, material data sheets, and evidence from literature on the determinants of exposures.

After the completion of data collection, the participants' job titles were coded according to the Australian and New Zealand Classification of Occupations (ANZSCO).[257] This study includes data for the ANZSCO codes for healthcare workers (i.e., medical practitioners, midwifery and nursing professionals, health therapy professionals, health diagnostic and promotion professionals, medical laboratory scientists, health and welfare support workers, social and welfare professionals, personal carers, managers in health facilities and hospital cleaners: Table 5.1).

Table 5.1 Australian and New Zealand Classification of Occupations (ANZSCO) codes for healthcare workers in the AWES studies

Occupation group	ANZSCO Code	Title
Managers	1342	Health and Welfare Services Managers
	2721	Counsellors
	2723	Psychologists
	2725	Social workers
Diagnostic and promotion professionals	2511	Dietitians
	2512	Medical Imaging Professionals
	2513	Occupational and Environmental Health Professionals
	2514	Optometrists and Orthoptists
	2515	Pharmacists
	2516	Other Health Diagnostic and Promotion Professionals
	2346	Medical Laboratory Scientists
Health therapy professionals	2521	Chiropractors and Osteopaths
	2522	Complementary Health Therapists
	2523	Dental Practitioners
	2524	Occupational Therapists
	2525	Physiotherapists
	2526	Podiatrists
	2527	Speech Professionals and Audiologists
Medical practitioners	2531	Generalist Medical Practitioners
	2532	Anaesthetists
	2533	Internal Medical Specialists
	2534	Psychiatrists
	2535	Surgeons
	2539	Other Medical Practitioners
Midwifery and nursing professionals	2541	Midwives
	2542	Nurse Educators and Researchers
	2543	Nurse Managers
	2544	Registered Nurses
Health and welfare support workers	4111	Ambulance Officers and Paramedics
	4112	Dental Hygienists, Technicians and Therapists
	4113	Diversional Therapists
	4114	Enrolled and Mother-craft Nurses
	4115	Indigenous Health Workers
	4116	Massage Therapists
	4117	Welfare Support Workers
Personal carers	4231	Aged and Disabled Carers
	4232	Dental Assistants
	4233	Nursing Support and Personal Care Workers
	4244	Special Care Workers
Cleaners	8112	Commercial Cleaners
	8113	Domestic Cleaners
	8116	Other Cleaners

5.3.3 Statistical analysis

All analyses were carried out using STATA 14 (StataCorp, College Station. TX). Frequencies were estimated to describe the demographic data. The continuous variable age was categorised into three groups with the cut off at 35 and 50 years using the methods of Abdolell.[261] Prevalence of exposure to each hazard was defined as the proportion of participants exposed to the agent in their current job, regardless of the frequency, duration and level of exposures.

Three dichotomous measures of exposure were used for the regression analysis to indicate whether there was exposure to at least one of the agents from the list of asthmagens, carcinogens and ototoxic agents, respectively. Logistic regressions were conducted and odds ratios (ORs) and 95% confidence intervals (CI) were calculated to examine any associations between demographic variables, occupation groups and exposure status. Frequencies were also estimated to describe the tasks that were associated with the most common agents (i.e., those with the highest prevalence) in each chemical hazard group.

5.4 Results

In total, there were 426 healthcare workers in the AWES-Asthma study, 369 in the AWES-Cancer study, and 531 in the AWES-Hearing study. In all the three samples, a majority of the participants were female, older (more than 34 years of age), born in Australia, had a university degree, lived in cities or inner regional areas, and were midwifery or nursing professionals (Table 5.2).

Table 5.2 Demographic characteristics of the sample of healthcare workers

	AWES Asthma (N=426) n (%)	AWES Cancer (N=369) n (%)	AWES Hearing (N=531) n (%)
Gender			
Male	80 (18.8)	86 (23.3)	130 (24.5)
Female	346 (81.2)	283 (76.7)	401 (75.5)
Age			
18-34	33 (7.7)	49 (13.4)	102 (19.4)
35-50	172 (40.4)	174 (47.5)	198 (37.7)
51+	221 (51.9)	143 (39.1)	225 (42.9)
Country of birth			
Australia	329 (77.2)	269 (72.9)	389 (73.7)
Other	97 (22.8)	100 (27.1)	139 (26.3)
Highest level of education			
High school or less	87 (20.4)	49 (13.3)	34 (6.5)
Trade certificate or diploma	118 (27.8)	94 (25.5)	114 (21.6)
Bachelor degree or higher	220 (51.8)	226 (61.2)	379 (71.9)
State of residence			
New South Wales and Australian	128 (30.1)	128 (34.7)	147 (27.7)
Capital Territory	139 (32.6)	115 (31.2)	166 (31.2)
Victoria and Tasmania	70 (16.4)	61 (16.5)	97 (18.3)
Queensland and Northern Territory	51 (12.0)	37 (10.0)	75 (14.1)
Western Australia	38 (8.9)	28 (7.6)	46 (8.7)
South Australia			
Socioeconomic status			
Highest quintile	77 (18.1)	108 (29.3)	133 (25.2)
Fourth	80 (18.8)	76 (20.6)	119 (22.5)
Third	96 (22.5)	71 (19.2)	114 (21.6)
Second	103 (24.2)	73 (19.8)	95 (18.0)
Lowest	70 (16.4)	41 (11.1)	67 (12.7)
Remoteness			
Major city	192 (45.1)	201 (54.5)	339 (64.2)
Inner regional	194 (45.5)	122 (33.1)	113 (21.4)
Outer regional/Remote/very remote	40 (9.4)	46 (12.4)	76 (14.4)
Occupation group			
Managers	14 (3.3)	16 (4.3)	89 (16.8)
Health diagnostic and promotion	32 (7.5)	28 (7.6)	32 (6.0)
professionals	15 (3.5)	36 (9.8)	54 (10.2)
Health therapy professionals	19 (4.5)	37 (10.1)	47 (8.8)
Medical practitioners	201 (47.2)	123 (33.3)	181 (34.1)
Midwifery and nursing professionals	34 (8.0)	75 (20.3)	37 (7.0)
Health and welfare support workers	96 (22.5)	48 (13.0)	88 (16.6)
Personal carers and assistants	15 (3.5)	6 (1.6)	3 (0.5)
Cleaners			

Among healthcare workers in the AWES-Asthma study, the prevalence of exposure to at least one asthmagen was very high at 92.3% (Table 5.3). These healthcare workers were exposed to 15 different asthmagens with the most common being cleaning and sterilising agents (77.5%) and latex (62.2%). In the AWES-Cancer sample, half of the healthcare workers were exposed to at least one carcinogen (50.7%). These participants were exposed to 10 different carcinogens, of which the most common were exposures to shift work (23.8%) and polycyclic aromatic hydrocarbons (PAHs: 9.8%). Among healthcare workers in the AWES-Hearing study, the prevalence of exposure to at least one ototoxic agent was 44.6% (mainly to low levels of exposure). They were exposed to 7 different ototoxic agents and the most common agents were toluene (41.6%), p-xylene (41.6%), ethyl benzene (39.7%) and n-hexane (39.7%).

Among those healthcare workers exposed to the most common asthmagen group - cleaning and sterilising agents (Table 5.4), the most frequent exposure circumstances were using chlorhexidine as an antiseptic (64.5%) or to clean hands (58.5%), and applying cetalkonium chloride as an antiseptic (28.5%). For exposure to carcinogens in the AWES-Cancer study, since the most common agent of exposure was shift work, the tasks associated with exposure to the next common agent, PAHs, were assessed. The most common task associated with PAHs exposure was operating diathermy equipment (80.6 %). For those healthcare workers exposed to the ototoxic agents, toluene and p-xylene, the common activities resulting in exposure were fuelling petrol vehicles themselves (75.6 %), and driving their vehicles on major (58.8 %) or minor (55.2 %) metropolitan roads.

Table 5.3 Prevalence of probable exposure to asthmagens, carcinogens, and ototoxic agents among health care workers in the three AWES studies*

Asthmagens	Exposed n (%)	Carcinogens	Exposed n (%)	Ototoxic agents	Exposed n (%)
Any asthmagen	393 (92.3)	Any carcinogen	187 (50.7)	Any ototoxic agent	237 (44.6)
Cleaning and sterilising agents	330 (77.5)	Shift work**	88 (23.8)	Toluene	221 (41.6)
Latex	265 (62.2)	Other PAHs[1]	36 (9.8)	p-xylene	221 (41.6)
Flowers	81 (19.0)	Formaldehyde	10 (2.7)	Ethyl benzene	211 (39.7)
Bio-aerosols	57 (13.4)	Benzene	9 (2.5)	n-hexane	211 (39.7)
Arthropods	56 (13.2)	ETS[2]	9 (2.4)	Carbon monoxide	210 (39.6)
Pesticides	51 (12.0)	Diesel engine exhaust	8 (2.2)	Styrene	158 (29.8)
Biological enzymes	45 (10.6)	Ethylene oxide	6 (1.6)	Mercury	9 (1.7)
Acrylates	27 (6.3)	Solar UV[3]	5 (1.4)		
Ammonia	21 (4.9)	Artificial UV[3]	5 (1.4)		
Aldehyde	21 (4.9)	Trichloroethylene	5 (1.4)		
Acids	17 (4.0)				
Agents derived from animals	11 (2.6)				
Drugs	6 (1.4)				
Reactive Dyes	5 (1.2)				
Epoxy	4 (1.0)				

*AWES-Asthma (N=426), AWES-Cancer (N=369). AWES-Hearing (N=531)
**Exposed to any one or more shift work agents (light at night, phase shift, sleep disturbance, diet and chronodisruption, alcohol and chronodisruption, lack of physical activity, and vitamin D insufficiency)
[1]Polycyclic Aromatic hydrocarbons; [2]Environmental tobacco smoke; [3]Ultraviolet radiation.

Table 5.4 Main tasks resulting in exposures to the most common asthmagen, carcinogen, and ototoxic agent among healthcare workers in the three AWES Studies*

	n (%)**
1. Cleaning and sterilising agents (Asthmagens)(number exposed=330)	
Applying chlorhexidine as antiseptic	213 (64.5)
Using chlorhexidine to clean hands	193 (58.5)
Applying cetalkonium chloride as antiseptic	94 (28.5)
Using bleach to clean the workplace	54 (16.4)
Using chlorhexidine to clean the workplace	45 (13.6)
Using chemicals for sterilisation	30 (9.1)
2. Polycyclic aromatic hydrocarbons (Carcinogens)(number exposed=36)	
Operating diathermy equipment	29 (80.6)
Applying coal tar ointment	6 (16.7)
3. Toluene and p-xylene (Ototoxic agents)(number exposed=221)	
Using petrol vehicles and fuelling the vehicles themselves	167 (75.6)
Driving their vehicles on major metropolitan roads	130 (58.8)
Driving their vehicles on minor metropolitan roads	122 (55.2)
Using diesel vehicles and fuelling their vehicles themselves	40 (18.1)

*AWES-Asthma (N=426), AWES-Cancer (N=369). AWES-Hearing (N=531)
**Percentages do not add to 100% because workers could have done more than one task.

Among healthcare workers in the AWES-Asthma study, after adjusting for demographic characteristics and occupation groups, exposure to at least one asthmagen was least common in those residing in South Australia (Table 5.5). Among healthcare workers in the AWES-Cancer study, exposure to at least one carcinogen was least common in older participants; and most common among midwifery and nursing professionals, health and welfare support workers, and personal carers, in the adjusted analyses. In the AWES-Hearing study, exposure to at least one ototoxic agent was least common among those healthcare workers with a vocational or trade certificate; and most common in those residing in inner regional areas, and among personal carers, in the adjusted analyses.

Table 5.5 Odds Ratios (ORs) and 95 % Confidence Intervals (CI) for association between demographic characteristics, occupation groups, and exposure to any asthmagens, carcinogens, and ototoxic agents among healthcare workers in the three AWES studies*

Demographic characteristics and occupational groups	Exposed n (%)			Asthmagens		Carcinogens		Ototoxic agents	
	Asthmagens	Carcinogens	Ototoxic agents	Unadjusted OR (95% CI)	Adjusted OR[1] (95% CI)	Unadjusted OR (95% CI)	Adjusted OR[1] (95% CI)	Unadjusted OR (95% CI)	Adjusted OR[1] (95% CI)
Gender									
Male	75 (93.8)	56 (65.1)	69 (53.1)	1.00	1.00	1.00	1.00	1.00	1.00
Female	318 (91.9)	131 (46.3)	168 (41.9)	0.75 (0.28 to 2.03)	0.63 (0.20 to 1.97)	**0.46 (0.28 to 0.77)**	0.29 (0.16 to 0.53)	**0.64 (0.43 to 0.95)**	0.64 (0.41 to 1.01)
Age									
18-34	31 (93.9)	33 (67.4)	40 (39.2)	1.00	1.00	1.00	1.00	1.00	1.00
35-64	362 (92.1)	152 (48.0)	194 (45.9)	0.75 (0.17 to 3.30)	0.87 (0.17 to 4.37)	**0.45 (0.24 to 0.84)**	**0.39 (0.19 to 0.77)**	1.31 (0.84 to 2.04)	1.31 (0.79 to 2.17)
Country of birth									
Australia	302 (91.8)	135 (50.2)	179 (46.0)	1.00	1.00	1.00	1.00	1.00	1.00
Other	91 (93.8)	52 (52.0)	58 (41.7)	1.36 (0.54 to 3.39)	1.68 (0.60 to 4.73)	1.08 (0.68 to 1.70)	1.11 (0.65 to 1.88)	0.84 (0.57 to 1.24)	0.74 (0.47 to 1.78)
Education									
High school or less	85 (97.7)	17 (34.7)	26 (76.5)	1.00	1.00	1.00	1.00	1.00	1.00
Vocation/trade	110 (93.2)	51 (54.3)	55 (48.3)	0.32 (0.07 to 1.56)	0.39 (0.07 to 2.12)	**2.23 (1.09 to 4.56)**	2.03 (0.89 to 4.63)	**0.29 (0.12 to0.69)**	**0.24 (0.08 to 0.67)**
Bachelor or higher	197 (89.6)	119 (52.7)	156 (41.2)	**0.20 (0.05 to 0.87)**	0.27 (0.05 to 1.41)	**2.09 (1.10 to 4.08)**	2.23 (0.95 to 5.23)	**0.22 (0.09 to 0.49)**	0.35 (0.12 to 1.04)
State of residence									
NSW[2] + ACT[3]	123 (96.1)	69 (53.9)	66 (44.9)	1.00	1.00	1.00	1.00	1.00	1.00
Victoria + Tasmania	125 (89.9)	55 (47.8)	73 (44.0)	0.36 (0.13 to 1.04)	0.26 (0.07 to 2.12)	0.78 (0.47 to 1.30)	0.66 (0.38 to 1.17)	0.96 (0.62 to 1.51)	0.94 (0.57 to 1.55)
Queensland + NT[4]	65 (92.9)	30 (49.2)	38 (39.2)	0.53 (0.15 to 1.89)	0.32 (0.08 to 1.34)	0.83 (0.45 to 1.52)	0.68 (0.34 to 1.38)	0.79 (0.47 to 1.33)	0.82 (0.45 to 1.49)
Western Australia	48 (94.1)	18 (48.7)	41 (54.5)	0.65 (0.15 to 2.83)	0.45 (0.09 to 2.15)	0.81 (0.40 to 1.68)	0.63 (0.27 to 1.44)	1.48 (0.85 to 2.59)	1.51 (0.79 to 2.88)
South Australia	32 (84.2)	15 (53.6)	19 (41.3)	**0.22 (0.06 to 0.76)**	**0.13 (0.03 to 0.60)**	0.99 (0.43 to 2.24)	0.83 (0.34 to 2.00)	0.86 (0.44 to 1.69)	1.01 (0.47 to 2.15)
Socioeconomic status									
Highest quintile	71 (92.2)	54 (50.0)	52 (39.1)	1.00	1.00	1.00	1.00	1.00	1.00
Fourth	71 (88.8)	39 (51.3)	49 (41.2)	0.67 (0.23 to 1.97)	0.66 (0.19 to 2.28)	1.05 (0.59 to 1.90)	1.08 (0.56 to 2.09)	1.09 (0.66 to 1.81)	1.07 (0.62 to 1.86)
Third	92 (95.8)	36 (50.7)	61 (53.5)	1.94 (0.53 to 7.15)	2.41 (0.52 to 11.13)	1.03 (0.59 to 1.87)	0.90 (0.45 to 1.79)	**1.79 (1.08 to 2.98)**	**1.88 (1.02 to 3.44)**
Second	94 (91.3)	38 (52.1)	46 (48.4)	0.88 (0.30 to 2.59)	1.03 (0.29 to 3.71)	1.09 (0.60 to 1.97)	0.70 (0.34 to 1.45)	1.46 (0.85 to 2.49)	1.09 (0.54 to 2.16)
Lowest quintile	65 (92.9)	20 (48.8)	29 (43.3)	1.10 (0.32 to 3.77)	1.28 (0.30 to 5.52)	0.95 (0.46 to 1.95)	0.76 (0.32 to 1.79)	1.19 (0.66 to 2.16)	0.91 (0.44 to 1.91)
Remoteness									
Major city	178 (92.7)	102 (50.8)	135 (39.8)	1.00	1.00	1.00	1.00	1.00	1.00
Inner regional	177 (91.2)	60 (49.2)	64 (56.6)	0.82 (0.39 to 1.71)	0.78 (0.21 to 2.93)	0.94 (0.60 to 1.47)	1.00 (0.56 to 1.78)	**1.97 (1.28 to 3.04)**	**1.99 (1.16 to 3.42)**
Outer regional/Remote/very remote	38 (95.0)	25 (54.4)	38 (50.0)	1.49 (0.33 to 6.85)	1.39 (0.20 to 9.74)	1.15 (0.61 to 2.20)	1.51 (0.67 to 3.37)	1.51 (0.92 to 2.49)	1.34 (0.70 to 2.58)

Occupation group										
Managers	11 (78.6)	5 (31.3)	43 (48.3)	1.00	1.00	1.00	1.00	1.00	1.00
Diagnostic/ promotion	25 (78.1)	14 (50.0)	12 (37.5)	0.97 (0.21 to 4.49)	0.52 (0.09 to 2087)	2.2 (0.61 to 8.00)	2.99 (0.76 to 11.73)	0.64 (0.28 to 1.47)	0.59 (0.25 to 1.41)
Health therapy	12 (80.0)	18 (50.0)	27 (50.0)	1.09 (0.18 to 6.58)	0.87 (0.12 to 6.77)	2.2 (0.63 to 7.63)	3.25 (0.86 to 12.23)	1.07 (0.54 to 2.10)	1.16 (0.56 to 2.37)
Medical practitioners	18 (94.7)	18 (48.7)	23 (48.9)	4.91 (0.45 to 53.27)	2.53 (0.19 to 32.63)	2.08 (0.60 to 7.19)	2.33 (0.63 to 8.66)	1.03 (0.51 to 2.08)	0.85 (0.39 to 1.84)
Midwifery and nursing	190 (94.5)	61 (49.6)	51 (28.2)	**4.71 (1.15 to 19.37)**	4.19 (0.89 to 19.62)	2.16 (0.71 to 6.60)	**4.97 (1.46 to 16.94)**	**0.42 (0.25 to 0.71)**	0.38 (0.22 to 0.66)
Health/ welfare support	29 (85.3)	46 (61.3)	18 (48.7)	1.58 (0.32 to 7.76)	1.03 (0.16 to 6.64)	**3.49 (1.10 to 11.07)**	**8.38 (2.28 to 30.82)**	1.01 (0.47 to 2.18)	1.04 (0.45 to 2.39)
Personal carers	94 (97.9)	25 (52.1)	62 (70.5)	**12.82 (1.93 to 85.28)**	7.39 (0.88 to 62.21)	2.39 (0.72 to 7.93)	**6.84 (1.68 to 27.84)**	**2.55 (1.37 to 4.74)**	**2.75 (1.26 to 6.00)**
Cleaners	14 (93.3)	0 (0.0)	1(33.3)	3.81 (0.35 to 41.96)	1.47 (0.10 to 21.97)	NA[5]	NA[5]	0.53 (0.05 to 6.11)	0.17 (0.01 to 2.26)

*AWES-Asthma (N=426), AWES-Cancer (N=369). AWES-Hearing (N=531)

[1]Adjusted for demographic variables and occupation group; [2]New South Wales; [3]Australian Capital Territory; [4]Northern Territory

[5] Not applicable

Bold denotes statistically significant differences

5.5 Discussion

This study examined the current prevalence of occupational exposures to a wide range of asthmagens, carcinogens, and ototoxic agents among Australian healthcare workers. It identified the common exposure agents and described the most frequent circumstances associated with such exposures. It also determined occupation groups within the healthcare sector that are most likely to be exposed to these agents. The results provide crucial initial evidence that may have implications for future prevention interventions of occupational asthma, cancers, and otological damage among healthcare workers.

5.5.1 Exposure to asthmagens

A very high proportion (92.3%) of healthcare workers in this study were exposed to at least one asthmagen, and the most common exposures were to cleaning and sterilising agents (77.5%) and latex (62.2%). It is difficult to compare the results of this study with other research as there are no studies that have investigated such a wide range of exposures in healthcare workers. However, previous research examining exposures to specific asthmagens have reported a similar high prevalence (78.3% to 98.8%) in the use of cleaning and disinfecting agents among healthcare workers.[18, 262] In the case of latex gloves, some studies have reported a decreasing prevalence in their use in the United States (69.7% pre-1992 decreasing to 3.2% after 2000),[14, 18] but previous Australian research has found their use to be quite prevalent (67% to 85%) in the healthcare sector.[19, 263] The application of infection prevention strategies to prevent hospital acquired infections requires healthcare workers to commonly engage in cleaning and disinfecting tasks, and to use barriers such as gloves.[39] Though efforts have been made to reduce these exposures, especially for latex by substitution with less allergenic (e.g., nitrile or powder-free gloves), and for cleaning agents by less toxic alternatives (e.g., green cleaning products), exposures still remain relatively common.

This study showed that applying chlorhexidine as an antiseptic and for hand hygiene were the main circumstance of exposure to the asthmagen group - cleaning and sterilising agents. Hospital employees wash their hands 5-30 times in a shift and for surgical asepsis, this involves washing with water- or alcohol-based preparations, some of which may contain chlorhexidine.[264] Research on occupational asthma and cleaning and sterilising agents in healthcare workers has mainly focused on instrument disinfection with high-level disinfectants (e.g., aldehydes) and surface disinfection with cleaning products (e.g., bleach, quaternary ammonium compounds).[29] There is not much research examining other common tasks such as hand hygiene using chemicals, increased frequencies of which have shown some association with asthma.[63] The findings of this study highlight the need for such research.

5.5.2 Exposure to carcinogens

The most common carcinogenic exposure in this study was to shift work. In Australia, the healthcare industry has the highest proportion of workers who work shifts (25%) compared to all other industries.[265] Night shift work has been classified as a probable carcinogen by the International Agency for Research on Cancer (IARC) based on limited evidence on breast cancer in humans.[266] It is difficult to compare prevalence of night shift work because definitions vary widely among different studies. For example, the prevalence of night shift work among healthcare workers was 9.8% in a study where night shift work was defined as "fixed night shifts", [267] and in another study it was 54.5% where the definition was "those on night shifts or rotating shifts that included at least an average of 4 nights per month during the year".[268]

The common activity for exposure to PAHs in this study was operating diathermy equipment. PAHs are the by-products of incomplete combustion and their carcinogenic properties are widely recognised.[85] The heating process of diathermy for blood vessel coagulation and tissue dissection during surgery generates a smoke plume that contains various hazardous chemicals, including significant amounts of PAHs. Effective smoke evacuation using smoke extractors and the use of respirators are recommended to minimise health hazards from surgical smoke.[90]

5.5.3 Exposure to ototoxic agents

Almost half of the healthcare workers in this study were exposed to at least one ototoxic agent, with the common exposures being to toluene and p-xylene. The common circumstances for exposure to these ototoxic agents were using and fuelling petrol vehicles. This is a quite a surprising finding as these tasks are not thought to be typically associated with healthcare workers. Travel undertaken to provide care to patients at home or the travel associated with patient transfers in ambulances could be the possible circumstances for such activities among healthcare workers. This finding supports the fact that job title alone is a poor surrogate for occupational exposures, and that task-based exposure assessments provide a more accurate measure of exposure.[269]

5.5.4 Associations with demographic characteristics and occupation groups

A few demographic variables were associated with exposures in this study. Exposures to carcinogens were less common among older workers; and exposure to ototoxic agents was common among those living in inner regional areas and less common among those with higher education levels. Of note, no significant gender differences were observed for all three categories of exposure agents. Gender differences in occupational epidemiology have been widely reported. Exposure disparity among genders has mainly been found to be due to differences in occupations or differences in gender assignment of tasks within occupations, which is thought largely to be based on socialised gender roles and perceived gender differences in physical capabilities.[269, 270] It appears that among healthcare workers in this study, there seems to be little gender-based assignment of tasks, with males and females performing the same tasks and hence having equal probabilities of exposures.

In this study, exposures were common among three occupational groups - nursing professionals, health and welfare support workers, and personal carers. Of these, personal carers were the only occupation group most likely to be exposed to both carcinogens and ototoxic agents. In Australia, personal carers provide care and support services to the elderly and to those living with disabilities, either in their homes or in hospitals and residential care facilities.[257] This occupation group has not been studied at length as being at risk of exposure to chemicals, [271] and therefore this finding has important implications for future research, policy development and formulation of intervention strategies. Moreover, not only is this occupation group the fastest growing in the developed world, [272] but these workers are also already vulnerable to health disparities by virtue of their social position. Personal carers are mostly women, are increasingly from racial/ethnic minority groups or immigrants, have low education attainment levels and earn very low wages.[273]

5.5.5 Limitations and strengths

There are several limitations in this study. First, levels of exposures could not be assessed as this information was not collected in the AWES-Asthma study. Therefore, the prevalence of exposure reported here is not a calculation of time-weighted exposure, but only an assessment of the number of people exposed irrespective of duration and frequency. A further limitation is the use of ANZSCO codes to group jobs into occupation groups, which is based on skill level and specialisation required to perform the tasks of the occupation group.[257] This may have resulted in exposure heterogeneity within a group resulting in the attenuation of the results presented in this study. Another limitation is the use of self-reported data which is subject to bias and which may have introduced some errors in exposure assessment. However, given that participants were asked about the tasks they performed and not about specific exposures, it is unlikely that the data were substantially affected with these biases since task-specific questions have been known to improve the accuracy of information obtained.[274] A further limitation is the under representation of younger healthcare workers in the sample, which may have affected the results of the study. There was also a gender skew towards females, however, this is comparable with national data (78.5% of those working in the healthcare industry are females).[258] In addition, if the OccIDEAS modules did not include all possible exposure circumstances, the prevalence of exposure to the various agents in this study might be underestimated. Also, as in any survey there is the potential of bias resulting from the issue of non-response. However, since no further information was available for non-responders, the impact of the bias could not be assessed. Finally, there were very few medical laboratory workers in all the three AWES samples, so this occupation group could not be examined separately. Further research on exposure to ototoxic agents in this occupation group is required because certain chemicals used in medical laboratories (e.g., toluene, xylene) can act in synergy with noise to cause hearing loss[15] and medical laboratory workers have been identified as an occupation group at high risk for noise induced hearing loss.[108] In terms of strengths, this study examined exposures to a wide range of asthmagens, carcinogens, and ototoxic agents thereby assessing exposures to a comprehensive list of chemical agents. In addition, the use of task-based questions and the large sample size enabled more detailed exposure assessments.

5.6 Conclusions

The results demonstrate that a substantial proportion of Australian healthcare workers are occupationally exposed to asthmagens, carcinogens, and ototoxic agents. The most common exposures were to cleaning and sterilising agents among asthmagens, shift work in the carcinogen group, and toluene and p-xylene among ototoxic agents. Among the occupational groups, personal carers were at an increased risk of exposure to both carcinogens and ototoxic agents, while nursing professionals and health and welfare support workers were at an increased risk of exposure to carcinogens. The study provides crucial information that will be useful in prioritising and implementing control strategies among healthcare workers.

Chapter 6 : Reliability and validity of an adapted questionnaire assessing occupational exposures to hazardous chemicals among healthcare workers in Bhutan

There are few standardised questionnaires available to collect occupational history data in LMICs. This chapter presents the findings of a pilot study conducted in Bhutan where a questionnaire developed by the NIOSH for collecting information on exposure to chemicals was adapted and tested among healthcare workers in Bhutan.

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In this chapter, the post-edited and reviewed version of the manuscript is presented. The publisher's version of the manuscript is presented in Appendix I.

The published paper received comments regarding validity measures. The comments and the response to the comments are presented in Appendix J.

6.1 Abstract

Background: Collection of reliable and valid occupational history data is of utmost importance to assess work-related exposures and their health effects. Few standardised questionnaires are available for the collection of occupational history data in low-and-middle income countries.

Objective: This study aimed to adapt and test a validated questionnaire developed in the United States by the National Institute for Occupational Safety and Health, in order to assess occupational chemical exposures among healthcare workers in Bhutan.

Methods: The questionnaire was first adapted to suit the Bhutanese context with the advice of an expert review committee. Thirty healthcare workers then completed the questionnaire at baseline and 10-14 days later. Test-retest reliability was assessed by calculating Cohen's Kappa and percentage agreement.

Results: The questionnaire had high test-retest reliability. Cohen's Kappa ranged from 0.61 to 1.00, and percentage agreement ranged from 86.67 to 100%. Further adaptations included omitting questions on chemicals not available in Bhutan.

Conclusions: The findings of this study suggest that the adapted questionnaire is appropriate for assessing occupational chemical exposures among healthcare workers in Bhutan

6.2 Introduction

Healthcare workers operate in an environment containing numerous hazards that pose daily risks to their health.[107] The healthcare sector has consistently reported a high prevalence of non-fatal injuries and illnesses in the United States (US), and Australia.[275, 276] With a worldwide population of 56 million healthcare workers, the healthcare sector employs 13% of the global workforce.[2] Job growth in this industry is expected to increase to meet the rising needs of an aging global population. A substantial population of healthcare workers will therefore be at risk of harm in the workplace, with the potential to adversely impact the quality of healthcare services.

Occupational exposures to biological and psychological hazards among healthcare workers are widely recognised.[1] Less apparent is that the healthcare environment also contains hazardous chemicals similar to those found in 'blue-collar' industries, exposures to which can increase the risk of long term adverse health outcomes. Exposures to chemicals such as ethylene oxide, formaldehyde, and antineoplastic drugs have been linked to certain types of cancers such as haematological and nasopharyngeal cancers.[9-11] Exposure to latex as well as a number of chemicals in cleaning and disinfecting agents have been associated with work-related asthma among healthcare workers.[13, 14] Chemicals used in hospital laboratories such as toluene, styrene and xylene have the potential to cause auditory damage and hearing loss.[15]

Research on occupational exposures to hazardous chemicals among healthcare workers has highlighted these risks, and safety programs and standards have been instituted to ensure the safety of these workers.[16] However, the majority of these studies have been conducted in high-income countries.[1] Very little work has been done on examining these hazards in low- and middle-income countries (LMICs).[277] The limited research in this area from LMICs has mainly examined exposure to latex.[224]

The collection of valid and reliable occupational history data is of utmost importance in estimating occupational exposures and work-related health effects. One way of obtaining this information is through questionnaires, which can collect details to assist in exposure assessment (e.g., tasks conducted within a job, use of control measures).[278] Unfortunately, there are very few standardised questionnaires available in this area,[279] especially so for use in LMICs.

The National Institute for Occupational Safety and Health (NIOSH) developed a questionnaire for the Health and Safety Practices Survey of Healthcare workers conducted in the US in 2011, which aimed to examine safety practices to minimise exposure to hazardous chemicals in the workplace.[280] The questionnaire used in the survey may not be directly applicable for use in LMICs due to differences in legislation, work environments and safety standards. Therefore, the aim of this study was to adapt and test this questionnaire for use in Bhutan to assess occupational exposures to asthmagens, carcinogens, and ototoxic chemicals among healthcare workers.

6.3 Methods

This study was conducted in two stages: 1) the adaptation of the NIOSH questionnaire, and 2) test-retest reliability assessment.

6.3.1 Stage 1: Adaptation of the NIOSH questionnaire

The NIOSH questionnaire was developed for a web-based survey of healthcare workers to examine safety practices to minimise exposure to chemicals in the workplace.[280] The survey instrument contains seven hazard modules and a core module. The core module includes questions about demographics and exposures to other occupational hazards (e.g., infectious agents). The hazard modules contain questions about frequency and duration of exposures, and work practices and control measures used to minimise exposure to chemicals that are commonly encountered in the healthcare setting (i.e., anaesthetic drugs, aerosolised medications, antineoplastic drugs, chemical sterilants, high-level disinfectants, and surgical smoke).

A committee of experts in Bhutan was consulted during the process of questionnaire adaptation. The committee of experts comprised of two senior doctors and a nurse with extensive practical experience within the Bhutanese healthcare system, and one nurse specialised in occupational health. The NIOSH questionnaire was developed for a high-income country with advanced medical technology and drugs, many of which are not available in Bhutan. The committee was asked whether to retain each question in the instrument to make the questionnaire appropriate for the Bhutanese context. For example, the module on high-level disinfectants in the original questionnaire included questions on the use of manual or automated disinfection systems. The questions on automated disinfection systems were excluded because they were not used in the country. Since the original questionnaire did not include chemicals used in laboratories, dental departments, and for cleaning, questions on these chemicals were adapted from the healthcare job module in OccIDEAS, a computer application that assesses occupational exposures.[122] OccIDEAS consists of job modules that include questions about various tasks carried out in a particular job, and about control measures that might influence exposure levels. These modules are developed based on evidence from literature and expert opinion.

The pre-final version of the modified questionnaire was then reviewed by the experts to assess the validity of the instrument. The experts evaluated whether the items in the questionnaire were relevant to the Bhutanese context, whether the questions were comprehensible to Bhutanese healthcare workers, and determined the comprehensiveness of the questionnaire. The experts felt that the hard-copy version of the questionnaire would be more acceptable to the population. Based on the experts' review, the final version of the modified questionnaire was consolidated for testing as a hard-copy version in English. Tertiary education in Bhutan is delivered in English[281] so health professionals have no difficulty with an English-language questionnaire. Questions about the survey instrument (comprehensibility, ease of use, and preferred mode of administration) were also included in the final version to obtain additional feedback from participants.

6.3.1.1 Questionnaire

Sociodemographic variables such as age, gender, ethnicity, and level of education were collected. For occupational history, participants were asked about the hospital and department they were currently working in, their job title, and the duration of employment as a healthcare worker. Participants were also asked about the tasks that were carried out as part of their job (e.g., sterilising instruments, working in the dental department, laboratory or surgery, preparing drugs, suturing, cleaning the workplace, administering antineoplastic drugs and anaesthetic gases), and about current work practices and control measures to minimise exposures to chemicals (e.g., using portable smoke evacuators to remove smoke during diathermy, fume hoods in the laboratory, waste gas scavenging systems to remove waste anaesthetic gases, biological safety cabinets while compounding antineoplastic drugs, and using gloves, water-resistant gowns, masks, and goggles while handling chemicals).

6.3.2 Stage 2: Test-retest reliability

6.3.2.1 Participants and procedure

A targeted convenience sample of 30 healthcare workers was recruited from three hospitals (a tertiary hospital in Thimphu, and two district hospitals in Wangdue and Paro) located in the western region of Bhutan in April and May, 2019. The state provides free healthcare services to all citizens as mandated in the Constitution of Bhutan.[281] Therefore, all healthcare facilities in the country are in the public sector and all healthcare professionals work in these facilities. The western region of Bhutan has the highest number of healthcare workers as compared to the eastern and central regions, and half of the hospitals are located in this region.[281]

The eligibility criteria for the study were healthcare workers who were 18 to 60 years of age, and currently working in any one of the three hospitals included in the study. Care was taken to include participants from different age groups, varying durations of employment, a range of job titles, and equal gender representation during the recruitment process.

Participants completed the questionnaire at two times, once at baseline (Time 1) and then 10-14 days (Time 2) later. This time interval is considered adequate to provide independent observations and to prevent true variations in exposure.[279] Hard-copy questionnaires were personally distributed among the participants and collected when completed. All the questionnaires were self-administered, except for one participant (a hospital cleaner) who completed the questionnaire as an interview conducted in the local language. Informed written consent was obtained from all participants. The study was approved by the Research Ethics Board of Health, Bhutan, and the Human Research Ethics Committee, Curtin University (approval numbers: REBH 2018/090 and HREC 2019-0079).

6.3.2.2 Exposure assessment

The data from the questionnaire were entered into OccIDEAS. Based on the participants' responses in the questionnaire, pre-determined algorithms were applied in OccIDEAS to determine exposure to various carcinogens, asthmagens, and ototoxic chemicals (see Table 6.1).[122] The rules in the algorithms were based on evidence from literature, material safety data sheets, and expert advice from occupational hygienists on the determinants of exposures.

Table 6.1 The list of asthmagens, carcinogens, and ototoxic chemicals assessed in a reliability study in Bhutan

Asthmagens	Carcinogens	Ototoxic chemicals
Acids Ammoniacal compounds Asthma aldehydes Acrylates Drugs Epoxy Industrial cleaning and sterilising agents Latex Reactive dyes Other reactive chemicals	<u>Industrial chemicals</u> Diethyl/dimethyl sulphate Epichlorhydrin Ethylene oxide Formaldehyde Ortho-toluidine <u>Solvents</u> Alcohol Aliphatic Solvents Benzene Chlorinated Solvents Tetrachloroethylene (Perc), Trichloroethylene <u>Products of combustion</u> Polycyclic aromatic hydrocarbons (PAH)	Toluene Styrene p-Xylene Trichloroethylene Ethyl benzene n-Hexane,

6.3.2.3 Feed-back on the questionnaire

Participants were asked whether they had difficulties in using the questionnaire and in understanding the questions, and to provide reasons if so. They were also asked to choose their preferred mode of questionnaire administration (hard-copy or web-based).

6.3.2.4 Statistical analysis

Statistical analyses were carried out using STATA 14 (StataCorp, College Station. TX). Descriptive statistics such as means and frequencies were estimated for sociodemographic variables. Cohen's κ (two levels) and weighted κ (more than two levels) statistics, and percentages of overall agreement were used to test the reliability of the questionnaire. These were calculated for the questions related to the main tasks (yes/no), for exposures to chemicals (exposed/unexposed), and for specific tasks questions if there were enough responses. Established cut-points for κ (i.e., poor 0.00-0.20, fair 0.21-0.40, moderate 0.41-0.60, strong 0.61-0.80, and almost perfect agreement 0.81-1.00) and percentages of agreement (≥75% was considered acceptable) were used to determine the adequacy of agreement of the estimates.[282]

6.4 Results

6.4.1 Adaptation of the questionnaire

On advice from the experts, questions on chemicals used in the laboratory, the dental department, and in cleaning, were retained in the questionnaire. Questions on some chemicals (ethylene oxide, hydrogen peroxide gas plasma), drugs (aerosolised medicines), and control measures (use of purifying respirators with chemical cartridges, environmental exposure monitoring, medical surveillance) were omitted because these were not available in Bhutan. The experts agreed that the adapted questionnaire was comprehensible and comprehensive.

6.4.2 Sample characteristics

Participants ranged in age from 24 to 52 years (M = 37.5 years, SD = 8.1) and 53% were female (Table 6.2). Two-thirds (66.7%) of the sample reported having a university degree as their highest level of education. A majority of participants (70%) were nurses and two-thirds (66.7%) of the participants worked in the National Referral Hospital in Thimphu.

Table 6.2 Demographic characteristics of the sample of health workers in Bhutan

	n (%)
Gender	
Male	14 (46.7)
Female	16 (53.3)
Ethnic group	
Ngalop	5 (16.7)
Sharshop	12 (40.0)
Lotshamp	10 (33.3)
Others	3 (10.0)
Education	
Primary/High school	4 (13.3)
Diploma	6 (20.0)
Bachelor’s degree	11 (36.7)
Postgraduate degree	9 (30.0)
Hospital	
National Referral hospital, Thimphu	20 (66.6)
Paro hospital	5 (16.7)
Wangdue hospital	5 (16.7)
Current occupation	
Medical doctor	1 (3.3)
Dental doctor	3 (10.0)
Nurse	21 (70.0)
Technologist/technician and support staff	5 (16.7)
Duration of work as health worker	
Less than 6 years	8 (26.7)
6 - 10 years	6 (20.0)
11 – 20 years	8 (26.7)
>21 years	8 (27.7)

6.4.3 Test-retest reliability

As shown in Table 6.3, the percentages of overall agreement on questions regarding the main tasks carried out between Time 1 and Time 2 were excellent (86.67 to 100%). All κ estimates also demonstrated strong or almost perfect agreement (0.63 to 1.00) on the main tasks carried out, except for the question on surgery which showed fair agreement (κ 0.35).
Participants were exposed to at least one chemical from each of the three categories (carcinogens, asthmagens, and ototoxic agents) of hazardous chemicals assessed (Table 6.3). The prevalence of exposure to industrial cleaning and sterilising agents was substantial at both Time 1 (86.7%) and Time 2 (83.3%). The percentages of overall agreement on the prevalence of exposures at Time 1 and Time 2 were excellent (86.67 to 93.33%). The κ estimates also demonstrated strong to almost perfect agreement (0.61 to 0.85).

The task of cleaning the workplace was reported by almost two-thirds (56.7-60%) of the participants (Table 6.4). The additional questions on cleaning asking about the use of cleaning chemicals, use of personal protective equipment, and training received on handling cleaning agents, showed a high degree of agreement between Time 1 and Time 2. All the κ estimates demonstrated almost perfect agreement (0.80 to 0.90) and the percentages of overall agreement were excellent (90.00 to 95.00%). Reliability tests were not conducted for the additional questions on the other main tasks due to the low number of responses to these questions.

6.4.4 Feed-back on the questionnaire from the participants

A majority of the participants (83%) chose hard-copy as their preferred mode of questionnaire administration. Four (13%) participants reported difficulties in using the questionnaire. One reported the questionnaire was too long and three participants said they found it tedious looking for the next questions after the skip questions (i.e., if they answered no to the main question regarding a task, they skipped all the subsequent questions on that task and went on to the next main question). Only one participant reported difficulty in understanding the questions. The difficulty reported was on the question asking about whether they worked in surgery. The participant found this confusing as “Do you work in surgery?” could mean either operating theatre, surgical ward, or minor surgery.

Table 6.3 Test-retest reliability of the questions regarding the main tasks and exposure assessment in healthcare workers in Bhutan

	n (%) answered yes		2 x 2				Cohen's κ (95% confidence interval)	% agreement
	Time 1	Time 2	YY[a]	YN[b]	NY[c]	NN[d]		
Main tasks								
Do you sterilise instruments or other equipment yourself?	4 (13.3)	2 (6.7)	2	2	0	26	0.63 (0.19 - 1.00)	93.33
Do you work in the dental department?	3 (10.0)	3 (10.0)	3	0	0	27	1.00	100.00
Do you work in the pharmacy department?	0 (0)	0 (0)	-	-	-	-	-	-
Do you work in the laboratory	3 (10.0)	3 (10.0)	3	0	0	27	1.00	100.00
Do you perform sutures?	11 (36.7)	11 (36.7)	9	2	2	17	0.71 (0.45 - 0.97)	86.67
Do you work in surgery?	3 (10.0)	2 (6.7)	1	2	1	26	0.35 (-0.22 - 0.92)	90.0
Do you administer antineoplastic drugs?	1 (3.3)	1 (3.3)	1	0	0	29	1.00	100.00
Do you compound antineoplastic drugs?	0 (0)	0 (0)	-	-	-	-	-	-
Do you wear gloves at work?	30 (100)	30 (100)	-	-	-	-	-	-
Is one of your tasks to clean the work place?	18 (60.0)	17 (56.7)	17	1	0	12	0.93 (0.80 -1.00)	96.67
Do you administer anaesthetic gases to patients?	2 (6.7)	2 (6.7)	2	0	0	2	1.00	100.00
Exposures								
Asthmagens								
Industrial cleaning and sterilising agents	26 (86.7)	25 (83.3)	24	2	1	3	0.61 (0.21 - 1.00)	90.00
Ammoniacal compounds	10 (33.3)	10 (33.3)	9	1	1	19	0.85 (0.65 - 1.00)	93.33
Ototoxic agents								
p-xylene	12 (40.0)	11 (36.7)	10	2	1	17	0.79 (0.56 - 1.00)	90.00
Toluene	11 (36.7)	11 (36.7)	9	2	2	17	0.71 (0. 45 - 0.97)	86.67
Carcinogens								
Aliphatic solvents	11 (36.7)	11 (36.7)	9	2	2	17	0.71 (0.45 - 0.97)	86.67

[a] Yes/Yes; [b] Yes/No; [c] No/Yes; [d] No/No

Table 6.4 Test-retest reliability of questions on cleaning in Bhutanese healthcare workers

	n (%)		Weighted Cohen's κ (95% confidence interval)	% agreement
	Time 1	Time 2		
Use bleach for cleaning				
Yes	17 (56.7)	15 (50.0)		
No	1 (3.3)	2 (6.7)	0.90 (0.89 - 0.93)	95.00
NA*	12 (40.0)	13 (43.3)		
Use chlorhexidine for				
cleaning	8 (26.7)	10 (33.3)		
Yes	10 (33.3)	7 (23.4)	0.82 (0.54 - 0.86)	91.67
No	12 (40.0)	13 (43.3)		
NA*				
Use disinfectants for cleaning				
Yes	9 (30.0)	9 (30.0)		
No	9 (30.0)	8 (26.7)	0.82 (0.78 - 0.93)	91.67
NA*	12 (40.0)	13 (43.3)		
Use spirits for cleaning				
Yes	11 (36.7)	11 (36.7)		
No	7 (23.33)	6 (20.0)	0.84 (0.74 - 0.89)	91.67
NA*	12 (40.0)	13 (43.3)		
Wear gloves when handling cleaning agents				
Always	12 (40.0)	13 (43.3)		
Sometimes	6 (20.0)	4 (13.4)	0.80 (0.76 - 1.00)	90.00
Never	0 (0.0)	0 (0.0)		
NA*	12 (40.0)	13 (43.3)		
Wear goggles when handling cleaning agents				
Always	1 (3.3)	0 (0.0)		
Sometimes	7 (23.3)	11 (36.7)	0.83 (0.72 - 0.90)	94.44
Never	10 (33.4)	6 (20.0)		
NA*	12 (40.0)	13 (43.3)		
Type of mask used when handling cleaning agents				
Standard surgical mask	17 (56.7)	17 (56.7)		
N95 respirator	0 (0.0)	0 (0.0)	0.90 (0.82 - 1.00)	95.00
Do not wear mask/respirators	1 (3.3)	0 (0.0)		
NA*	12 (40.0)	13 (43.3)		
Training received for handling cleaning agents				
Within past 12 months	3 (10.0)	4 (13.3)		
More than 12 months	5 (16.7)	5 (16.7)	0.85 (0.80 - 0.88)	94.44
Never received training	10 (33.3)	8 (26.7)		
NA*	12 (40.0)	13 (43.3)		

* NA: not applicable, did not answer the cleaning questions

6.5 Discussion

The objective of this study was to adapt and test a validated questionnaire to examine occupational exposures to hazardous chemicals among healthcare workers in Bhutan since standardised questionnaires suitable for use in LMICs are currently not available. This was achieved by modifying the questionnaire to make it relevant to Bhutan, followed by validation and reliability testing. The adapted questionnaire exhibited good content validity and strong to almost perfect test-retest reliability.

The modification of the questionnaire mainly involved omission and substitution of certain questions to make the questionnaire relevant to the Bhutanese context. The original questionnaire had been developed in a high-income country with advanced medical technology, much of which is not available in low-income countries. Questions on some of these advanced technologies were omitted (e.g., automated disinfection systems), or substituted with those being used in the country (e.g., chemotherapy gloves substituted with plain gloves). In addition, questions on laboratory, dental, and cleaning chemicals were adapted from OccIDEAS to make the questionnaire more comprehensive in assessing chemicals that healthcare workers use in Bhutan. The experts agreed that the modified questionnaire was comprehensible, comprehensive, and relevant to the Bhutanese context.

The reliability of the questionnaire was assessed by test-retest analyses. There was a high degree of agreement on the questions asking about the main tasks carried out. The only exception was the question asking about whether they worked in surgery, which demonstrated fair agreement. This could be because the question was not well understood as stated by one of the participants in the feed-back, who found this question confusing. It is important that words used in the questionnaire are clear and unambiguous for optimum comprehension and accurate interpretation,[283] hence this question was re-worded as “Do you work in the operation theatre?” in the final questionnaire to make it clearer. Since the majority of participants reported cleaning the workplace as one of their main tasks, the reliability of the additional questions on cleaning was also assessed. These questions on the use of various chemicals and control measures also demonstrated very strong agreement.

The information gathered from the questionnaires at the two time periods was sufficiently consistent to result in excellent agreement in exposure assessment. Detailed self-reported occupational exposure information gathered from questionnaires has previously been shown to have a high degree of sensitivity[284] and reliability.[285] Using a list of specific agents to prompt recall, asking about agents that can be easily identified, and using familiar terminology (e.g., using trade names instead of generic names), is known to improve accuracy of exposure assessment when using questionnaires.[284]

The main difficulties reported in using the questionnaire in this study were the length of the questionnaire and the tediousness in looking for the next questions after the skip questions. This is to be expected because the original questionnaire was designed for use as a web-based survey, where the questions after the skip questions would be presented automatically, and the main questions would help screen the subsequent questions thus making the survey shorter. However, as indicated by both the study participants and the expert panel, the hard-copy version was the preferred mode of questionnaire administration in Bhutan. Both on-line and traditional paper-based surveys have been shown to be comparable in terms of reliability and validity, [286, 287]and the selection of the most appropriate method depends on factors such as study aims, budget, and geographic area of the research.[288] The preference of the hard-copy version by participants in this study could be because the web-based version requires an internet connection, access to which might be problematic in a low-income country like Bhutan due to the high costs and poorer quality of internet connectivity.[289] So measures to improve the appearance of the questionnaire such as making the skip questions and page numbers more visible by presenting these in coloured bold font, could assist in improving the usability of the hard-copy questionnaire.[283, 290]

Cross-cultural adaptations of questionnaires usually involve translation, review by an expert committee, and pre-testing.[291] There are multiple ethnic groups (three main groups, many tribal groups) in Bhutan, each with their own language and, since English is used as the medium of instruction in all schools and institutions in Bhutan and therefore widely used,[281] administering the questionnaire in English was deemed appropriate, with a provision for the questionnaire to be administered as an interview in the local language when necessary (e.g., for healthcare workers with little English proficiency such as cleaners, ambulance drivers). Although the questionnaire was not translated, almost all participants reported no difficulties in understanding the questionnaire endorsing the adequacy of presenting the questionnaire in English to Bhutanese healthcare workers.

The major limitations of this study are the use of a convenience sample and the small sample size. Although a sample size of 30 is adequate to achieve a power of 80% in detecting a problem with a 5% prevalence,[292] the results of this study, though encouraging, should be interpreted with caution due to non-random selection of the participants. In addition, despite attempts to recruit participants having a range of job titles, the majority were nurses and there was no representation of some job titles such as pharmacists. Further, having the questionnaire only in English requires presenting the questionnaire as an interview in the local language by experienced interviewers to those workers with limited English proficiency, which could affect study resources such as time and costs.

The process of questionnaire adaptation and testing used in this study could assist in developing questionnaires for other LMICs. This process could be useful for countries with similar healthcare systems and medical technology.

6.6 Conclusion

This is one of the few studies testing a questionnaire to examine occupational exposures to chemical hazards in LMICs. The overall findings from this study suggest that the modified questionnaire had good validity and reliability to measure workplace exposures to hazardous chemicals among healthcare workers in Bhutan. Administering the questionnaire in English, with a provision for interpretation when required, was suitable for Bhutanese healthcare workers, and translation of the questionnaire was not imperative. The hard-copy version was the preferred mode of questionnaire administration.

Chapter 7 : Occupational exposures to hazardous chemicals and agents among healthcare workers in Bhutan

In the previous chapter, a questionnaire was adapted and tested for use in Bhutan. This chapter presents the findings of a cross-sectional study conducted in Bhutan using the adapted questionnaire to examine workplace exposures to hazardous chemicals and agents among healthcare workers in Bhutan.

The findings of the study were submitted as a short report on 7 July, 2020 and accepted for publication on 18 September, 2020. This chapter presents the accepted version of the following article:

Rai R, El-Zaemey S, Dorji N, Fritschi L. Occupational exposures to hazardous chemicals and agents among healthcare workers in Bhutan. American Journal of Industrial Medicine. 2020 Dec; 63(12):1109-15.

It has been published in the final form at: https://onlinelibrary.wiley.com/doi/full/10.1002/ajim.23192 . This article may be used for non-commercial purposes in accordance with the Wiley Self-Archiving Policy [http://www.wileyauthors.com/self-archiving].

This chapter is the longer version of the submitted paper as the findings of the regression analysis were not included in the short report due to word limitations. The additional sections that were not in the published paper are presented in italics. Figure 7.1 and Table 7.6 were also added in this chapter.

7.1 Abstract

Objectives: Occupational exposures to hazardous chemicals among healthcare workers can result in long-term adverse health outcomes. The aim of this study was to estimate the prevalence of exposures to a range of chemicals used in healthcare settings among Bhutanese healthcare workers.

Methods: A cross sectional study was conducted among healthcare workers (n=370) working in three hospitals in the western region of Bhutan. Demographic and occupational information was collected, and exposures to asthmagens, carcinogens, ototoxic and other agents were assessed using a web-based tool. Prevalence of exposure to these chemicals was calculated and the circumstances resulting in such exposures were examined. *Regression analysis was carried out to examine associations between occupational and demographic factors with exposure status.*

Results: The prevalence of exposure to at least one asthmagen, carcinogen, and ototoxic agent was 98.7%, 28.1%, and 7.6%, respectively; and was 6.2% for anaesthetic gases and 2.2% for antineoplastic drugs. The most common exposures were to latex, and cleaning and disinfecting agents in the asthmagens group; formaldehyde in the carcinogens group; and p-xylene among ototoxic agents. The circumstances resulting in exposures were using latex gloves, using bleach and chlorhexidine for cleaning, using formaldehyde as a disinfectant and in the laboratory, and using p-xylene in the laboratory.

Exposure to asthmagens was least common among older healthcare workers and exposure to carcinogens was least common among healthcare workers from district hospitals. Exposure also varied by occupation group, with the group of other health professionals and technicians most likely to be exposed to asthmagens and ototoxic agents, and nurses most likely to be exposed to asthmagens.

Conclusions: The results indicate that a large proportion of Bhutanese healthcare workers are occupationally exposed to chemicals linked to chronic diseases, with exposure prevalence higher than in high-income countries. The study provides information that can be used to formulate policies and to implement control measures to protect healthcare workers.

7.2 Introduction

Healthcare workers are occupationally exposed to a wide range of hazardous chemicals that can result in long-term adverse health effects.[107] Exposures to cleaning and disinfecting agents and latex have been associated with occupational asthma among healthcare workers.[14, 29] Ethylene oxide, antineoplastic drugs, and formaldehyde have been linked to cancers such as haematological, breast and nasopharyngeal cancers.[9-11] Exposures to anaesthetic gases and antineoplastic drugs have been associated with an increased risk of spontaneous abortions and congenital anomalies.[11, 94]

Research on workplace exposures has highlighted these risks leading to the institution of safety standards to protect workers.[16] However, the majority of this work has been undertaken in high-income countries and research in this area from low- and middle- income countries (LMICs) is limited.[1] A review on occupational hazards among healthcare workers in developing countries conducted in 2016 describes exposures to infectious agents, musculoskeletal injuries, workplace stress, and violence but does not mention exposure to any chemicals except for latex exposure.[21]

In Bhutan, the context of this study, occupational health and safety (OHS) is still a relatively new concept and, therefore, has not yet attained a priority status as a public health problem. Although commitment to OHS was initiated in 2007 with the enactment of the Labour and Employment Act, the implementation of OHS management is still in its infancy, with the formulation of a health and safety policy still at the drafting stage, no baseline occupational health data and no occupational diseases surveillance systems in place.[293] As such, research into OHS issues in Bhutan is scarce. The aim of this study is to estimate the prevalence of occupational exposures to asthmagens, carcinogens, ototoxic and other agents among Bhutanese healthcare workers and to describe the circumstances that lead to such exposures. *In addition, the study also examined the association of occupation groups and demographic variables with these exposures.*

7.3 Methods

7.3.1 Study design and setting

This was a cross-sectional study carried out during October and November, 2019 in three public hospitals in the western region of Bhutan (a tertiary hospital in Thimphu and two district hospitals in Paro and Wangdue). *The Constitution of Bhutan mandates the provision of free healthcare services to all citizens by the state.[281] Therefore, the health facilities in the* *country are in the public sector and all healthcare workers are employed in these facilities. The hospitals were purposively selected to include the apex referral hospital in the country and two hospitals from the neighbouring districts for comparison. The western region was selected because of the location of the apex hospital, and this region also has the highest number of healthcare workers as compared to the southern and eastern regions.*[281]

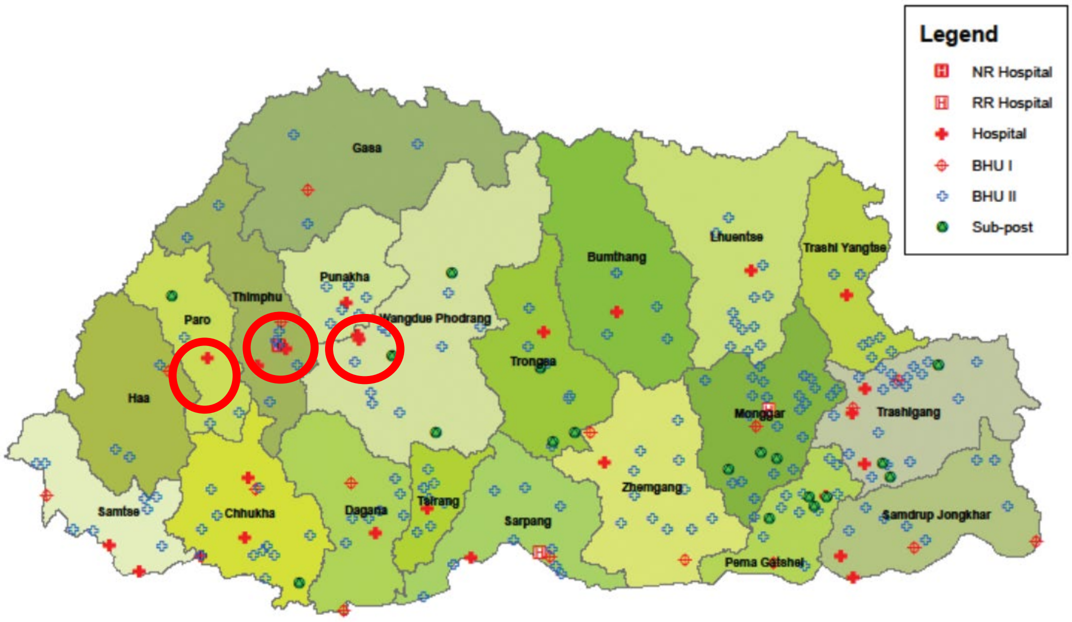

Figure 7.1 Map of Bhutan indicating the location of the health facilities (circled in red) selected for the study *(additional figure)*

7.3.2 Sample selection and study population

A list of healthcare workers employed in the three hospitals was obtained from the hospital administration. Stratified random sampling was carried out based on the hospitals and job categories. Based on the assumption of a 50% prevalence of exposure to chemical hazards among Bhutanese healthcare workers, with a confidence interval of 95% and a 5% margin of error, a sample size of 384 was calculated.

All healthcare workers who were 18 to 60 years of age, and were currently working in any of the three hospitals included in the study were eligible to participate. Administrative personnel and traditional medical practitioners were the only job categories that were excluded from the study as these occupation groups were determined as less likely to be exposed to the chemicals examined in the study.

7.3.3 Data collection

Data were collected using a questionnaire that was adapted from one developed by the National Institute for Occupational Safety and Health (NIOSH).[280] The adapted questionnaire was pre-tested in a pilot study conducted in Bhutan in April-May, 2019.[294] With the assistance of key contact people within the hospitals, hard-copy questionnaires were distributed among the healthcare workers. The questionnaires were self-administered by a majority of participants. For a minority of participants (n=41) who had limited English language proficiency, the questionnaire was administered as an interview in the local language. Informed written consent was obtained from all participants.

The questionnaire collected demographic information including age, gender, ethnicity, and education level. For occupational history, participants were asked about their current job title, the hospital they were currently working in, and the duration of employment as a healthcare worker. Information was also collected on the tasks that were carried out as part of the participants' current job (e.g., suturing, operating diathermy equipment, sterilising instruments, using various laboratory reagents, working with chemicals used in dental practice such as sodium hypochlorite during endodontic treatment, cleaning the workplace, administering anaesthetic gases, and compounding and administering antineoplastic drugs). In addition, information on work practices and control measures to minimise exposures was also obtained (e.g., the use of fume hoods in the laboratory, portable smoke evacuators for the removal of diathermy smoke, closed disinfection systems for sterilisation, waste gas scavenging systems for the removal of waste anaesthetic gases, biological safety cabinets when compounding antineoplastic drugs, and the use of personal protective equipment such as gloves, water-resistant gowns, masks, and goggles when handling chemicals).

7.3.4 Exposure assessment

The data from the questionnaires were entered into OccIDEAS, a computer application that assesses occupational exposures.[122] Based on the participants' responses to questions relating to specific tasks that have been identified as potential determinants of exposure to chemicals and the use of control measures where appropriate, predetermined algorithms were applied to determine the likelihood of exposure to various asthmagens, carcinogens, ototoxic and other agents ("no", "possible" or "probable"). These algorithms were based on evidence from published literature, material data sheets, and expert opinion.[295] For example, if they used a sterilising agent (e.g., glutaraldehyde) and handled it manually, they were considered as exposed to the agent; but if they used a closed disinfection system for sterilisation they were considered as not exposed. The "possible" exposures that were automatically assigned by OccIDEAS were manually reviewed and categorized as either probable or no exposure using all available information.

7.3.5 Statistical analysis

Each of the participants' job titles was coded using the International Standard Classification of Occupations, 2008 (ISCO-08).[296] These codes were then classified into four major occupational groups containing occupations that were broadly similar with regard to exposure to the various chemical groups (medical doctors and dentists, midwifery and nursing professionals, other health professionals and technicians which included allied health professionals/technicians such as dieticians, physiotherapists, pharmacists, occupational therapists, laboratory technicians, X-ray technicians, anaesthesia technicians, dental hygienists, and community health workers , and support staff: Table 7.1).
All analyses were carried out using STATA 14 (StataCorp, College Station. TX). Frequencies were calculated to describe the prevalence of exposure in the occupation groups and the tasks that were associated with the most common chemical exposure (i.e., those with the highest prevalence) in each chemical hazard group.

For the regression analyses, three dichotomous measures of exposure were created to indicate exposure to at least one of the agents from the list of asthmagens, carcinogens, and ototoxic agents. Since almost all participants were exposed to latex, the dichotomous variable for exposure to any asthmagen excluded latex exposure. Logistic regressions were used to compute the odds ratios (ORs) and 95% confidence intervals (CIs) to determine associations between demographic variables, occupation groups and exposure status. Regression analyses were not conducted for exposure to antineoplastic drugs and anaesthetic gases because of the low prevalence of exposure to these agents.

Table 7.1 The ISCO-08[1] codes for healthcare workers used in this study based on the International Classification of healthcare workers (World Health Organization)

Occupation group	ISCO-08[1] Code	Title
Medical doctors and dentists	2211	Generalist Medical Practitioners
	2212	Specialist Medical Practitioners
	2240	Clinical officers
	2261	Dentists
Nursing and Midwifery Professionals	2221	Nursing Professionals
	2222	Midwifery Professionals
Other Health Professionals, and Health Associate Professionals/Technicians	2262	Pharmacists
	2265	Dieticians and Nutritionists
	2269	Health professionals not elsewhere classified (e.g., occupational therapist)
	2131	Life science professionals (e.g., Microbiologist, bacteriologist)
	3211	Medical Imaging and Therapeutic Equipment
	3212	Technicians
	3213	Medical and Pathology Laboratory Technicians
	3251	Pharmaceutical Technicians and Assistants
	3253	Dental Assistants and Therapists
	3255	Community Health Workers
	3256	Physiotherapy Technicians and Assistants
	3259	Medical assistants (e.g., Ophthalmic technicians) Health associate professionals not elsewhere classified (e.g., Anaesthesia technician)
Support staff/Elementary occupations	9112	Cleaners
	9121	Launderers
	8322	Ambulance drivers
	5239	Hospital orderlies

[1]International Standards Classification of Occupations, 2008

7.4 Results

In total, 370 participants completed the questionnaires and were included in the study, resulting in a response fraction of 96.4%. Participants ranged in age from 21 to 58 years (mean= 34.2 years, *SD* = 8.1) and 55.7% were female. Almost half of the sample reported having a diploma certificate (45.1%) as their highest level of education, were Tsangla in ethnicity (45.9%) and were nurses by profession (47.6%). Two-thirds (65.9%) of the participants worked in the tertiary hospital, and almost two-thirds (63.5%) of the sample reported working as a healthcare worker for ≤ 10 years (Table 7.2).

The current prevalence of exposure to at least one asthmagen was very high at 98.7% (Table 7.3). These healthcare workers were exposed to seven different asthmagen groups, with a majority being exposed to latex (94.6%) and cleaning and sterilising agents (87.3%). More than a quarter (28.1%) of the healthcare workers were exposed to at least one carcinogen. Of the five different carcinogens these healthcare workers were exposed to, the most common exposures were to formaldehyde (18.7%) and polycyclic aromatic hydrocarbons (PAHs; 17.3%). The current prevalence of exposure to at least one ototoxic agent was low at 7.6%. These healthcare workers were exposed to only two ototoxic agents, and the most common exposure was to p-xylene (7.6%). The current prevalence of exposure to the other agents assessed was also low at 6.2% for anaesthetic gases and 2.2% for antineoplastic drugs.

Table 7.2 Demographic characteristics of the sample of healthcare workers in three hospitals in Bhutan

	N = 370 **n (%)**
Gender	
Male	164 (44.3)
Female	206 (55.7)
Age (years)	
18-34	222 (60.8)
35-60	143 (39.2)
Highest level of education	
High school or less	84 (22.7)
Diploma	167 (45.1)
Bachelor degree or higher	119 (32.2)
Ethnic group	
Ngalop	81 (21.9)
Tsangla/Sharchop	170 (45.9)
Lotshampa	74 (20.0)
Others	45 (12.2)
Hospital	
Jigme Dorji Wangchuk National Referral Hospital	244 (65.9)
Paro Hospital	58 (15.7)
Wangdue Hospital	68 (18.4)
Duration of working as a healthcare worker (years)	
≤ 10	235 (63.5)
> 10	135 (36.5)
Monthly income in Ngultrums[1]	
9000-15000	65 (17.7)
> 15000-25000	228 (62.1)
> 25000	74 (20.2)
Occupation group	
Medical doctors and dentists	59 (15.9)
Midwifery and nursing professionals	176 (47.6)
Other health professionals and technicians	94 (25.4)
Support staff/elementary occupations	41 (11.1)

[1] 1 Ngultrum = USD 0.01

Table 7.3 Prevalence of most recent exposure to asthmagens, carcinogens, ototoxic and other agents reported among health care workers in three hospitals in Bhutan (N=370)

Asthmagens	Exposed n (%)	Carcinogens	Exposed n (%)	Ototoxic agents	Exposed n (%)	Other agents	Exposed n (%)
Any asthmagen	365 (98.7)	Any carcinogen	104 (28.1)	Any ototoxic agent	28 (7.6)		
Any asthmagen excluding latex	328 (88.7)						
Latex	350 (94.6)	Formaldehyde	69 (18.7)	p-xylene	28 (7.6)	Anaesthetic gases	23 (6.2)
Cleaning and sterilising agents	323 (87.3)	Other PAHs[1]	64 (17.3)	Toluene	4 (1.1)	Antineoplastic agents	8 (2.2)
Ammoniacal compounds	201 (54.3)	Benzene	6 (1.6)	Ethyl benzene	0 (0)		
Acrylates	40 (10.8)	Chlorinated solvents	5 (1.4)	n-hexane	0 (0)		
Acids	39 (10.5)	Trichloroethylene	5 (1.4)	Styrene	0 (0)		
Reactive dyes	26 (7.0)	Alcohol	0 (0)				
Epoxy	3 (0.8)	Aliphatic solvents	0 (0)				
Bio-aerosols	0 (0)	Diethyl/dimethyl sulphate	0 (0)				
Amines	0 (0)	Epichlorhydrin	0 (0)				
Isocyanates	0 (0)	Ethylene oxide	0 (0)				
Drugs	0 (0)	Ortho-toluidine	0 (0)				
Other reactive chemicals	0 (0)	Tetrachloroethylene	0 (0)				

[1] Polycyclic aromatic hydrocarbons

The most common asthmagen exposure was to latex through the use of latex gloves, of which 96.0% reported the use of powdered latex gloves (Table 7.4). Among healthcare workers exposed to cleaning and sterilising agents, the most frequent exposure circumstances were using bleach (79.6%) and chlorhexidine (63.5%) to clean the workplace and using glutaraldehyde for sterilisation (34.7%). The tasks associated with exposure to the most common carcinogen, formaldehyde, were using it for instrument sterilisation/disinfection (72.5%) and in the laboratory (31.9%). The exposure circumstance resulting in exposure to the ototoxic agent, p-xylene, was using it in the laboratory.

Table 7.4 Main tasks resulting in exposures to the most common asthmagen, carcinogen, and ototoxic agent among healthcare workers in three hospitals in Bhutan (N=370)

	n (%)
1a. Latex (asthmagens; number exposed=350)	
Use of latex gloves	350 (100.0)
Use of powdered latex gloves	336 (96.0)
1b. Cleaning and sterilising agents (asthmagens; number exposed=323)	
Using bleach to clean the workplace	257 (79.6)
Using chlorhexidine to clean the workplace	205 (63.5)
Using glutaraldehyde for sterilisation/disinfection	112 (34.7)
2. Formaldehyde (carcinogens; number exposed=69)	
Using formaldehyde for instrument sterilisation/disinfection	50 (72.5)
Using formaldehyde in the laboratory	22 (31.9)
3. p-xylene (ototoxic agents; number exposed=28)	
Using xylene in the laboratory	28 (100.0)

When exposure to individual chemicals was examined among the four occupation groups, other health professionals and technicians was the only occupation group exposed to all the chemicals assessed (Table 7.5). Physicians were mainly exposed to latex among the asthmagens, PAHs among the carcinogens, and anaesthetic agents. Nurses were exposed to almost all the asthmagens, the carcinogens formaldehyde and PAHs, antineoplastic drugs, and anaesthetic agents, but not to ototoxic agents. Support staff were mainly exposed to asthmagens and formaldehyde.

Table 7.5 Prevalence of most recent exposure reported in the occupation groups of the asthmagens, carcinogens, and ototoxic chemicals assessed among healthcare workers in three hospitals in Bhutan (N=370)

	Medical doctors and dentists (N=59)	Midwifery and nursing professionals (N=176)	Other health professionals and technicians (N=94)	Support staff/ Elementary occupations (N=41)
	n (%)	*n (%)*	*n (%)*	*n (%)*
Asthmagens				
Latex	56 (94.9)	173 (98.3)	87 (92.6)	34 (82.9)
Cleaning and sterilising agents	40 (67.8)	157 (89.2)	87 (92.6)	39 (95.1)
Ammoniacal compounds	4 (6.8)	106 (60.2)	64 (68.1)	27 (65.9)
Acrylates	4 (6.8)	30 (17.1)	5 (5.3)	1 (2.4)
Acids	1 (1.7)	4 (2.3)	32 (34.0)	2 (4.9)
Reactive dyes	1 (1.7)	0 (0)	25 (26.6)	0 (0)
Epoxy	1 (1.7)	0 (0)	2 (2.1)	0 (0)
Carcinogens				
Formaldehyde	3 (5.1)	32 (18.2)	30 (31.9)	4 (9.8)
Other PAHs[1]	18 (30.5)	38 (21.6)	8 (8.5)	0 (0)
Benzene	1 (1.7)	0 (0)	5 (5.3)	0 (0)
Chlorinated solvents	1 (1.7)	0 (0)	4 (4.3)	0 (0)
Trichloroethylene	1 (1.7)	0 (0)	4 (4.3)	0 (0)
Ototoxic agents				
p-xylene	1 (1.7)	0 (0)	27 (28.7)	0 (0)
Toluene	1 (1.7)	0 (0)	3 (3.2)	0 (0)
Other agents				
Antineoplastic agents	0 (0)	7 (4.0)	1 (1.1)	0 (0)
Anaesthetic gases	6 (10.2)	10 (5.7)	7 (7.5)	0 (0)

[1] Polycyclic aromatic hydrocarbons

After adjusting for demographic variables and occupation groups, exposure to at least one asthmagen (excluding latex) was least common among older healthcare workers and most common among midwifery and nursing professionals, and the group of other health professionals and technicians (Table 7.6). In the adjusted analyses, exposure to at least one carcinogen was less common among healthcare workers in the district hospitals as compared to those in the referral hospital, and also less common among nurses and support staff as compared to doctors. Exposure to at least one ototoxic agent was most common among other health professionals and technicians in the adjusted analyses.

Table 7.6 Odds Ratios (ORs) and 95 % Confidence Intervals (CI) for association between demographic characteristics, occupation groups, and exposure to any asthmagens (excluding latex), carcinogens, and ototoxic agents among healthcare workers in three hospitals in Bhutan *(additional table not included in the published paper)*

Demographic characteristics and occupational groups	Exposed n (%)			Asthmagens		Carcinogens		Ototoxic agents	
	Asthmagens	Carcinogens	Ototoxic agents	Unadjusted OR (95% CI)	Adjusted OR[1] (95% CI)	Unadjusted OR (95% CI)	Adjusted OR[1] (95% CI)	Unadjusted OR (95% CI)	Adjusted OR[1] (95% CI)
Gender									
Male	140 (85.4)	55 (33.5)	11 (6.7)	1.00	1.00	1.00	1.00	1.00	1.00
Female	188 (91.3)	49 (23.8)	17 (8.3)	1.79 (0.94 to 3.43)	1.36 (0.61 to 3.04)	**0.62 (0.39 to 0.98)**	0.65 (0.39 to 1.08)	1.25 (0.57 to 2.75)	3.21 (0.99 to 10.33)
Age									
18-34	204 (91.9)	56 (25.2)	9 (4.1)	1.00	1.00	1.00	1.00	1.00	1.00
35-60	121 (84.6)	48 (33.6)	18 (12.6)	**0.49 (0.25 to 0.94)**	**0.21 (0.05 to 0.84)**	1.50 (0.94 to 2.37)	1.84 (0.75 to 4.54)	**3.41 (1.49 to 7.82)**	1.00(0.14 to 7.07)
Education									
High school or less	80 (95.2)	17 (20.2)	4 (4.8)	1.00	1.00	1.00	1.00	1.00	1.00
Diploma	154 (92.2)	57 (34.1)	19 (11.4)	0.59 (0.19 to 1.88)	0.83 (0.16 to 4.36)	**2.04 (1.10 to 3.80)**	1.03 (0.45 to 2.34)	2.57(0.84 to 7.81)	3.34 (0.81 to 13.80)
Bachelor or higher	94 (79.0)	30 (25.2)	5 (4.2)	**0.19 (0.06 to 0.56)**	0.43 (0.07 to 2.65)	1.33 (0.68 to 2.61)	0.39 (0.13 to 1.13)	0.88 (0.23 to 3.37)	7.84 (1.11 to 55.28)
Ethnic group									
Ngalop	74 (91.4)	24 (29.6)	3 (3.7)	1.00	1.00	1.00	1.00	1.00	1.00
Sharshop	150 (88.2)	48 (28.2)	17 (10.0)	0.71 (0.29 to 1.75)	0.64 (0.22 to 1.81)	0.93 (0.52 to 1.67)	0.79 (0.42 to 1.50)	2.89 (0.82 to 10.16)	1.41(0.28 to 7.17)
Lotshamp	68 (91.9)	18 (24.3)	5 (6.8)	1.07 (0.34 to 3.35)	1.39 (0.40 to 4.89)	0.76 (0.37 to 1.56)	0.71 (0.32 to 1.55)	1.88 (0.43 to 8.17)	0.75(0.09 to 5.91)
Others	36 (80.0)	14 (31.1)	3 (6.7)	0.38 (0.13 to 1.10)	0.45 (0.13 to 1.50)	1.07 (0.49 to 2.37)	0.70 (0.31 to 1.68)	1.86 (0.36 to 9.61)	0.45(0.04 to 4.73)
Hospital									
JDWNRH[2]	212 (86.9)	81 (33.2)	17 (7.0)	1.00	1.00	1.00	1.00	1.00	1.00
Paro	52 (89.7)	9 (15.5)	4 (6.9)	1.31 (0.52 to 3.29)	0.92 (0.31 to 2.73)	**0.37 (0.17 to 0.79)**	**0.31 (0.13 to 0.74)**	0.99 (0.32 to 3.06)	0.75(0.15 to 3.78)
Wangdue	64 (94.1)	14 (20.6)	7 (10.3)	2.42 (0.82 to 7.09)	2.21 (0.64 to 7.68)	**0.52 (0.27 to 0.99)**	**0.45 (0.22 to 0.92)**	1.53 (0.61 to 3.86)	1.11(0.30 to 4.15)
Duration of working as a healthcare worker									
Less than 10 years	212 (90.2)	58 (24.7)	9 (3.8)	1.00	1.00	1.00	1.00	1.00	1.00
More than 10 years	116 (85.9)	46 (34.1)	19 (14.1)	0.66 (0.35 to 1.27)	1.43 (0.39 to 5.23)	1.58 (0.99 to 2.50)	0.98 (0.41 to 2.35)	**4.11 (1.80 to 9.38)**	5.98 (0.79 to 45.15)

Monthly income (Ngultrums)										
9000-15000	63 (96.9)	12 (18.5)	4 (6.2)	1.00	1.00	1.00	1.00	1.00	1.00	
16000-25000	204 (89.5)	66 (29.0)	21(9.2)	0.27 (0.06 to 1.73)	0.20 (0.01 to 2.82)	1.80 (0.90 to 3.58)	0.90 (0.36 to 2.26)	1.55 (0.51 to 4.68)	0.64(0.13 to 3.16)	
More than 25000	59 (79.7)	24 (32.4)	2 (2.7)	**0.12 (0.03 to 0.57)**	0.46 (0.03 to 7.64)	2.12 (0.96 to 4.69)	1.05 (0.32 to 3.46)	0.42 (0.08 to 2.39)	0.51(0.04 to 6.11)	
Occupation group										
Doctors and dentists	40 (67.8)	20 (33.9)	1 (1.7)	1.00	1.00	1.00	1.00	1.00	1.00	
Midwifery and nursing	159 (90.3)	46 (26.1)	0 (0)	**4.44 (2.12 to 9.31)**	**3.90 (1.39 to 10.91)**	0.69 (0.37 to 1.30)	**0.42 (0.17 to 0.99)**	NA[3]	NA[3]	
Other health profs and technicians	90 (95.7)	34 (36.2)	27 (28.7)	**10.69 (3.42 to 33.44)**	**9.47 (2.14 to 41. 81)**	1.11 (0.56 to 2.19)	0.63 (0.23 to 1.69)	**23.37 (3.08 to 177.37)**	**29.59 (2.26 to 387.44)**	
Support staff	39 (95.1)	4 (9.8)	0 (0)	**9.26 (2.02 to 42.45)**	1.66 (0.06 to 43.97)	**0.21 (0.06 to 0.69)**	**0.14 (0.02 to 0.80)**	NA[3]	NA[3]	

[1]Adjusted for demographic variables and occupation group; [2]Jigme Dorji Wangchuk national referral hospital

Bold denotes statistically significant differences

7.5 Discussion

This study estimated the current prevalence of occupational exposures to asthmagens, carcinogens, ototoxic and other agents among healthcare workers in three hospitals in Bhutan. The prevalence of occupational exposures among Bhutanese healthcare workers in this study was high for asthmagens (98.7%) and low for ototoxic (7.6%) and other agents (6.2% for anaesthetic gases and 2.2% for antineoplastic drugs). The prevalence of exposure to carcinogens was 28.1%.

7.5.1 Exposure to asthmagens

The most common asthmagen exposure was to latex. The prevalence of latex gloves use among Bhutanese healthcare workers (94.6%) was much higher than that reported from high-income countries such as Australia (63%)[297] and the United States (69.7%),[18] where substitution with less allergenic alternatives has been initiated in efforts to reduce exposures. The use of powdered latex gloves, however, is still thought to be prevalent in LMICs due to resource limitations,[226] though actual figures are not available for comparison. There has not been much research on occupational asthma among healthcare workers in these countries, but the few studies that have examined latex allergy reported a high prevalence among healthcare workers (16% in India,[223] 16.3% in Sri Lanka,[224] 18% in Thailand[228]). The prevalent use of powdered latex gloves among healthcare workers in this study is a cause for concern and warrants further research and interventions.

Cleaning and sterilising agents was the second most common asthmagen group the healthcare workers in this study were exposed to, with 87.3% being exposed to these chemicals. This finding is in line with previous research which have reported a similar high prevalence (78.3% to 98.8%) in the use of cleaning and disinfecting chemicals among healthcare workers in the US.[18, 262] Exposure to cleaning and sterilisation agents was high among all the occupation groups in this study, which is consistent with previous research reporting a range of occupation groups within the healthcare sector (nurses, medical technicians, dental assistants, laboratory technicians) besides cleaners engaging in a high frequency of cleaning and disinfecting tasks.[298]Though cleaning and disinfecting tasks are crucial for infection control, the increased incidence of work-related asthma among healthcare workers reported in epidemiological studies have raised concerns about the occupational health risks of cleaning and disinfecting agents.[18] Substitution with safer alternatives, such as green cleaners, have been initiated in high-income countries in an effort to reduce exposures.[16]

The most common task associated with exposure to cleaning and sterilising agents in this study was using bleach to clean the workplace, which was reported by 79.6% of the participants exposed to cleaning and sterilising agents and 69.5% of the total participants. The use of bleach as a cleaning agent seems to be more common among healthcare workers in this study than among those in developed countries (45.2% in France, 55.5% in the US).[13, 299] This finding has implications for interventions since exposure to bleach has been shown to be independently associated with work-related asthma among healthcare workers.[13, 28]

Using glutaraldehyde to sterilise instruments was another common task associated with exposure to cleaning and sterilising agents, and was reported by 34.7% of participants exposed to these agents and by 30.3% of the total participants. This is similar to the use reported from high-income countries (38%).[13] Engineering controls such as the use of a closed automated disinfection system is one of the control measures that helps in reducing exposures and is used quite commonly in high-income countries such as the US (48%).[112] However, such systems are not available in Bhutan and disinfection with glutaraldehyde is done manually (as determined in the pilot study), thus increasing exposure levels to this chemical.

7.5.2 Exposure to carcinogens

Formaldehyde exposure (18.7%) was the most common carcinogenic exposure in this study and was mainly used for instrument sterilisation and in the laboratory. This prevalence is slightly lower than reported in previous studies from high-income countries (26.5% to 27.2%).[13, 299]Various guidelines have been published in developed countries setting occupational exposure limits to formaldehyde,[300] however such standards do not exist in most LMICs including Bhutan. Chemical substitution where possible, effective ventilation, and good work practices are recommended to reduce workplace exposures.[16]

7.5.3 Exposure to ototoxic and other agents

The prevalence of exposure to ototoxic agents was low in this study (7.6%). The main exposure circumstance resulting in exposure to p-xylene, the most common ototoxic agent, was using it in the laboratory. Medical laboratory workers have previously been identified as a high risk occupation group for noise-induced hearing loss,[108] and ototoxic chemicals such as xylene have the potential to act in synergy with noise to cause hearing loss.[15] Further research on exposure to ototoxic agents is required in this occupation group.

The prevalence of exposure to the other agents assessed in this study was also low, especially for exposure to antineoplastic drugs (2.2%). Specialised cancer care services have only been recently introduced in Bhutan and is still in its infancy.[301] Cancer patients are referred to India for treatment due to the lack of specialised facilities and human resources in the country.[281] The expansion of cancer services to tackle the growing incidence of cancer in Bhutan[301] will result in a higher proportion of healthcare workers being potentially exposed to antineoplastic drugs in the near future and will require formulation of policies and implementation of control measures to protect from occupational exposures.

7.5.4 Association with demographic characteristics and occupation groups

There were only two demographic characteristics associated with exposure status in this study. Exposure to asthmagens was least common among older healthcare workers. This could be because of organizational factors such as the hierarchical allotment of tasks where older workers by virtue of their senior position levels may be responsible for tasks other than cleaning the workplace and sterilising instruments. Exposure to carcinogens was less common among those healthcare workers working in the two district hospitals as compared to those in the referral hospital. Given the primary carcinogenic exposures were to formaldehyde and PAHs, which occurred mainly through instrument sterilisation and laboratory work for formaldehyde and operating diathermy instruments for PAHs (results not shown), it is to be expected that healthcare workers in the apex hospital with its many operating theatres and larger laboratories are more likely to be exposed to these agents.[281]

This study identified occupation groups that were more likely to be exposed to certain chemical groups. Other health professionals and technicians were most likely to be exposed to asthmagens and ototoxic agents, and nurses most likely to be exposed to asthmagens. The use of cleaning and disinfecting agents was very common and was one of the main exposure circumstances resulting in asthmagens exposure. Although substitution with safer alternatives, such as green cleaners, have been initiated in high income countries in an effort to reduce exposures, there is no standard definition of green cleaning and disinfecting agents and there is limited research on the effectiveness of these products on infection prevention as well as on their health effects.[39] When substitution is not possible, the use of engineering controls (e.g., effective ventilation) and personal protective equipment, together with regular training on safe handling of cleaning agents are the other control measures recommended for protection from such exposures.[16] The results of this study indicate that in LMICs such as

Bhutan these control measures are not only important for cleaners, but also for nurses and other health professionals and technicians who are at an increased risk of being exposed to these agents.

7.5.5 Limitations and strengths

This study has some limitations. First, levels of exposures were not assessed and hence, the prevalence reported is an assessment of the number of people exposed, regardless of frequency and duration, and not a calculation of time-weighted exposure. Further, the data were based on self-reports which is subject to bias and may have resulted in some errors in exposure classification. However, it is unlikely that there was a substantial effect on the data since participants were asked about specific tasks, and task-specific questions have been shown to provide more accurate information on exposures.[274] Lastly, the hospitals included in this study were purposively selected, which may have affected the representativeness of the sample. However, because of the structure of the healthcare system in Bhutan, the findings are likely to be generalizable to other healthcare workers in the country and in other countries with similar healthcare systems. The health system in Bhutan is predominantly publicly financed and managed, and health services are delivered through a three-tiered structure: basic health units at the primary level, district hospitals at the secondary level, and regional and national referral hospitals at the tertiary level.[281] Each health facility is equipped according to a standard equipment list based on the level/tier of the facility, the drugs/chemicals and equipment are mainly centrally supplied and staff move to different hospitals regularly. Therefore, the health facilities in each tier are similar in terms of the services provided and facilities available and hence, are likely to be similar in their chemical exposure profiles.

In terms of strength, this is the first study to assess occupational exposures to chemical hazards among healthcare workers in Bhutan. The study examined exposures to a comprehensive list of chemicals used in healthcare facilities and used detailed task-based questions to assess these exposures. A high response fraction (96.4%) was achieved.

7.6 Conclusion

The results indicate that a large proportion of Bhutanese healthcare workers in all professions are occupationally exposed to chemicals linked to chronic diseases, with exposure prevalence higher than in high income countries. This study provides information to guide occupational interventions and policies to protect healthcare workers in Bhutan and other LMICs.

Chapter 8 : Comparison of agreement between exposure assessments to asthmagens in healthcare workers in Australia and Bhutan using rule-based automatic algorithms and a Job Exposure Matrix

This chapter presents the findings of the final study in this thesis. Exposure assessment for the studies in this thesis was carried out using OccIDEAS, which is a newer approach in assessing exposures in epidemiological studies. In this study, exposure assessment using OccIDEAS is compared to assessment using a traditional method, the JEM, to assess exposure to asthmagens among healthcare workers.

8.1 Abstract

Objectives: To estimate the agreement between assessment of occupational asthmagen exposures in healthcare workers in a high-income country and a LMIC using algorithms based on task-based questionnaires (OccIDEAS) and an occupational asthma-specific JEM (OAsJEM).

Methods: Data for this study were obtained from two studies: 1) healthcare workers' data in a national cross-sectional survey of exposure to asthmagens in Australia (AWES-Asthma study: Chapters 4 and 5), and 2) a cross-sectional survey of occupational exposures to chemicals among healthcare workers in Bhutan (Chapter 7). Exposure to asthmagens was assessed using OccIDEAS and the OAsJEM. Prevalence of exposure to the asthmagens was calculated and inter-rater agreement was evaluated using Cohen's Kappa coefficient (κ).

Results: In Australia, the prevalence was higher for a majority of agents when assessed by OccIDEAS than when assessed by the OAsJEM (13 versus 3). The exposure assessment by OccIDEAS also identified exposures to a greater number of agents than that by the OAsJEM (16 versus 7). The agreement as indicated by κ for six of the seven agents assessed was poor to fair (ranging from 0.02 to 0.37), except for exposure to agents derived from animals where the agreement was moderate (κ = 0.52). In Bhutan, the prevalence of exposure assessed by OccIDEAS was higher for four agents (latex, cleaning and disinfecting agents, acrylates, and epoxy) and the prevalence assessed by the OAsJEM was higher for three agents (high level disinfectants, drugs, and amines). Agreement as indicated by κ was poor for all the four agents assessed (ranging from -0.06 to 0.13). In both countries, the OAsJEM overestimated exposures to high level disinfectants by assigning exposures to all participants from 10 (Bhutan) and 12 (Australia) ISCO-88 codes; whereas OccIDEAS assigned exposures to a varying proportion of participants from these ISCO-codes.

Conclusions: There was poor to fair agreement in the assessment of exposure to asthmagens in healthcare workers between the two methods. OccIDEAS identified exposures to more agents than the OAsJEM, including agents that were less common, and appeared to be more appropriate for evaluating cross-country exposures to asthmagens in healthcare workers.

8.2 Introduction

Assessment of occupational exposures is an integral component of population-based studies investigating the epidemiology of occupational diseases. However, exposure assessment in large population-based studies is often difficult because direct measurements of exposures are usually not feasible or available.[114] As discussed in Chapter 2, there are several traditional methods to assess occupational exposures such as self-reports, JEMs, and expert opinion.[114, 118] In recent years, newer methods have also been developed for exposure assessment such as the use of automated algorithms derived from experts and JEMs where exposure estimates are derived from historical exposure measurements.[118, 121]

Exposures in LMICs are likely to be different from those in high-income countries because of differences in legislation, healthcare systems, work environments and the availability of control measures. Previous studies have shown (Chapters 3 and 6) that many control measures and safer alternatives are not available in LMICs. In addition, there is weak enforcement of regulations, low workplace safety culture, and a lack of OHS expertise in these countries.[20, 123] All the available methods for hazardous exposure assessment have been developed, tested and used in high-income countries. To my knowledge, there is no research on whether these methods are appropriate for assessing exposure in LMICs, where the working conditions and exposure circumstances may be very different from those in high-income countries. In this study, two methods of exposure assessments are compared, OccIDEAS and a JEM, in the assessment of asthmagen exposures among healthcare workers in a high-income country and a LMIC.

OccIDEAS has been described in previous chapters throughout this thesis. As mentioned in Chapter 4, OccIDEAS was used to assess exposure to asthmagens in a large population-based cross-sectional study carried out among the working population in Australia in 2014 (AWES-Asthma study).[249] Exposure was assessed to 27 asthmagen groups, which included a comprehensive list of agents that were known to be asthmagens and were used in occupational settings in Australia. Based on the questions on specific tasks carried out in a job, algorithms automatically assign the likelihood of exposure to asthmagens as no/possible/probable. The possible exposures are then manually reviewed and assigned as 'no' or 'probable' exposure using all available evidence.

The occupational asthma-specific JEM (OAsJEM: http://oasjem.vjf.inserm.fr/ index-en.htmindex.htm#) is a recently updated version of an asthma-specific JEM developed in the late 1990s.[302] The original JEM, developed in France and known as the SK-JEM, is a cross-tabulation with a two-digit or four-digit International Standard Classification of Occupations, 1988 (ISCO-88) on one axis and the asthmagen agents on the other axis.[116] This JEM assessed exposures (exposed/unexposed) to 18 asthmagens and four agents with low risk for asthma and has been used in several large epidemiological studies.[116, 303] The updated version assesses exposures to 30 asthmagen agents and classifies exposures semi-quantitatively into three groups: i) high: high probability of exposure and moderate to high intensity, ii) medium: low to moderate probability or low intensity of exposure, such as 'high probability and low intensity' or 'low probability and moderate to high intensity, and iii) no exposure: unlikely to be exposed (low probability and low intensity).[302] The updated version has been used in epidemiological studies conducted in Northern Europe, Australia and Denmark.[304-306]

The aim of this study is to estimate the agreement between the assessment of occupational exposures to asthmagens among healthcare workers in Australia and Bhutan using OccIDEAS and the OAsJEM.

8.3 Methods

8.3.1 Study population and data collection

The present study uses data from two sources: 1) The Australian Work Exposures Study-Asthma (AWES-Asthma) and 2) a cross-sectional study conducted in Bhutan (hereafter referred to as the Bhutan healthcare workers study). Detailed methodologies for study populations and data collection have been described in Chapters 5 and 7. In brief, in the AWES-Asthma study, participants were randomly selected from a list of Australian households provided by a commercial broker. All Australian residents aged 18 to 64 years currently in paid employment who were able to complete an interview in English were eligible for the study. A total of 38,051 households were contacted, of which 6314 were eligible for the study and 4878 participants completed the interviews. Participants were asked to provide demographic information such as age, gender, education, country of birth and postcode. They were then asked about their job and the main tasks they performed in that job. The present study uses data from 426 healthcare workers in the AWES-Asthma study.

In the Bhutan healthcare workers study, all healthcare workers aged 18 to 60 years who were working in the three study hospitals located in the western region of Bhutan were eligible to participate, except for traditional medical practitioners and administrative personnel. Data were collected using hard-copy questionnaires distributed to healthcare workers who were randomly selected from the three hospitals. A total of 384 questionnaires were distributed, of which 370 were completed. These questionnaires collected demographic information such as age, gender, education, ethnicity, and information on the participants' current job such as job title, hospital they were working in and how long they had worked as a healthcare worker. The questionnaire also obtained information on the tasks carried out in their jobs and about any control measures used.

8.3.2 Exposure assessment by OccIDEAS

Exposure assessment by OccIDEAS has also been described in detail in Chapters 5 and 7. In brief, exposure was assessed to 27 asthmagen groups in the AWES-Asthma study and to 14 asthmagen groups in the Bhutan healthcare workers study (Table 8.1). The exposure was assigned as 'no' or 'probable' exposure. Levels of exposure were not assessed in either of the studies.

Table 8.1 Grouping of agents assessed in OccIDEAS and the Asthma-specific JEM (OAsJEM) for the analyses

No.	OAsJEM agents	No.	OccIDEAS agents	No.	Agents for the present study
1.	Animals	1.	Derived from animals	1.	Animals
2.	Fish/shellfish	2.	Derived from fish/shellfish	2.	Fish
3.	Flour	3.	Flour	3.	Flour
4.	Foods	4.	Foods	4.	Foods
5.	Plant-related dusts	5. 6.	Flowers Derived from plants-other	5.	Plants
6.	Enzymes	7.	Biological enzymes	7.	Enzymes
7. 8. 9.	House dust mites Storage mites Plant mites	8.	Arthropods or mites	6.	Mites
10.	Latex	9.	Latex*	8.	Latex
11. 12.	Moulds Endotoxins	10.	Bio aerosols*	9.	Bio aerosols
13.	Drugs	11.	Medications*	10.	Drugs
14.	High level disinfectants	12. 13.	Aldehydes* Ethylene oxide*	11.	High level disinfectants
15.	Aliphatic amines	14.	Amines*	12.	Amines
16.	Isocyanates	15.	Isocyanates*	13.	Isocyanates
17.	Acrylates	16.	Acrylates*	14.	Acrylates
18.	Epoxy resins	17.	Epoxy*	15.	Epoxy
19.	Wood	18.	Wood dusts	16.	Wood
20.	Metals	19. 20.	Metals soldering	17.	Metals
21. 22. 23.	Herbicides Insecticides Fungicides	21.	Pesticides	18.	Pesticides
24. 25.	Indoor cleaning + Bleach	22. 23.	Industrial cleaning /sterilising agents* + Ammonia*	19.	Cleaning agents
26.	Textile		-		dropped
27.	Persulphates/henna		-		dropped
28.	Metal working fluids		-		dropped
29.	Organic solvents		-		dropped
30.	Exhaust fumes		-		dropped
	-	24.	Acids*		dropped
	-	25.	Anhydrides		dropped
	-	26.	Other reactive chemicals*		dropped
	-	27.	Reactive dyes*		dropped

*OccIDEAS agents assessed in the Bhutan healthcare workers study. All 27 OccIDEAS agents were assessed in the AWES-Asthma study

8.3.3 Exposure assessment using the OAsJEM

Since the OAsJEM uses ISCO-88 coding, participants' jobs were first coded according to the ISCO-88 four digit coding system using information on job titles, main tasks performed, employer industry and education for both the studies. As per the JEM instructions, the OAsJEM was applied in two steps. In the first step, the OAsJEM was applied to all ISCO-88 groups and exposures were assigned as high/medium/no exposures. The application of the OAsJEM also includes a second step where certain ISCO-88 codes with heterogeneous exposures require re-evaluation using specific recommendations provided in the JEM for reviewing these exposures (Table 8.2). In the second step, exposures in certain ISCO-88 groups were reviewed and a new exposure level was assigned as per the instructions/recommendations in the JEM. For example, for all nursing and midwifery professionals (ISCO-88 code 2230), in step one, the exposure assigned for high level disinfectants was medium. In step two, for those nurses working in highly exposed units such as endoscopy, dialysis, intensive care unit, histology, pathology, pharmacology and operating rooms, exposures were re-assigned as high instead of medium.

In step two for the AWES-Asthma study, exposures were re-assigned from high/medium to no exposure for 24 participants (for fish/shellfish and latex) and from no exposure to high exposure for four participants (for high level disinfectants and drugs: Table 8.2). Exposures were re-assigned from medium to high for 51 participants (for latex, high level disinfectants and house mites) and from high to medium for one participant (for drugs).

In the Bhutan healthcare workers study in step two, exposures were re-assigned from medium to no exposures for 19 participants (for fish/shellfish and acrylates) and from no exposures to medium/high exposures for 53 participants (for amines, drugs, latex, and high level disinfectants). Exposures were re-assigned from medium to high for 146 participants (for latex and high level disinfectants).

Table 8.2 Occupation groups in the AWES-Asthma and Bhutan healthcare workers studies where exposures were re-assigned in step two according to OAsJEM instructions

ISCO-88 Code	ISCO-88 Description	Agent	Original level of exposure assigned	New exposure level assigned in step two	Number of participants who were assigned a new exposure		Instructions in the OAsJEM for re-assigning exposures in step two*
					AWES-Asthma study	Bhutan healthcare workers study	
2211	Biologists, botanists, zoologists and related professionals	Fish/shellfish	Medium	No	8	5	If there is no evidence of this person works regularly with fish recode fish=0
2122	Pharmacologists, pathologists and related professionals	High level disinfectants	Medium	High	1	1	Recode chemical disinfectants =2, if clear evidence that this person works in highly exposed units such as in histology, pathology, pharmacology, operating room, intensive care unit, endoscopy, dialysis
2221	Medical doctors	Latex	Medium	High	2	12	Recode latex=2 if surgeon
2230	Nursing and midwifery professionals	Latex	High	No	14	0	Recode latex=0 for nurses not based in hospitals (e.g. public health nurse, district nurse, nurse in school, occupational health nurse, research nurse, nurse educator etc.)
2230	Nursing and midwifery professionals	High level disinfectants	Medium	High	31	74	Recode chemical disinfectants=2 if midwife or bronchoscopy, operating room or gastroenterology or geriatric or pediatric nurse or if clear evidence that this worker is using frequently such products (histology, pathology, pharmacology, intensive care unit, endoscopy, dialysis)
2230	Nursing and midwifery professionals	Drugs	No	High	2	10	Recode drugs=2 only if oncology or geriatric nurse or if clear evidence that this worker is preparing drugs, keep 0 in other cases
3133	Medical equipment operators	High level disinfectants	Medium	High	10	7	Recode chemical disinfectants=2 if radiography, histology, bronchoscopy, or gastroenterology technician, or if technician working in hospital sterile supply department; otherwise keep 1
3211	Life science technicians	High level disinfectants	No	High	2	19	Recode chemical disinfectants=2 if clear evidence that this person works in histology, pathology, pharmacology otherwise keep 0

3221	Medical assistants	High level disinfectants	No	High	0	1	Recode chemical disinfectants =2 if clear evidence that this person works in highly exposed units such as in histology, pathology, pharmacology, operating room, intensive care unit, endoscopy, dialysis
3225	Dental assistants	Acrylates	Medium	No	0	14	If working as a dental hygienist recode acrylate=0
3228	Pharmaceutical assistants	Latex	Medium	No	1	0	Recode latex=0 if clear evidence of no use of latex gloves
3228	Pharmaceutical assistants	Drugs	High	Medium	1	0	Recode drugs=1 if not clear evidence that this worker is preparing drugs, keep 2 in other cases
3228	Pharmaceutical assistants	Amines	No	Medium	0	7	If clear evidence of daily use of drugs, recode amines=1, otherwise leave as is
3229	Modern health associate professionals (except nursing) not elsewhere classified	High level disinfectants	No	High	0	8	Recode chemical disinfectants=2 if clear evidence that this person works in in highly exposed units such as in histology, pathology, pharmacology, operating room, intensive care unit, endoscopy, dialysis
3229	Modern health associate professionals (except nursing) not elsewhere classified	Latex	No	High	0	8	Recode latex=2 if clear evidence that this person works in personal nursing care in an operating room, a dental practice, or a geriatric care facility, otherwise leave as is
3231	Nursing associate professionals	Latex	High	No	1	0	Recode latex=0 for associate nursing professionals not based in hospitals (e.g. public health, in school, occupational health nurse, research, education etc.)
5132	Institution-based personal care workers	Latex	Medium	High	0	18	Recode latex=2 if clear evidence that this person works in personal nursing care in an operating room, oncology, a dental practice, or a geriatric care facility or in hospital , otherwise leave as is
5132	Institution-based personal care workers	High level disinfectants	Medium	High	0	18	Recode chemical disinfectant=2 if clear evidence that this person works in personal nursing care in an operating room, oncology, a dental practice, or a geriatric care facility or in hospital , otherwise leave as is
5133	Home-based personal care workers	House dust mites	Medium	High	16	0	Recode house dust mite=2 if evidence that a major part of the work is cleaning or sweeping in private home and mites are common in homes in the considered country

9132	Helpers and cleaners in offices, hotels and other establishments	High level disinfectants	Medium	High	9	16	Recode as chemical disinfectant=2 if work is mainly indoor cleaning or extensive personal care of elderly persons in institution; otherwise leave as it is

Note:* 0= No exposure, 1= medium exposure and 2= High exposure

8.3.4 Grouping of agents for the analyses

Since OccIDEAS assesses exposures to 27 asthmagen groups and the OAsJEM assesses exposures to 30 agents, some agents were grouped together for the analyses in this study and some were dropped (Table 8.1). This resulted in the assessment of exposure to a total of 19 agents for the AWES-Asthma study and nine agents for the Bhutan healthcare workers study.

8.3.5 Statistical analysis

In OccIDEAS, exposures were assigned as 'no' or 'probable' whereas the exposures in the OAsJEM were assigned as 'high', 'medium', and 'no' exposures. Therefore, a binary variable (exposed/unexposed) was created for exposures assessed by the JEM, where high and medium exposures were combined together and recoded as exposed.

All analyses were conducted using STATA 16 (StataCorp, College Station. TX). Frequencies were calculated to describe the prevalence of exposures to the various asthmagens assessed by OccIDEAS and the OAsJEM. Cohen's Kappa coefficients (κ) and confidence intervals together with percentage agreement were estimated to analyse the agreement between the exposures assessed by the two methods. The agreement was interpreted using established cut-points for κ (i.e., poor 0.00-0.20, fair 0.21-0.40, moderate 0.41-0.60, strong 0.61-0.80, and almost perfect agreement 0.81-1.00) and percentages of agreement (≥75% was considered acceptable).[282] In addition, for agents with lowest agreement between the two methods (for high level disinfectants and acrylates), the proportion of participants assigned as exposed by each method was calculated.

8.4 Results

8.4.1 The AWES-Asthma study

With both exposure assessment methods, there were high prevalences of exposure to cleaning and disinfecting agents (77.9% by OccIDEAS and 76.3% by the OAsJEM: Table 8.3) and latex (62.2% by OccIDEAS and 79.1% by the OAsJEM). The most striking difference in prevalence was seen for exposure to high level disinfectants (4.9% in OccIDEAS versus 81.7% in the OAsJEM). For all other agents, the prevalence of exposures were quite low. For a majority of agents, the prevalence was higher when assessed by OccIDEAS than when assessed by the OAsJEM. In addition, the exposure assessment by OccIDEAS identified exposures to a greater number of agents than that by the OAsJEM (16 versus 7). Of the eight additional agents identified by OccIDEAS, the ISCO-88 titles of the two agents with the highest prevalence who were assigned as exposed by OccIDEAS were as follows: i) exposure to plants - nursing and midwifery professionals, nursing associate professionals, and personal care workers (institution and home-based); and ii) exposure to bio-aerosols - biologists, botanists, zoologists and related professionals, nursing and midwifery professionals, nursing associate professionals, personal care workers (institution and home-based), and helpers and cleaners in offices, hotels and other establishment.

Agreement between the two methods could be assessed for seven agents (Table 8.3). Although the percentage agreement was acceptable for five of the seven agents (i.e., ≥75%), the agreement as indicated by κ for all agents was poor to fair (ranging from 0.02 to 0.37), except for exposure to agents derived from animals where the agreement was moderate (κ = 0.52).

Table 8.3 Comparison of OccIDEAS and the Asthma-specific JEM (OAsJEM) assessments of exposure to asthmagens among healthcare workers in Australia (N=426)

	n (%) exposed		2 x 2				Cohen's Kappa (95% confidence interval)	% agreement
	OccIDEAS	OAsJEM	YY[a]	YN[b]	NY[c]	NN[d]		
Cleaning/disinfecting agents	332 (77.9)	325 (76.3)	266	66	59	35	0.17 (0.07 - 0.27)	70.66
Latex	265 (62.2)	337 (79.1)	219	46	118	43	0.10 (0.01 - 0.19)	61.50
Arthropods/mites antigens	56 (13.2)	28 (6.6)	18	38	10	360	0.37 (0.24 - 0.51)	88.73
Acrylates	27 (6.3)	11 (2.6)	2	25	9	390	0.07 (-0.06 - 0.21)	92.02
High level disinfectants	21 (4.9)	348 (81.7)	20	1	328	77	0.02 (0.00 - 0.03)	22.77
Derived from animals	11 (2.6)	8 (1.9)	5	6	3	412	0.52 (0.24 - 0.79)	97.89
Drugs	6 (1.4)	10 (2.4)	3	3	7	413	0.36 (0.06 - 0.67)	97.65
Plants	81 (19.0)	0 (0.0)	-	-	-	-	-	-
Bio-aerosols	57 (13.4)	0 (0.0)	-	-	-	-	-	-
Pesticides	51 (12.0)	0 (0.0)	-	-	-	-	-	-
Biological enzymes	45 (10.6)	0 (0.0)	-	-	-	-	-	-
Epoxy	4 (0.9)	0 (0.0)	-	-	-	-	-	-
Foods	3 (0.7)	0 (0.0)	-	-	-	-	-	-
Amines	2 (0.5)	0 (0.0)	-	-	-	-	-	-
Derived from fish	1 (0.2)	0 (0.0)	-	-	-	-	-	-
Isocyanates	1 (0.2)	0 (0.0)	-	-	-	-	-	-
Flour associated antigens	0 (0.0)	0 (0.0)	-	-	-	-	-	-
Metals	0 (0.0)	0 (0.0)	-	-	-	-	-	-
Wood dusts	0 (0.0)	0 (0.0)	-	-	-	-	-	-

[a] Yes/Yes; [b] Yes/No; [c] No/Yes; [d] No/No with the first yes/no representing assessment by OccIDEAS

Table 8.4 shows the proportion of participants assigned as exposed to high level disinfectants using the two methods. All participants (100%) in twelve ISCO-88 codes were assigned as exposed by the OAsJEM; whereas in the OccIDEAS assessment, the proportion of participants who were exposed in the same ISCO-88 codes varied.

Table 8.4 Participants assigned as exposed to high level disinfectants in AWES-Asthma study by the OAsJEM and OccIDEAS

ISCO-88 code	ISCO-88 Title	Total participants in each ISCO-88 code	Exposure assessment by OAsJEM		Exposure assessment by OccIDEAS	
			Exposed n	Exposed %	Exposed n	Exposed %
2211	Biologists, botanists, zoologists and related professionals	8	8	100.0	6	75.0
2212	Pharmacologists, pathologists and related professionals	1	1	100.0	0	0.0
2221	Medical doctors	18	18	100.0	0	0.0
2222	Dentists	2	2	100.0	0	0.0
2230	Nursing and midwifery professionals	200	200	100.0	9	4.5
3133	Medical equipment operators	10	10	100.0	1	10.0
3211	Life science technicians	2	2	100.0	1	50.0
3225	Dental assistants	9	9	100.0	1	11.1
3231	Nursing associate professionals	23	23	100.0	1	4.3
3232	Midwifery associate professionals	1	1	100.0	0	0.0
5132	Institution-based personal care workers	60	60	100.0	1	1.7
5133	Home-based personal care workers	28	0	0.0	1	3.6
9132	Helpers and cleaners in offices, hotels and other establishment	14	14	100.0	0	0.0

Table 8.5 shows the proportion of participants assigned as exposed to acrylates using the two methods. All participants (100%) in two ISCO-88 codes were assigned as exposed by the OAsJEM, whereas in the OccIDEAS assessment, participants from four ISCO-88 codes were exposed to acrylates and the proportions varied.

Table 8.5 Participants assigned as exposed to acrylates in AWES-Asthma study by the OAsJEM and OccIDEAS

ISCO-88 code	ISCO-88 Title	Total participants in each ISCO-88 code	Exposure assessment by OAsJEM		Exposure assessment by OccIDEAS	
			Exposed n	Exposed %	Exposed n	Exposed %
2221	Medical doctors	18	0	0.0	8	44.4
2222	Dentists	2	2	100.0	0	0.0
2230	Nursing and midwifery professionals	200	0	0.0	16	8.0
3225	Dental assistants	9	9	100.0	2	22.2
5132	Institution-based personal care workers	60	0	0.0	1	1.7

8.4.2 The Bhutan healthcare workers study

In the Bhutan study, only nine of the 19 agents were assessed. The prevalence of exposure assessed by OccIDEAS was higher for four agents (latex, cleaning and disinfecting agents, acrylates, and epoxy) and the prevalence assessed by the OAsJEM was higher for three agents (high level disinfectants, drugs, and amines: Table 8.6). In this study, as in the Australian study, exposure to latex and cleaning and disinfecting was high by both methods and the greatest difference in prevalence was seen for exposure to high level disinfectants (35.1% in OccIDEAS versus 89.2% in the OAsJEM). Exposure assessment by the OAsJEM identified a slightly higher number of agents than by OccIDEAS assessment (6 versus 5). Agreement between the two methods could be assessed for four agents (Table 8.6). Agreement as indicated by κ was poor for all the four agents (ranging from -0.06 to 0.13), although the percentage agreement was acceptable for two agents (i.e., ≥75% for latex and acrylates).

Table 8.6 Comparison of OccIDEAS and the Asthma-specific JEM (OAsJEM) assessments of exposure to asthmagens among healthcare workers in Bhutan (N=370)

	n (%) exposed		2 x 2				Cohen's Kappa (95% confidence interval)	% agreement
	OccIDEAS	OAsJEM	YY[a]	YN[b]	NY[c]	NN[d]		
Latex	350 (94.6)	293 (79.2)	281	69	12	8	0.09 (-0.01 - 0.18)	78.11
Cleaning/ disinfecting agents	318 (86.0)	213 (57.6)	194	124	19	33	0.13 (0.05 - 0.21)	61.35
High level disinfectants	130 (35.1)	330 (89.2)	121	9	209	31	0.04 (0.00 - 0.09)	41.08
Acrylates	40 (10.8)	14 (3.8)	0	40	14	316	-0.06 (-0.09 - -0.03)	85.41
Epoxy	3 (0.8)	0 (0.0)	-	-	-	-	-	-
Drugs	0 (0.0)	21 (5.7)	-	-	-	-	-	-
Amines	0 (0.0)	7 (1.9)	-	-	-	-	-	-
Bio-aerosols	0 (0.0)	0 (0.0)	-	-	-	-	-	-
Isocyanates	0 (0.0)	0 (0.0)	-	-	-	-	-	-

[a] Yes/Yes; [b] Yes/No; [c] No/Yes; [d] No/No with the first yes/no representing assessment by OccIDEAS

Table 8.7 shows the proportion of participants assigned as exposed to high level disinfectants using the two methods. All participants (100%) in ten ISCO-88 codes were assigned as exposed by the OAsJEM, whereas in the OccIDEAS assessment, the proportion of participants who were exposed in the same ISCO-88 codes varied.

Table 8.8 shows the proportion of participants assigned as exposed to acrylates using the two methods. All dentists and dental assistants who were not dental hygienists were assigned as exposed to acrylates by the OAsJEM, whereas in the OccIDEAS assessment, participants from six ISCO-88 codes were exposed to acrylates and the proportions varied.

Table 8.7 Participants assigned as exposed to high level disinfectants in the Bhutan healthcare workers study by the OAsJEM and OccIDEAS

ISCO-88 code	ISCO-88 Title	Total participants in each ISCO-88 code	Exposure assessment by OAsJEM		Exposure assessment by OccIDEAS	
			Exposed n	Exposed %	Exposed n	Exposed %
2211	Biologists, botanists, zoologists and related professionals	5	5	100.0	4	80.0
2212	Pharmacologists, pathologists and related professionals	1	1	100.0	1	100.0
2221	Medical doctors	42	42	100.0	3	7.1
2222	Dentists	13	13	100.0	8	61.5
2224	Pharmacists	3	0	0.0	1	33.3
2230	Nursing and midwifery professionals	176	176	100.0	54	30.7
3133	Medical equipment operators	7	7	100.0	1	14.3
3211	Life science technicians	32	19	59.4	22	68.8
3221	Medical assistants	10	10	100.0	2	20.0
3225	Dental assistants	15	15	100.0	15	100.0
3226	Physiotherapist and related associated professionals	5	0	0.0	1	20.0
3229	Modern health associate professionals (except nursing) not elsewhere classified	9	8	88.9	5	55.6
5132	Institution-based personal care workers	18	18	100.0	9	50.0
8322	Car, taxi and van drivers	4	0	0.0	1	12.5
9132	Helpers and cleaners in offices, hotels and other establishment	16	16	100.0	3	18.8

Table 8.8 Participants assigned as exposed to acrylates in AWES-Asthma study by the OAsJEM and OccIDEAS

ISCO-88 code	ISCO-88 Title	Total participants in each ISCO-88 code	Exposure assessment by OAsJEM		Exposure assessment by OccIDEAS	
			Exposed n	Exposed %	Exposed n	Exposed %
2221	Medical doctors	42	0	0.0	4	9.5
2222	Dentists	13	13	100.0	0	0.0
2230	Nursing and midwifery professionals	176	0	0.0	30	17.0
3225	Dental assistants	15	1	6.7	1	6.7
3226	Physiotherapist and related associated professionals	5	0	0.0	1	20.0
3229	Modern health associate professionals (except nursing) not elsewhere classified	9	0	0.0	3	33.3
9132	Helpers and cleaners in offices, hotels and other establishment	16	0	0.0	1	6.3

8.5 Discussion

This study aimed to compare exposure assessment of asthmagens in healthcare workers by rule-based automated algorithms (OccIDEAS) and a previously developed asthma-specific JEM (OAsJEM) using data from two separate studies conducted in Australia and Bhutan. The agreement between the two methods as assessed by Cohen's κ was poor to fair for most of the agents assessed in the AWES-Asthma study and was poor for all the agents assessed in the Bhutan healthcare workers study.

The poor agreement between the two methods appears to be mainly due to the inter-individual variation of tasks within a job. OccIDEAS consists of task-based questions to which expert-derived algorithms are applied for assigning exposures, whereas in the OAsJEM the same exposure is assigned to a job title irrespective of inter-individual variations. This was shown when the proportion of participants assigned as exposed was compared between the two methods for the agents with the lowest agreement (for high level disinfectants and acrylates). For exposure assessment to high level disinfectants in the OAsJEM, all participants in twelve and ten ISCO-88 codes were assigned as exposed in the AWES-Asthma and the Bhutan healthcare workers studies, respectively, resulting in an overestimation of exposure. When exposures were assessed by OccIDEAS, the proportion of participants in each ISCO-88 codes varied considerably. In OccIDEAS, participants were asked specifically if they carried out sterilisation or instrument disinfection, and if so, they were asked to select the chemical they used from a list of chemicals (glutaraldehyde, formaldehyde, ethylene oxide, quaternary ammonium compounds, peracetic acid, or other chemicals they could volunteer). For exposure to acrylates, exposure assessment by OccIDEAS assigned exposures to varying proportions of participants from four to six different ISCO-88 groups, whereas only participants who were dentists or dental assistants (but were not dental hygienists) were assigned as exposed to acrylates by the OAsJEM resulting in an underestimation of exposure. For acrylate exposure in OccIDEAS, participants were asked if they handled bone cement, used cyanoacrylate super glues, or whether they manufactured crowns, false teeth or bridges and if they used an enclosed system to do so. Rule-based algorithms principally aim to increase inter-individual contrasts in exposures using task-based determinants of exposures.[121] Task-specific questions are not only less prone to recall bias as participants are able to report work tasks more accurately,[114] but as shown in this study, they also assist in identifying within-job differences in exposure. The findings of this study are similar to the only other study that has evaluated agreement between a task-based questionnaire algorithm and a JEM, where similar low levels of agreement between the two methods was reported in the assessment of exposure to asbestos ($\kappa = 0.36$ and weighted $\kappa = 0.26$).[117]

The level of agreement between the two methods was poor for all four agents that could be assessed in both the Australian and Bhutanese studies (i.e., cleaning and disinfecting agents, latex, acrylates and high level disinfectants), with most of the κ values lower in the Bhutanese study. In addition to task-based inter-individual variations, the poor agreement between the two methods could also be due to inter-country differences in exposure circumstances such as work environments and available control measures. Exposure circumstances were taken into account in OccIDEAS. The task-based questions in OccIDEAS for the AWES-Asthma study were developed for the Australian workplaces and included the use of various control measures where appropriate (Chapters 4 and 5). Similarly, the questionnaire used in the Bhutan healthcare workers study was adapted to suit the Bhutanese work environment (Chapter 6). The findings from this study raise the issue of the applicability of a JEM developed for one country to exposure circumstances in another country. Previous studies have shown differences in agreement between JEMs developed in different countries. In a study comparing the SK-JEM (developed in France) to a JEM developed for use primarily in Northern Europe (N-JEM), the kappa score for asthma-related exposure was 0.78.[307] However, when the N-JEM was compared to a JEM developed in the US (USA-JEM), the kappa score was 0.54.[308] Other studies have reported some misclassification of exposures in the application of JEMs outside the country of origin or geographical region, and reported that this misclassification depended on the agents assessed and their prevalence of exposures.[309, 310] As indicated by the very low levels of agreement between the two methods in the Bhutan healthcare workers study, the issue of cross-country applicability of JEMs is of particular significance when applying a JEM from a high-income country to a low-income country where the exposure circumstances may be completely different.

OccIDEAS identified exposures to a greater number of agents than the JEM in the present study. This included agents that are not typically associated with healthcare workers, and hence were not detected by the JEM, such as plants, bioaerosols, pesticides and biological enzymes. This finding provides additional support for the advantage of task-based exposure assessment over using job title as a surrogate measure of exposure.

The expert assessment method is considered the best available method for exposure assessment and is usually used as a gold standard for comparison.[114, 117, 118] Although comparisons were not made with the expert assessment method in this study, a previous study assessing the agreement between OccIDEAS and expert assessment showed moderate to almost perfect agreement in assessing exposures to 10 common asthmagens.[311] Other studies that have compared rule-based exposure assessment methods using task level data to expert assessments have shown reasonable agreements for agents such diesel exhausts, pesticides, solvents and asbestos.[117, 119, 312] On the other hand, studies comparing inter-method agreement between JEMs and experts have largely shown poor to fair agreement for various agents such as asbestos (κ = 0.10 to 0.36), silica (κ =0.38), solvents (κ =0.07 to 0.28), lead (κ =0.33), insecticides (κ =0.46) and polycyclic aromatic hydrocarbons (κ =0.40).[117, 310, 313, 314]

This study has some limitations. Since OccIDEAS assessed exposures as yes/no, the semi-quantitative metrics of the OAsJEM were recoded to correspond to that of OccIDEAS. The agreement was therefore assessed for yes/no and not for intensity. Further, because of small numbers of healthcare workers exposed to some agents, the agreement could not be evaluated for all the agents, and exposures to only a small number of agents could be compared (especially for the Bhutan healthcare workers study). In addition, there could have been some discrepancies when grouping the agents for comparison, which may have affected the exposure metrics assigned to these grouped agents. This might have occurred when grouping the agents for cleaning and sterilising agents and for high level disinfectants since these groups comprise a wide variety of chemicals. Despite these limitations, this is one of the few studies that has assessed the agreement between rule-based automatic algorithms and a JEM and is the first study to do so for asthmagen exposures. This study is also the first study to include comparison of exposure assessment in a low-income country.

8.6 Conclusion

There was poor to fair agreement in the assessment of exposure to asthmagens in healthcare workers between rule-based automatic algorithms (OccIDEAS) and an asthma-specific JEM (OAsJEM), which was mainly due to differences in inter-individual variations of tasks within a job. The task-based assessments by OccIDEAS appeared to be more accurate in the assessment of asthmagen exposures in healthcare workers than the OAsJEM, which overestimated or underestimated certain exposures (e.g. high level disinfectants, acrylates). OccIDEAS identified exposures to more agents than the OAsJEM, including agents that were not typically associated with healthcare workers. As compared to the OAsJEM, OccIDEAS appeared to be more appropriate for evaluating cross-country exposures to asthmagens in healthcare workers due to its inherent quality of assessing task-based determinants and its versatility in being adaptable for use in different countries with different exposure circumstances.

Chapter 9 : General Discussion and conclusion

In this final chapter, the aims are revisited, and the key findings of the thesis and implications are discussed. This chapter also discusses the strengths and limitations of the thesis as a whole, explores future directions and ends with overall conclusions.

9.1 Discussion of key findings and implications

9.1.1 Exposure to asthmagens, carcinogens and ototoxic agents among healthcare workers in Australia and Bhutan

The main aim of the thesis was to examine occupational exposures to hazardous chemicals and agents among healthcare workers in Australia and Bhutan. Data were analysed from three population-based cross-sectional studies conducted in Australia (Chapter 5). A cross-sectional survey was conducted among healthcare workers in three hospitals in Bhutan (Chapter 7) using a questionnaire adapted and tested for use in Bhutan (Chapter 6). The prevalence of exposures to various hazardous agents was calculated, the main agents and tasks leading to these exposures were determined, and any associations with demographic and occupational characteristics were examined.

The findings show that a substantial proportion of healthcare workers were exposed to a wide range of hazardous agents linked to chronic diseases in both Australia, a high-income country and Bhutan, a LMIC. The prevalences of exposure to many of the chemicals assessed were higher in Bhutan than in Australia. Each country had a distinctive exposure profile, with the main tasks and agents leading to exposures and the at-risk occupation groups for exposures being different in the two countries.

In both countries, the prevalence of exposure to asthmagens was high, with >90.0% of healthcare workers (92.3% in Australia and 98.7% in Bhutan) being exposed to at least one asthmagen (Chapters 5 and 7). A common asthmagen exposure with a high prevalence in both countries was to cleaning and disinfecting agents (77.5% in Australia and 87.3% in Bhutan). The most common tasks leading to asthmagen exposures were also related to the use of these agents: the use of chlorhexidine as an antiseptic and to clean hands in Australia and the use of bleach to clean the workplace in Bhutan.

Since the use of cleaning and disinfecting agents is essential in infection control, the complete elimination of these agents is not possible. A working group in the US has proposed the need for an integrated approach for effective cleaning and disinfecting practices to prevent infections, while protecting healthcare workers at the same time.[39] They propose establishing a committee comprising of OSH personnel, infection control staff and other stakeholders including workers. The committee would hold regular meetings to discuss and address cleaning and disinfecting issues. This committee would also be responsible for the development of a framework for selecting, implementing and monitoring preventive practices. The key preventative measure is substitution with a less toxic alternative where possible.[41] For example, chlorhexidine used in hand washing can be substituted with other alternatives such as alcohol-based hand rubs or povidone-iodine, which have shown to be as effective as chlorhexidine for their antiseptic properties.[315] In the case of cleaning products, countries such as the US have started using green cleaning products and nonchemical cleaning and disinfecting technologies (e.g., ultraviolet light, steam cleaning) in healthcare facilities as a safer alternative.[39] However, this might not be possible in low-income countries such as Bhutan due to costs. Hence, other control measures such as the use of effective ventilation where possible, replacing sprays with wipes (to prevent aerosol generation), using appropriate PPE, safe work practices and training of healthcare workers in the safe handling of these agents should be used to help reduce exposures.[41]

As shown in Chapters 5 and 7, the prevalence of exposure to latex was very high among Bhutanese healthcare workers (94.6%) as compared to Australian healthcare workers (62.2%). In high-income countries, the use of latex gloves has decreased due to prevention policies and programs aimed to reduce latex sensitization that mainly focused on substitution of latex gloves with less allergenic alternatives such as non-powdered low-protein gloves.[41] This reduction in latex glove use among healthcare workers resulted in the decrease in incidence of latex induced occupational asthma, as reported from various countries such as Belgium,[316] Canada,[35] the UK[37] and France.[38] However, latex gloves are still widely used in resource-poor countries as shown in Chapter 7. The scoping review (Chapter 3) also found evidence of wearing of latex gloves and a high prevalence of latex allergy among healthcare workers from countries such as India (16%), Sri Lanka (16.3%) and Thailand (18%). The successful implementation of primary prevention interventions in reducing latex sensitization in high-income countries needs to be replicated in LMICs to protect healthcare workers in these countries. There is a requirement for cost-effective alternatives to eliminate latex from the healthcare environment in low-income countries such as Bhutan.

The prevalence of exposure to at least one carcinogen among healthcare workers was 50.7% in Australia and 28.1% in Bhutan (Chapters 5 and 7). These figures are not directly comparable because in the Bhutanese study, only exposure to chemicals was assessed whereas in the Australian study, exposures to wider range of agents, such as shift work and environmental tobacco smoke, were assessed. However, when comparing only the chemicals, the prevalence of exposure was higher in Bhutan than in Australia for the two most common chemicals formaldehyde (18.7% versus 2.7%) and PAHs (17.3% versus 9.8%). The main tasks leading to exposure to formaldehyde were instrument disinfection and its use in the laboratory, and to PAHs was the use of diathermy. To reduce healthcare workers exposure to formaldehyde, substitution where possible, use of effective ventilation and safe work practices including the use of appropriate PPE should be carried out.[16] There is also a need to establish occupational exposure limits for chemicals such as formaldehyde in Bhutan and to institute occupational health and safety programs for surveillance and monitoring. Unlike in high-income countries, where guidelines and standards have been published setting occupational exposure limits for formaldehyde exposures,[300] such standards do not exist in many LMICs including Bhutan. There are no previous studies of exposure to diathermy smoke from other LMICs (Chapter 3). To reduce exposure to surgical smoke, the use of engineering controls such as smoke evacuation devices is recommended in all surgeries using diathermy.[92] This may not be affordable in many LMICs.

The prevalence of exposure to ototoxic agents was 44.6% among Australian healthcare workers and was only 7.6% among Bhutanese healthcare workers (Chapters 5 and 7). Here again, the figures are not directly comparable because only exposure to chemicals were assessed in the Bhutanese study whereas in the Australian study, other agents such as carbon monoxide were assessed in addition to ototoxic chemicals. In Australia, the most common ototoxic agent exposures were to toluene and p-xylene, which occurred through using and refuelling of petrol vehicles. This task is not typically associated with healthcare workers and may be related to travel undertaken to provide care to patients at home or transfer of patients in ambulances. In Bhutan, the most common exposure was to p-xylene occurring through its use in laboratories. It is important that these workers be protected from exposure to ototoxic chemicals because medical laboratory workers are an occupation group at risk for noise exposures, and ototoxic chemicals such as p-xylene can act in synergy with noise to cause hearing loss.[108] There are no previous studies of ototoxic agents from LMICs (Chapter 3).

The prevalence of the other agents assessed in Bhutan, but not in Australia, was low (anaesthetic gases 6.2% and antineoplastic gases 2.2%). The low prevalence of exposure to antineoplastic drugs is because cancer services are not yet well-established in Bhutan due to the lack of trained personnel and specialized facilities.[301] Cancer patients are usually referred to India for treatment.[281] There is a plan for the expansion of cancer services in the near future.[301] This will lead to a higher proportion of healthcare workers being potentially exposed to antineoplastic drugs and will require formulation of policies, intervention strategies and use of control measures (e.g., biological safety cabinets, use of PPE) to reduce exposures.

Exposure to the various agents varied by occupation in both countries. In Australia, nurses and health and support workers were most likely to be exposed to carcinogens and personal carers were most likely to be exposed to both carcinogens and ototoxic agents. In Bhutan, nurses were most likely to be exposed to asthmagens and other health professionals and technicians were most likely to be exposed to both asthmagens and ototoxic agents. Prevention policies and intervention strategies should be prioritised and targeted to these occupation groups. Targeted policies are particularly relevant for personal carers in Australia since this group is already vulnerable to health disparities due to their social position. Personal carers are often women from racial/ethnic minority groups, with low education levels and low income.[273]

9.1.2 Exposure to occupational hazards among healthcare workers in LMICs

Most of the research on occupational hazards are conducted in high-income countries, with research from LMICs reported to be limited.[21] A systematic scoping review was conducted as part of this research project to synthesize the available literature on occupational hazards among healthcare workers in LMICs, to determine the scope and volume of the available research and to identify any research gaps (Chapter 3). The findings show that substantial proportions of healthcare workers in LMICs were exposed to a wide range of hazards (biological, psychosocial, ergonomic and chemical) and the implementation of preventive measures was lacking. The review also found that there was a considerable body of literature on occupational hazards from LMICs, which had mostly increased in the last decade. However, almost half (48%) of this research was on biological hazards and the literature on other types of hazards was limited in comparison.

With the high population-prevalence of infectious diseases in LMICs, research on biological hazards is important. However, as indicated by the results of this review, other occupational hazards are also prevalent in LMICs and require equal attention in terms of policy changes, interventions and research. There is a need to invest in larger, well-designed studies to examine not only biological hazards, but also the other types of occupational hazards in LMICs to build up the evidence base in order to promote political commitment in prioritising occupational health and safety in these countries.

The Bhutan healthcare workers study (Chapter 7) is one of the few studies that has examined occupational exposures to chemicals among healthcare workers in a LMIC and the first to examine the prevalence of exposure to such a wide range of agents. As with exposure to other occupational hazards (biological, psychosocial and ergonomic) in LMICs, Chapter 7 showed that large proportions of healthcare workers were exposed to chemical hazards and most of the high-level control measures (engineering controls) and safer chemicals for substitution were not available in Bhutan (Chapter 6).

9.1.3 Comparison of methods of assessment of exposure to asthmagens among healthcare workers in Australia and Bhutan

Exposure assessment is an important component of occupational epidemiology studies. A secondary aim of this thesis was to compare OccIDEAS, the exposure assessment method used in this research project to a more traditional method of exposure assessment, the OAsJEM, in the assessment of exposure to asthmagens in a high-income country and a LMIC. Using healthcare workers' data from the AWES-Asthma study and the cross-sectional study conducted in Bhutan, the agreement between the two methods was assessed by calculating Cohen's kappa (Chapter 8). The results showed that the agreement between the two methods was poor to fair for most of the agents assessed in the AWES-Asthma study and poor for all the agents assessed in the Bhutan healthcare workers study.

The poor agreement was mainly because of inter-individual variations in tasks that were not accounted for in the OAsJEM. The task-based assessment carried out in OccIDEAS appeared to be more accurate in the assessment of asthmagens in healthcare workers than the OAsJEM, which overestimated or underestimated certain exposures. For example, exposure to high level disinfectants was overestimated because all participants from twelve ISO-88 were assigned as exposed by the OAsJEM; and exposure to acrylates was underestimated because only participants in two ISCO-88 groups were assigned as exposed. By assessing tasks, OccIDEAS also identified a greater number of agents than the OAsJEM and this included agents that are not typically associated with healthcare workers, which were not detected by the JEM.

The poor agreement may also be due to inter-country differences in exposure circumstances. This was not accounted for in the OAsJEM, which was developed for use in France, but was taken into account in OccIDEAS because the questionnaires used were adapted for the specific countries (Australia and Bhutan). The JEMs that are currently available are developed in high-income countries and may not be applicable to low-income countries due to differences in work circumstances such as work environments and available control measures. This difference was exemplified in Chapter 8 by the lower levels of agreement, as indicated by κ, in the Bhutan healthcare workers study as compared to the Australian study. There is a need for the development of exposure assessment methods more suitable to assess exposures to chemicals in epidemiological studies carried out in LMICs since there is usually a lack of OHS expertise and exposure measurement data in these countries.[20, 317] Chapter 8 demonstrated that OccIDEAS was appropriate for evaluating cross-country exposures, including in LMICs, since it is based on task-level determinants of exposure and because it can be adapted for use in countries with different exposure circumstances.

9.2 Strengths and limitations of the research

The strengths and limitations of the research were addressed in each chapter for the individual studies. This chapter presents an overview of these.

A major strength of this research project is that it examines occupational hazardous exposures among healthcare workers in both a high-income country and a LMIC. This allows comparisons to be made in exposure profiles and contributes to understanding the epidemiology of these exposures. For example, in both countries, exposure to cleaning and disinfecting agents was high whereas exposure to latex was higher in Bhutan than in Australia. This research also examined healthcare workers’ exposure to a wide range of hazards and agents, thus enabling the determination of the most common exposures and tasks, which can assist in the development of interventions to reduce exposures. In addition, Chapter 8 also compared two types of exposure assessment methods (a new approach, OccIDEAS versus a traditional method, the OAsJEM) to assess exposure to asthmagens among healthcare workers in both a high-income country and a LMIC, and determined which method was more appropriate for exposure assessment in each country.

Another strength is the comprehensive scoping review that synthesized the available research on occupational hazards in LMICs and identified research gaps (Chapter 3). This demonstrated the lack of studies examining occupational exposure to chemical hazards among healthcare workers in LMICs and Chapter 7 was therefore one of the few studies to address this lack and was the first study to do so in Bhutan. It was notable that the Bhutan healthcare workers study achieved a very high response fraction of 96.4%, thus demonstrating the feasibility of doing more such research in LMICs.

The research project has several limitations. The data for this research project were collected using self-reports, which can be subject to recall bias and could have resulted in some misclassification of exposures. However, it is unlikely that the data were substantially affected by this bias because participants were asked about tasks and not about exposures, and task-based questions are known to provide more accurate exposure information.[274] In addition, since the levels of exposure were not assessed, the prevalence of exposure reported is not a calculation of time-weighted exposure, but only the number of people exposed, irrespective of frequency and duration of exposure. It is important to assess levels of exposure, especially for chemicals that have standardized occupational exposure limits (e.g. for carcinogens such as formaldehyde). However, for sensitizing agents there are no exposure limit values, and any exposure can trigger allergic symptoms if a person is already sensitized to the agent.[318] Furthermore, information was collected only on the current job and not on the longest-held jobs. The use of the last job has been reported to be a satisfactory surrogate for all jobs in studies investigating the cause of diseases that are not usually preceded by disability such as cancers.[319, 320] However, in diseases leading to disability (e.g., asthma), the use of the last job can result in underestimation of the exposure since symptomatic workers are likely to change jobs to decrease exposure to the chemicals causing their symptoms.[319] In such circumstances, the first job and the longest-held job have shown to be better surrogates of exposure. Additionally, exposure to antineoplastic drugs and anaesthetic gases were not assessed in the AWES studies, and hence comparisons regarding these agents could not be made between the Australian and Bhutanese studies.

A limitation of the scoping review (Chapter 3) was that studies assessing exposure to night shift work were excluded because there is no consistent definition of night shift work. For example, in a meta-analysis published in 2014, some of the articles defined night shift work as working for more than one night per week, some defined it as two or three rotating shifts, while others had no definitions.[321] Since healthcare workers carry out night shift work, the exclusion of shift work studies would bias the results if there is existing research on exposure to shift work in healthcare workers in LMICs resulting in an incomplete representation of the research on occupational hazards among healthcare workers carried out in LMICs.

A particular limitation with the study carried out in Bhutan was that although the participants were selected by stratified random sampling, the hospitals were purposively selected. This may have resulted in selection bias affecting the representativeness of the sample and the generalisability of the results. However, as explained in Chapter 7, the healthcare system in Bhutan is publicly funded with a three-tier system of healthcare delivery, drugs and chemicals are centrally supplied, all facilities within a tier are similar in terms of the availability of drugs/chemicals, and staff are regularly transferred between these hospitals. These circumstances suggest that the findings are likely to be generalizable to other healthcare workers in the country. In addition, the questionnaire used in the study was in English and for a minority of participants (one participant in the pilot study and 41 participants in the main study) who were not proficient in the English language, the questionnaire was administered as an interview in the local language by myself during the data collection. Lastly, the 'possible' exposures were assigned as 'probable' or 'no exposures' by myself using information from material data sheets and evidence from the literature. The possible exposures were usually assigned when the participant had to fill in a response as a free text. For example, in question number 6 (pg.181) in the questionnaire (Appendix F), where the participant had to select the chemicals used in sterilisation, one of the responses was "Others (please specify)". Based on the name of the chemical provided by the participant, the exposures were assigned. If they provided a trade name instead of a generic name, the material data sheet of the product was consulted. Any uncertainties related to the exposures assigned were discussed with my supervisors, who have extensive experience in occupational epidemiology.

9.3 Future directions

Despite there being well-established and sophisticated occupational health systems in Australia, Chapter 5 demonstrated that significant proportions of healthcare workers are still being exposed to hazardous agents linked to chronic diseases. Future studies should examine why these exposures are occurring and develop interventions and policies that can reduce these exposures to prevent occupational diseases. Control measures will reduce exposures only if the workers choose to use them (e.g., the use of smoke evacuators to control exposure to surgical smoke, use of PPE). An area of research to focus on would be bringing about behaviour change in workers so that they adopt safe work practices and use control measures. A previous three-year randomized controlled study that used behavioural theory to design a feedback intervention showed a moderately significant sustained improvement in compliance with hand hygiene among healthcare workers in 16 English and Welsh hospitals.[322] Future research could focus on whether similar interventions based on behaviour theory can bring about positive behaviour change in the use of control measures and in the adoption of safe work practices to protect healthcare workers from workplace exposures.

Exposure to cleaning and disinfecting agents was a common exposure among healthcare workers in both Bhutan and Australia (Chapters 5 and 7). Since the use of cleaning and disinfection chemicals is crucial in the prevention of hospital acquired infections, there is a need for safer alternatives to reduce exposures. Green cleaning products and nonchemical cleaning and disinfecting technologies (e.g., ultraviolet light, steam cleaning) are being introduced in some countries as safer alternatives to the current chemicals used.[323] However, further research is required on the effectiveness of these products to prevent infections and on the harmful health effects associated with the use of these products since there is limited evidence to date.[39]

There is a high prevalence of exposure to workplace hazardous chemicals in Bhutanese healthcare workers (Chapter 7). In Bhutan, occupational health and safety (OSH) is still a relatively new concept. Although OSH laws have been formulated since 2007 and implemented by various government organisations, a Department of Labour report released in 2012 found that the impact on workplace safety culture was minimal and attributed this to a scarcity of OHS expertise and a general lack of awareness on the subject.[293] Future research should assess whether healthcare workers are aware of the various workplace hazards and the available control measures. This will assist in designing interventions that will reduce workplace exposures. Also, many higher-level controls (substitution and engineering controls) are not available in Bhutan (e.g., closed disinfection systems, chemotherapy gloves: Chapter 6), which may be mainly due to costs. There is a need for investment in the institution of higher level controls since this can help reduce exposure and protect healthcare workers from occupational diseases, which might be cheaper in the long run by resulting in the retention of healthcare workers. In the meantime, lower level controls (administrative and PPE) should be applied consistently to reduce exposure to chemicals. Healthcare workers should be trained on safe work practices, safe handling of chemicals and the use of appropriate PPE. There should be a system to monitor exposures and to carry out medical surveillance of occupational diseases. This requires investment in OHS human resource capacity building such as occupational hygienists and occupational health physicians, who can carry out surveillance and monitoring and provide healthcare worker training.

Chapters 5 and 7 also identified certain vulnerable occupation groups such as personal carers and medical laboratory workers that require special attention. Exposure to chemical hazards has not been studied in detail in personal carers as an occupation group.[271] More research is required in this occupation group to identify determinants of exposure and to develop interventions. Similarly, medical laboratory workers are at risk of developing hearing loss since they are at risk of exposure to both noise and ototoxic agents.[108] Further research examining these exposures is required in this occupation group.

Chapters 7 and 8 clearly showed that exposures in LMICs are different from those in high-income countries and that exposure assessment methods that are valid in high-income countries are not necessarily valid in LMICs. There is a need for further research to understand the epidemiology of occupational diseases among healthcare workers in LMICs in order to prevent them. This requires research and development of occupational assessment methods that are more suitable for accurate assessment of exposures in LMICs.

9.4 Overall conclusions

This thesis represents an important addition to the scientific literature, contributing to understanding the epidemiology of occupational hazardous exposure among healthcare workers in both Australia, a high-income country, and Bhutan, a LMIC. In addition to providing information on the prevalence of exposures to these agents, this research also determined the main tasks and agents leading to exposures, identified at-risk occupation groups and allowed for comparisons to be made on certain exposures between the two countries. The information obtained from this research can be beneficial in formulating policies and implementing control measures to protect healthcare workers. In addition, the comparison of two types of exposure assessment methods (a new approach, OccIDEAS versus a traditional method, the OAsJEM) to assess exposure to asthmagens among healthcare workers in both countries contributed to understanding the drawbacks and advantages of these methods and highlighted the importance of the development of exposure assessment methods that are more appropriate for LMICs.

References

1. McDiarmid MA. Hazards of the health care sector: Looking beyond infectious disease. Ann Glob Health. 2014; 80(4):315-9.
2. World Health Organization. The world health report 2006 - working together for health. Geneva: World Health Organization; 2006.
3. Davis KG, Kotowski SE. Prevalence of musculoskeletal disorders for nurses in hospitals, long-term care facilities, and home health care: a comprehensive review. Hum Factors. 2015; 57(5):754-92.
4. Maslach C. Burnout: The cost of caring. Cambridge, MA, USA: Malor books; 2003.
5. Phillips JP. Workplace violence against health care workers in the United States. N Engl J Med. 2016; 374(17):1661-9.
6. McDiarmid MA. Chemical hazards in health care: high hazard, high risk, but low protection. Ann N Y Acad Sci. 2006; 1076(1):601-6.
7. Lie J-AS, Andersen A, Kjærheim K. Cancer risk among 43 000 Norwegian nurses. Scand J Work Environ Health. 2007; 33(1):66-73.
8. Lie J-AS, Kjærheim K. Cancer risk among female nurses: a literature review. Eur J Cancer Prev. 2003; 12(6):517-26.
9. Vaughan TL, Stewart PA, Teschke K, et al. Occupational exposure to formaldehyde and wood dust and nasopharyngeal carcinoma. Occup Environ Med. 2000; 57(6):376-84.
10. Coggon D, Harris E, Poole J, Palmer K. Mortality of workers exposed to ethylene oxide: extended follow up of a British cohort. Occup Environ Med. 2004; 61(4):358-62.
11. Ratner PA, Spinelli JJ, Beking K, et al. Cancer incidence and adverse pregnancy outcome in registered nurses potentially exposed to antineoplastic drugs. BMC Nurs. 2010; 9:15.
12. Wiszniewska M, Walusiak-Skorupa J. Occupational allergy: respiratory hazards in healthcare workers. Curr Opin Allergy Clin Immunol. 2014; 14(2):113-8.
13. Arif AA, Delclos GL. Association between cleaning-related chemicals and work-related asthma and asthma symptoms among healthcare professionals. Occup Environ Med. 2012; 69(1):35-40.
14. Trapé M, Schenck P, Warren A. Latex gloves use and symptoms in health care workers 1 year after implementation of a policy restricting the use of powdered gloves. Am J Infect Control. 2000; 28(5):352-8.

15. Fuente A, McPherson B. Organic solvents and hearing loss: the challenge for audiology. Int J Audiol. 2006; 45(7):367-81.

16. National Institute for Occupational Safety and Health. State of the Sector: Healthcare and Social Assistance. Atlanta: Centers for Disease Control and Prevention; 2009.

17. Boiano JM, Steege AL, Sweeney MH. Adherence to safe handling guidelines by health care workers who administer antineoplastic drugs. J Occup Environ Hyg. 2014; 11(11):728-40.

18. Delclos GL, Gimeno D, Arif AA, et al. Occupational risk factors and asthma among health care professionals. Am J Respir Crit Care Med. 2007; 175(7):667-75.

19. Safe Work Australia. National hazard exposure worker surveillance. Canberra: Safe Work Australia; 2011.

20. Naidoo S. Challenges for exposure science in developing countries. Ann Work Expo Health. 2019; 63(6):614-8.

21. Owie H, Apanga P. Occupational health hazards prevailing among healthcare workers in developing countries. J AIDS Clin Res. 2016; 7(8):596.

22. World Health Organization. Raising awareness of stress at work in developing countries: protecting workers' health Series No. 6. Geneva: World Health Organization; 2007.

23. The Lancet. COVID-19: protecting health-care workers. Lancet 2020; 395(10228):922.

24. World Health Organization. World Day for Safety and Health at Work: WHO key facts & key messages to support the day [Internet]. 2020 [updated 28/04/2020; cited 5/06/2020]. Available from: https://www.who.int/news/item/28-04-2020-who-calls-for-healthy-safe-and-decent-working-conditions-for-all-health-workers-amidst-covid-19-pandemic.

25. Rix BA, Lynge E. Cancer incidence in Danish health care workers. Scand J Soc Med. 1996; 24(2):114-20.

26. McHugh MK, Symanski E, Pompeii LA, Delclos GL. Prevalence of asthma by industry and occupation in the US working population. Am J Ind Med. 2010; 53(5):463-75.

27. Gonzalez M, Jégu J, Kopferschmitt MC, et al. Asthma among workers in healthcare settings: role of disinfection with quaternary ammonium compounds. Clin Exp Allergy. 2014; 44(3):393-406.

28. Mirabelli MC, Zock J-P, Plana E, et al. Occupational risk factors for asthma among nurses and related healthcare professionals in an international study. Occup Environ Med. 2007; 64(7):474-9.

29. Arif AA, Delclos GL, Serra C. Occupational exposures and asthma among nursing professionals. Occup Environ Med. 2009; 66(4):274-8.

30. Alenius H, Turjanmaa K, Palosuo T. Natural rubber latex allergy. Occup Environ Med. 2002; 59(6):419-24.

31. Sussman GL, Beezhold DH, Liss G. Latex allergy: historical perspective. Methods. 2002; 27(1):3-9.

32. Liss GM, Sussman GL, Deal K, et al. Latex allergy: epidemiological study of 1351 hospital workers. Occup Environ Med. 1997; 54(5):335-42.

33. Lagier F, Vervloet D, Lhermet I, Poyen D, Charpin D. Prevalence of latex allergy in operating room nurses. J Allergy Clin Immunol. 1992; 90(3):319-22.

34. Filon FL, Radman G. Latex allergy: a follow up study of 1040 healthcare workers. Occup Environ Med. 2006; 63(2):121-5.

35. Tarlo SM, Easty A, Eubanks K, et al. Outcomes of a natural rubber latex control program in an Ontario teaching hospital. J Allergy Clin Immunol. 2001; 108(4):628-33.

36. Bousquet J, Flahault A, Vandenplas O, et al. Natural rubber latex allergy among health care workers: a systematic review of the evidence. J Allergy Clin Immunol. 2006; 118(2):447-54.

37. Walters G, Moore V, McGrath E, Burge P, Henneberger P. Agents and trends in health care workers' occupational asthma. Occup Med. 2013; 63(7):513-6.

38. Paris C, Ngatchou-Wandji J, Luc A, et al. Work-related asthma in France: recent trends for the period 2001–2009. Occup Environ Med. 2012; 69(6):391-7.

39. Quinn MM, Henneberger PK, Braun B, et al. Cleaning and disinfecting environmental surfaces in health care: toward an integrated framework for infection and occupational illness prevention. Am J of Infect Control. 2015; 43(5):424-34.

40. Rosenman KD, Reilly MJ, Schill DP, et al. Cleaning products and work-related asthma. J Occup Environ Med. 2003; 45(5):556-63.

41. Tarlo SM, Arif AA, Delclos GL, Henneberger P, Patel J. Opportunities and obstacles in translating evidence to policy in occupational asthma. Ann Epidemiol. 2018; 28(6):392-400.

42. Occupational Safety and Health Administration. Best practices for the safe use of glutaraldehyde in health care. U.S. Department of Labor: OSHA; 2006.

43. Safe Work Australia. Workplace exposure standards for airborne contaminants. Canberra: Safe Work Australia; 2018.

44. Waters A, Beach J, Abramson M. Symptoms and lung function in health care personnel exposed to glutaraldehyde. Am J Ind Med. 2003; 43(2):196-203.

45. Dimich-Ward H, Wymer ML, Chan-Yeung M. Respiratory health survey of respiratory therapists. Chest. 2004; 126(4):1048-53.

46. Gannon P, Bright P, Campbell M, O'hickey S, Burge PS. Occupational asthma due to glutaraldehyde and formaldehyde in endoscopy and x ray departments. Thorax. 1995; 50(2):156-9.

47. Vyas A, Pickering C, Oldham L, et al. Survey of symptoms, respiratory function, and immunology and their relation to glutaraldehyde and other occupational exposures among endoscopy nursing staff. Occup Environ Med. 2000; 57(11):752-9.

48. Rideout K, Teschke K, Dimich-Ward H, Kennedy S. Considering risks to healthcare workers from glutaraldehyde alternatives in high-level disinfection. J Hosp Infect. 2005; 59(1):4-11.

49. Fujita H, Ogawa M, Endo Y. A case of occupational bronchial asthma and contact dermatitis caused by ortho-phthalaldehyde exposure in a medical worker. J Occup Health. 2006; 48(6):413-6.

50. Occupational Safety and Health Administration. OSHA Factsheets: Formaldehyde. U.S. Department of Labor: OSHA. 2011. Available from: https://www.osha.gov/OshDoc/data_General_Facts/formaldehyde-factsheet.pdf.

51. Burge PS, Harries M, Lam W, O'brien I, Patchett P. Occupational asthma due to formaldehyde. Thorax. 1985; 40(4):255-60.

52. International Agency for Reasearch on Cancer. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Volume 88: Formaldehyde, 2-Butoxyethanol and 1-tert-Butoxypropan-2-ol. Lyon, France: IARC; 2006.

53. Kwon S-C, Kim I, Song J, Park J. Does formaldehyde have a causal association with nasopharyngeal cancer and leukaemia? Ann Occup Environ Med. 2018; 30:5.

54. Rowland AS, Baird DD, Shore DL, Darden B, Wilcox AJ. Ethylene oxide exposure may increase the risk of spontaneous abortion, preterm birth, and postterm birth. Epidemiology. 1996; 7(4):363-8.

55. Hogstedt C, Aringer L, Gustavsson A. Epidemiologic support for ethylene oxide as a cancer-causing agent. JAMA. 1986; 255(12):1575-8.

56. Hogstedt L. Epidemiological studies on ethylene oxide and cancer: an updating. IARC Sci Publ. 1988; (89):265-70.
57. Norman SA, Berlin JA, Soper KA, Middendorf BF, Stolley PD. Cancer incidence in a group of workers potentially exposed to ethylene oxide. Int J Epidemiol. 1995; 24(2):276-84.
58. Steenland K, Stayner L, Greife A, et al. Mortality among workers exposed to ethylene oxide. N Engl J Med. 1991; 324(20):1402-7.
59. International Agency for Reasearch on Cancer. IARC monographs on the evaluation of carcinogenic risks to humans: Volume 60. Some industrial chemicals. Lyon, France: IARC; 1994.
60. National Institute for Occupational Safety and Health. Control technology for ethylene oxide sterilization in hospitals. Cincinnati, Ohio: National Institute for Occupational Safety and Health; 1989.
61. Nagendran V, Wicking J, Ekbote A, Onyekwe T, Heise Garvey L. IgE-mediated chlorhexidine allergy: a new occupational hazard? Occup Med. 2009; 59(4):270-2.
62. Garvey L, Roed-Petersen J, Husum B. Is there a risk of sensitization and allergy to chlorhexidine in health care workers? Acta Anaesthesiol Scand. 2003; 47(6):720-4.
63. Dumas O, Varraso R, Boggs KM, et al. Association of hand and arm disinfection with asthma control in US nurses. Occup Environ Med. 2018; 75(5):378-81.
64. Pałaszewska-Tkacz A, Czerczak S, Konieczko K, Kupczewska-Dobecka M. Cytostatics as hazardous chemicals in healthcare workers' environment. Int J Occup Med Environ Health. 2019; 32(2):141-59.
65. National Institute for Occupational Safety and Health. NIOSH Alert: preventing occupational exposures to antineoplastic and other hazardous drugs in health care settings. Cincinnati, OH: National Institute for Occupational Safety and Health; 2004.
66. Connor TH, McDiarmid MA. Preventing occupational exposures to antineoplastic drugs in health care settings. CA Cancer J Clin. 2006; 56(6):354-65.
67. Connor TH, DeBord DG, Pretty JR, et al. Evaluation of antineoplastic drug exposure of health care workers at three university-based US cancer centers. J Occup Environ Med. 2010; 52(10):1019-27.
68. Sessink PJ, Connor TH, Jorgenson JA, Tyler TG. Reduction in surface contamination with antineoplastic drugs in 22 hospital pharmacies in the US following implementation of a closed-system drug transfer device. J Oncol Pharm Pract. 2011; 17(1):39-48.

69. Sugiura S, Nakanishi H, Asano M, et al. Multicenter study for environmental and biological monitoring of occupational exposure to cyclophosphamide in Japan. J Oncol Pharm Pract. 2011; 17(1):20-28.
70. Sessink PJ, Van De Kerkhof MC, Anzion RB, Noordhoek J, Bos RP. Environmental contamination and assessment of exposure to antineoplastic agents by determination of cyclophosphamide in urine of exposed pharmacy technicians: is skin absorption an important exposure route? Arch Environ Health. 1994; 49(3):165-9.
71. World Health Organization. Good practice in occupational health services : a contribution to workplace health. Copenhagen: WHO Regional Office for Europe; 2002.
72. Hon C-Y, Barzan C, Astrakianakis G. Identification of knowledge gaps regarding healthcare workers' exposure to antineoplastic drugs: review of literature, North America versus Europe. Saf Health Work. 2014; 5(4):169-74.
73. Davis J, McLauchlan R, Connor TH. Exposure to hazardous drugs in healthcare: an issue that will not go away. J Oncol Pharm Practice. 2011; 17:9-13.
74. Power LA, Coyne JW. ASHP guidelines on handling hazardous drugs. Am J Health Syst Pharm. 2018; 75(24):1996-2031.
75. Skov T, Maarup B, Olsen J, et al. Leukaemia and reproductive outcome among nurses handling antineoplastic drugs. Br J Ind Med. 1992; 49(12):855-61.
76. Connor TH, Lawson CC, Polovich M, McDiarmid MA. Reproductive health risks associated with occupational exposures to antineoplastic drugs in health care settings: a review of the evidence. J Occup Environ Med. 2014; 56(9):901-10.
77. Lawson CC, Rocheleau CM, Whelan EA, et al. Occupational exposures among nurses and risk of spontaneous abortion. Am J Obstet Gynecol. 2012; 206(327): e1-8.
78. Connor TH, Anderson RW, Sessink PJ, Broadfield L, Power LA. Surface contamination with antineoplastic agents in six cancer treatment centers in Canada and the United States. Am J Health Syst Pharm. 1999; 56(14):1427-32.
79. Sessink PJ, Trahan J, Coyne JW. Reduction in surface contamination with cyclophosphamide in 30 US hospital pharmacies following implementation of a closed-system drug transfer device. Hosp Pharm. 2013; 48(3):204-12.
80. Swerdlow BN. Surgical smoke and the anesthesia provider. J Anesth. 2020; 34:575-84.
81. Barrett WL, Garber SM. Surgical smoke: a review of the literature. Surg Endosc. 2003; 17:979-87.

82. Georgesen C, Lipner SR. Surgical smoke: risk assessment and mitigation strategies. J Am Acad Dermatol. 2018; 79(4):746-55.
83. Limchantra IV, Fong Y, Melstrom KA. Surgical smoke exposure in operating room personnel: a review. JAMA Surg. 2019; 154(10):960-7.
84. Choi DH, Choi SH, Kang DH. Influence of surgical smoke on indoor air quality in hospital operating rooms. Aerosol Air Qual Res. 2016; 17(3):821-30.
85. Tseng H-S, Liu S-P, Uang S-N, et al. Cancer risk of incremental exposure to polycyclic aromatic hydrocarbons in electrocautery smoke for mastectomy personnel. World J Surg Oncol. 2014; 12:31.
86. Baggish MS, Elbakry M. The effects of laser smoke on the lungs of rats. Am J Obstet Gynecol. 1987; 156(5):1260-5.
87. Baggish MS, Baltoyannis P, Sze E. Protection of the rat lung from the harmful effects of laser smoke. Lasers Surg Med. 1988; 8(3):248-53.
88. Lewin JM, Brauer JA, Ostad A. Surgical smoke and the dermatologist. J Am Acad Dermatol. 2011; 65(3):636-41.
89. Yoshifumi T, Shigenobu M, Kazuto N, et al. Mutagenicity of smoke condensates induced by CO2-laser irradiation and electrocauterization. Mutat Res. 1981; 89(2):145-9.
90. Hill D, O'Neill J, Powell R, Oliver D. Surgical smoke–a health hazard in the operating theatre: a study to quantify exposure and a survey of the use of smoke extractor systems in UK plastic surgery units. J Plast Reconstr Aesthet Surg. 2012; 65(7):911-6.
91. Benson SM, Maskrey JR, Nembhard MD, et al. Evaluation of personal exposure to surgical smoke generated from electrocautery instruments: a pilot study. Ann Work Expo Health. 2019; 63(9):990-1003.
92. National Institute for Occupational Safety and Health. Control of smoke from laser/electrical surgical procedures. Washington, DC: National Institute for Occupational Safety and Health; 1996.
93. Alp E, Bijl D, Bleichrodt R, Hansson B, Voss A. Surgical smoke and infection control. J Hosp Infect. 2006; 62(1):1-5.
94. Byhahn C, Wilke H-J, Westphal K. Occupational exposure to volatile anaesthetics. CNS Drugs. 2001; 15(3):197-215.
95. Cohen EN, Bellville JW, Brown Jr BW. Anesthesia,pregnancy and miscarriage: a study of operating room nurses and anesthetists. Anesthesiology. 1971; 35:343–7.
96. Nilsson R, Björdal C, Andersson M, et al. Health risks and occupational exposure to volatile anaesthetics–a review with a systematic approach. J Clin Nurs. 2005; 14(2):173-86.

97. Schifilliti D, Mondello S, D'Arrigo MG, Chillè G, Fodale V. Genotoxic effects of anesthetic agents: an update. Expert Opin Drug Saf. 2011; 10(6):891-9.
98. Guirguis S, Pelmear P, Roy M, Wong L. Health effects associated with exposure to anaesthetic gases in Ontario hospital personnel. Occup Environ Med. 1990; 47(7):490-7.
99. Rowland AS, Baird DD, Shore DL, et al. Nitrous oxide and spontaneous abortion in female dental assistants. Am J Epidemiol. 1995; 141(6):531-8.
100. Tannenbaum TN, Goldberg RJ. Exposure to anesthetic gases and reproductive outcome. A review of the epidemiologic literature. J Occup Med. 1985; 27(9):659-68.
101. Buring JE, Hennekens CH, Mayrent SL, et al. Health experiences of operating room personnel. Anesthesiology. 1985; 62(3):325-30.
102. Boivin J-F. Risk of spontaneous abortion in women occupationally exposed to anaesthetic gases: a meta-analysis. Occup Environ Med. 1997; 54(8):541-8.
103. Molina Aragonés J, Ayora AA, Ribalta AB, et al. Occupational exposure to volatile anaesthetics: a systematic review. Occup Med. 2016; 66(3):202-7.
104. Occupational Safety and Health Administration. Safety and Health Topics. Waste Anesthetic Gases [Internet]. [cited 12/01/2020]. Available from: https://www.osha.gov/waste-anesthetic-gases.
105. Irwin MG, Trinh T, Yao C-L. Occupational exposure to anaesthetic gases: a role for TIVA. Expert Opin Drug Saf. 2009; 8(4):473-83.
106. Deng H-B, Li F-X, Cai Y-H, Xu S-Y. Waste anesthetic gas exposure and strategies for solution. J Anesth. 2018; 32(2):269-82.
107. Vecchio D, Sasco AJ, Cann CI. Occupational risk in health care and research. Am J Ind Med. 2003; 43(4):369-97.
108. Gowda S, Saito K. Occupational hearing loss: what are some occupations not commonly considered at risk? J Occup Environ Med. 2018; 60(9):e507-8.
109. Manuele FA. Risk assessment & hierarchies of control. Prof Safety. 2005; 50(5):33-39.
110. Steege AL, Boiano JM, Sweeney MH. Secondhand smoke in the operating room? Precautionary practices lacking for surgical smoke. Am J Ind Med. 2016; 59(11):1020-31.
111. Boiano JM, Steege AL, Sweeney MH. Adherence to precautionary guidelines for compounding antineoplastic drugs: a survey of nurses and pharmacy practitioners. J Occup Environ Hyg. 2015; 12(9):588-602.

112. Henn SA, Boiano JM, Steege AL. Precautionary practices of healthcare workers who disinfect medical and dental devices using high-level disinfectants. Infect Control Hosp Epidemiol. 2015; 36(2):180-5.

113. Tsai RJ, Boiano JM, Steege AL, Sweeney MH. Precautionary practices of respiratory therapists and other health-care practitioners who administer aerosolized medications. Respir Care. 2015; 60(10):1409-17.

114. Teschke K, Olshan A, Daniels J, et al. Occupational exposure assessment in case–control studies: opportunities for improvement. Occup Environ Med. 2002; 59(9):575-94.

115. Fritschi L, Siemiatycki J, Richardson L. Self-assessed versus expert-assessed occupational exposures. Am J Epidemiol. 1996; 144(5):521-7.

116. Kennedy SM, Le Moual N, Choudat D, Kauffmann F. Development of an asthma specific job exposure matrix and its application in the epidemiological study of genetics and environment in asthma (EGEA). Occup Environ Med. 2000; 57(9):635-41.

117. Bourgkard E, Wild P, Gonzalez M, et al. Comparison of exposure assessment methods in a lung cancer case-control study: performance of a lifelong task-based questionnaire for asbestos and PAHs. Occup Environ Med. 2013; 70(12):884-91.

118. Ge CB, Friesen MC, Kromhout H, et al. Use and reliability of exposure assessment methods in occupational case–control studies in the general population: past, present, and future. Ann Work Expo Health. 2018; 62(9):1047-63.

119. Peters S, Glass DC, Milne E, Fritschi L. Rule-based exposure assessment versus case-by-case expert assessment using the same information in a community-based study. Occup Environ Med. 2014; 71(3):215-9.

120. Wheeler DC, Burstyn I, Vermeulen R, et al. Inside the black box: starting to uncover the underlying decision rules used in a one-by-one expert assessment of occupational exposure in case-control studies. Occup Environ Med. 2013; 70(3):203-10.

121. Sauvé J-F, Friesen MC. Using decision rules to assess occupational exposure in population-based studies. Curr Environ Health Rep. 2019; 6(3):148-59.

122. Fritschi L. OccIDEAS–occupational exposure assessment in community-based studies. Occup Med. 2019; 69:156-7.

123. Nuwayhid IA. Occupational health research in developing countries: a partner for social justice. Am J Public Health. 2004; 94(11):1916-21.

124. Ingersoll GL, Olsan T, Drew-Cates J, DeVinney BC, Davies J. Nurses' job satisfaction, organizational commitment, and career intent. J Nurs Admin. 2002; 32(5):250-63.

125. Liese B, Dussault G. The state of the health workforce in sub-Saharan Africa: evidence of crisis and analysis of contributing factors. Washington, DC, USA: The World Bank; 2004.
126. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol. 2005; 8(1):19-32.
127. Daudt HM, van Mossel C, Scott SJ. Enhancing the scoping study methodology: a large, inter-professional team's experience with Arksey and O'Malley's framework. BMC Med Res Methodol. 2013; 13(1):1-9.
128. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci. 2010; 5:69.
129. Colquhoun HL, Levac D, O'Brien KK, et al. Scoping reviews: time for clarity in definition, methods, and reporting. J Clin Epidemiol. 2014; 67(12):1291-4.
130. Peters M, Godfrey C, McInerney P, et al. Methodology for JBI scoping reviews. The Joanna Briggs Institute Reviewers' Manual 2015. Adelaide, South Australia: The Joanna Briggs Institute; 2015.
131. Tricco AC, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018; 169(7):467-73.
132. World Health Organization. Sources and classification of health workforce statistics. Geneva: WHO; 2008.
133. World Bank. World Bank country classification 2020 [Internet]. 2020 [cited 17th April, 2020]. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.
134. Joshi R, Reingold AL, Menzies D, Pai M. Tuberculosis among health-care workers in low-and middle-income countries: a systematic review. PLoS Med. 2006; 3(12):e494.
135. World Health Organization. Health workforce requirements for universal coverage and the sustainable development goals Geneva: WHO; 2016.
136. Cavalcante NJF, Abreu ES, Fernandes MEL, et al. Risk of health care professionals acquiring HIV infection in Latin America. AIDS Care. 1991; 3(3):311-6.
137. Adegboye AA, Moss GB, Soyinka F, Kreiss JK. The epidemiology of needlestick and sharp instrument accidents in a Nigerian hospital. Infect Control Hosp Epidemiol. 1994; 15(1):27-31.
138. Olubuyide I. Doctors at risk of hepatitis B and HIV infection from patients in Nigeria. J Roy Soc Health. 1996; 116(3):157-60.

139. Gumodoka B, Favot I, Berege Z, Dolmans W. Occupational exposure to the risk of HIV infection among health care workers in Mwanza Region, United Republic of Tanzania. Bull World Health Organ. 1997; 75(2):133-40.
140. Khuri-Bulos NA, Toukan A, Mahafzah A, et al. Epidemiology of needlestick and sharp injuries at a university hospital in a developing country: a 3-year prospective study at the Jordan University Hospital, 1993 through 1995. Am J Infect Control. 1997; 25(4):322-9.
141. Gounden YP, Moodley J. Exposure to human immunodeficiency virus among healthcare workers in South Africa. Int J Gynecol Obstet. 2000; 69(3):265-70.
142. Phipps W, Honghong W, Min Y, et al. Risk of medical sharps injuries among Chinese nurses. Am J Infect Control. 2002; 30(5):277-82.
143. Talaat M, Kandeel A, El-Shoubary W, et al. Occupational exposure to needlestick injuries and hepatitis B vaccination coverage among health care workers in Egypt. Am J Infect Control. 2003; 31(8):469-74.
144. Kermode M, Jolley D, Langkham B, Thomas MS, Crofts N. Occupational exposure to blood and risk of bloodborne virus infection among health care workers in rural north Indian health care settings. Am J Infect Control. 2005; 33(1):34-41.
145. Kermode M, Jolley D, Langkham B, et al. Compliance with Universal/Standard Precautions among health care workers in rural north India. Am J Infect Control. 2005; 33(1):27-33.
146. Nsubuga FM, Jaakkola MS. Needle stick injuries among nurses in sub-Saharan Africa. Trop Med Int Health. 2005; 10(8):773-81.
147. Obi S, Waboso P, Ozumba B. HIV/AIDS: occupational risk, attitude and behaviour of surgeons in Southeast Nigeria. Int J STD AIDS. 2005; 16(5):370-3.
148. Chelenyane M, Endacott R. Self-reported infection control practices and perceptions of HIV/AIDS risk amongst emergency department nurses in Botswana. Accid Emerg Nurs. 2006; 14(3):148-54.
149. Akinleye AA, Omokhodion FO. Work practices of primary health care workers in urban and rural health facilities in south-west Nigeria. Aust J Rural Health. 2008; 16(1):47-48.
150. Okeke E, Ladep N, Agaba E, Malu A. Hepatitis B vaccination status and needle stick injuries among medical students in a Nigerian university. Niger J Med. 2008; 17(3):330-2.
151. Taegtmeyer M, Suckling R, Nguku P, et al. Working with risk: occupational safety issues among healthcare workers in Kenya. AIDS Care. 2008; 20(3):304-10.

152. Chen L, Zhang M, Yan Y, et al. Sharp object injuries among health care workers in a Chinese province. AAOHN J. 2009; 57(1):13-16.
153. Simon LP. Prevention and management of needlestick injury in Delhi. Br J Nurs. 2009; 18(4):252-6.
154. Chakravarthy M, Singh S, Arora A, Sengupta S, Munshi N. The epinet data of four Indian hospitals on incidence of exposure of healthcare workers to blood and body fluid: A multicentric prospective analysis. Indian J Med Sci. 2010; 64(12):540-8.
155. Yacoub R, Al Ali R, Moukeh G, et al. Hepatitis B vaccination status and needlestick injuries among healthcare workers in Syria. J Glob Infect Dis. 2010; 2(1):28-34.
156. Sangwan B, Kotwal A, Verma A. Occupational exposure to blood and body fluids amongst health care workers in a teaching hospital of the armed forces. Med J Armed Forces India. 2011; 67(1):21-24.
157. Irmak Z. Needlestick and sharps injury among nurses at a state hospital in Turkey. Aust J Adv Nurs. 2012; 30(2):48-55.
158. Nasim S, Shahid A, Mustufa MA, et al. Biosafety perspective of clinical laboratory workers: a profile of Pakistan. J Infect Dev Ctries. 2012; 6(8):611-9.
159. Omorogbe VE, Omuemu VO, Isara AR. Injection safety practices among nursing staff of mission hospitals in Benin City, Nigeria. Ann Afr Med. 2012; 11(1):36-41.
160. Phillips EK, Simwale OJ, Chung MJ, et al. Risk of bloodborne pathogen exposure among Zambian healthcare workers. J Infect Public Heal. 2012; 5(3):244-9.
161. Sethi AK, Acher CW, Kirenga B, et al. Infection Control Knowledge, Attitudes, and Practices among Healthcare Workers at Mulago Hospital, Kampala, Uganda. Infect Control Hosp Epidemiol. 2012; 33(9):917-23.
162. Abkar MAA, Wahdan IMH, Sherif AAR, Raja'a YA. Unsafe injection practices in Hodeidah governorate, Yemen. J Infect Public Heal. 2013; 6(4):252-60.
163. Afridi AAK, Kumar A, Sayani R. Needle stick injuries-risk and preventive factors: a study among health care workers in tertiary care hospitals in Pakistan. Glob J Health Sci. 2013; 5(4):85-92.
164. Rajkumari N, Thanbuana BT, John NV, et al. A prospective look at the burden of sharps injuries and splashes among trauma health care workers in developing countries: true picture or tip of iceberg. Injury. 2014; 45(9):1470-8.
165. Bekele T, Gebremariam A, Ahmed K. Attitude, reporting behavour and management practice of occupational needle stick and sharps injuries among hospital healthcare workers in Bale zone, Southeast Ethiopia: a cross-sectional study. J Occup Med Toxicol. 2015; 10:42.

166. Priya NL, Krishnan KU, Jayalakshmi G, Vasanthi S. An analysis of multimodal occupational exposure leading to blood borne infections among health care workers. Indian J Pathol Microbiol. 2015; 58(1):66-68.
167. Sabermoghaddam M, Sarbaz M, Lashkardoost H, et al. Incidence of occupational exposure to blood and body fluids and measures taken by health care workers before and after exposure in regional hospitals of a developing country: a multicenter study. Am J Infect Control. 2015; 43(10):1137-8.
168. Türe Z, Ulu Kiliç A, Cevahir F, et al. Predictive factors for percutaneous and mucocutaneous exposure among healthcare workers in a developing country. J Epidemiol Glob Health. 2016; 6(3):141-6.
169. Konlan KD, Aarah-Bapuah M, Kombat JM, Wuffele GM. The level of nurses' knowledge on occupational post exposure to Hepatitis B infection in the Tamale metropolis, Ghana. BMC Health Serv Res. 2017; 17(1):1-7.
170. Matsubara C, Sakisaka K, Sychareun V, Phensavanh A, Ali M. Prevalence and risk factors of needle stick and sharp injury among tertiary hospital workers, Vientiane, Lao PDR. J Occup Health. 2017; 59(6):581-5.
171. Geberemariyam BS, Donka GM, Wordofa B. Assessment of knowledge and practices of healthcare workers towards infection prevention and associated factors in healthcare facilities of West Arsi District, Southeast Ethiopia: a facility-based cross-sectional study. Arch Public Health. 2018; 76:69.
172. Mandić B, Mandić-Rajčević S, Marković-Denić L, Bulat P. Occupational exposure to blood and bodily fluids among healthcare workers in Serbian general hospitals. Arh Hig Rada Toksikol. 2018; 69(1):61-68.
173. Hebo HJ, Gemeda DH, Abdusemed KA. Hepatitis B and C viral infection: prevalence, knowledge, attitude, practice, and occupational exposure among healthcare workers of Jimma University Medical Center, southwest Ethiopia. Sci World J. 2019; 2019:11. doi:10.1155/2019/9482607.
174. Lien LT, Hang NTL, Kobayashi N, et al. Prevalence and risk factors for tuberculosis infection among hospital workers in Hanoi, Viet Nam PLoS ONE. 2009; 4(8):e6798.
175. Mathew A, David T, Thomas K, et al. Risk factors for tuberculosis among health care workers in South India: a nested case-control study. J Clin Epidemiol. 2013; 66(1):67-74.
176. Wei Z, Yang M, Quan B, et al. Prevalence of latent tuberculosis infection among healthcare workers in China as detected by two interferon-gamma release assays. J Hosp Infect. 2013; 84(4):323-5.

177. Whitaker J, Mirtskhulava V, Kipiani M, et al. Prevalence and incidence of latent tuberculosis infection in Georgian healthcare workers. PLoS ONE. 2013; 8(3):e58202.
178. Tudor C, Van der Walt M, Margot B, et al. Tuberculosis among health care workers in KwaZulu-Natal, South Africa: a retrospective cohort analysis. BMC Public Health. 2014; 14(1):891.
179. El-Sokkary R, Abu-Taleb A, El-Seifi O, et al. Assessing the prevalence of latent tuberculosis among health care providers in Zagazig city, Egypt using Tuberculin skin test and Quantiferon-TB gold in-tube test. Cent Eur J Public Health 2015; 23(4):324-30.
180. Tudor C, Van der Walt ML, Margot B, et al. Occupational risk factors for tuberculosis among healthcare workers in KwaZulu-Natal, South Africa. Clin Infect Dis. 2016; 62(Suppl 3):S255-61.
181. He W, Chen B-D, Lv Y, et al. Use of low-dose computed tomography to assess pulmonary tuberculosis among healthcare workers in a tuberculosis hospital. Infect Dis Poverty. 2017; 6(1):68.
182. Erawati M, Andriany M. The prevalence and demographic risk factors for latent tuberculosis infection (LTBI) among healthcare workers in Semarang, Indonesia. J. Multidiscip Healthc. 2020; 13:197-206.
183. Kisa A, Dziegielewski SF, Ates M. Sexual harassment and its consequences: a study within Turkish hospitals. J Health Soc Policy. 2002; 15(1):77-94.
184. Kamchuchat C, Chongsuvivatwong V, Oncheunjit S, Yip TW, Sangthong R. Workplace violence directed at nursing staff at a general hospital in Southern Thailand. J Occup Health. 2008; 50(2):201-7.
185. Aydin B, Kartal M, Midik O, Buyukakkus A. Violence against general practitioners in Turkey. J Interpers Violence. 2009; 24(12):1980-95.
186. Gimeno D, Barrientos-Gutiérrez T, Burau KD, Felknor SA. Safety climate and verbal abuse among public hospital-based workers in Costa Rica. Work 2012; 42(1):29-38.
187. Atan ŞU, Baysan Arabaci L, Sirin A, et al. Violence experienced by nurses at six university hospitals in Turkey. J Psychiatr Ment Health Nurs. 2013; 20(10):882-9.
188. Khademloo M, Moonesi FS, Gholizade H. Health care violence and abuse towards nurses in hospitals in north of Iran. Glob J Health Sci. 2013; 5(4):211-6.
189. da Silva ATC, Peres MFT, de Souza Lopes C, et al. Violence at work and depressive symptoms in primary health care teams: a cross-sectional study in Brazil. Soc Psychiatry Psychiatr Epidemiol. 2015; 50(9):1347-55.

190. Baig LA, Shaikh S, Polkowski M, et al. Violence against health care providers: a mixed-methods study from Karachi, Pakistan. J Emerg Med. 2018; 54(4):558-66.
191. Zhao S, Xie F, Wang J, et al. Prevalence of workplace violence against Chinese nurses and its association with mental health: a cross-sectional survey. Arch Psychiatr Nurs. 2018; 32(2):242-7.
192. Abate A, Abebaw D, Birhanu A, Zerihun A, Assefa D. Prevalence and associated factors of violence against hospital staff at Amanuel Mental Specialized Hospital in Addis Ababa, Ethiopia. Psychiatry J. 2019; 2019:11. doi:10.1155/2019/3642408.
193. Yenealem DG, Woldegebriel MK, Olana AT, Mekonnen TH. Violence at work: determinants & prevalence among health care workers, northwest Ethiopia: an institutional based cross sectional study. Ann Occup Environ Med. 2019; 31:8.
194. Hacer TY, Ali A. Burnout in physicians who are exposed to workplace violence. J Forensic Leg Med. 2020; 69:101874.
195. Ashkar K, Romani M, Musharrafieh U, Chaaya M. Prevalence of burnout syndrome among medical residents: experience of a developing country. Postgrad Med J. 2010; 86(1015):266-71.
196. Ayala E, Carnero AM. Determinants of burnout in acute and critical care military nursing personnel: A cross-sectional study from Peru. PLoS ONE. 2013; 8(1):e54408.
197. Zubairi AJ, Noordin S. Factors associated with burnout among residents in a developing country. Ann Med Surg. 2016; 6:60-63. doi:10.1016/j.amsu.2016.01.090.
198. Colindres CV, Bryce E, Coral-Rosero P, et al. Effect of effort-reward imbalance and burnout on infection control among Ecuadorian nurses. Int Nurs Rev. 2018; 65(2):190-9.
199. Khan FA, Shamim MH, Ali L, Taqi A. Evaluation of job stress and burnout among anesthesiologists working in academic institutions in 2 major cities in Pakistan. Anesth Analg. 2019; 128(4):789-95.
200. Mumbwe MC, McIsaac D, Jarman A, Bould MD. A cross-sectional survey to determine the prevalence of burnout syndrome among anesthesia providers in Zambian hospitals. Anesth Analg. 2020; 130(2):310-7.
201. Li J, Fu H, Hu Y, et al. Psychosocial work environment and intention to leave the nursing profession: Results from the longitudinal Chinese NEXT study. Scand J Public Health. 2010; 38(Suppl 3):69-80.
202. Ayamolowo SJ, Irinoye O, Oladoyin MA. Job satisfaction and work environment of primary health care nurses in Ekiti State, Nigeria: an exploratory study. Int J Caring Sci. 2013; 6(3):531-42.

203. Ogunlade O, Ogunfowokan A. Clinical nurses' satisfaction with night shift in selected hospitals in Ile-Ife, Osun state, Nigeria. Int J Caring Sci. 2014; 7(1):129-39.
204. Ayalew E, Workineh Y. Job satisfaction and associated factors among nurses in Bahir Dar city administrative, North West Ethiopia, 2017. BMC Res Notes. 2019; 12:319.
205. Smith DR, Wei N, Zhao L, Wang R-S. Musculoskeletal complaints and psychosocial risk factors among Chinese hospital nurses. Occup Med. 2004; 54(8):579-82.
206. Tezel A. Musculoskeletal complaints among a group of Turkish nurses. Int J Neurosci. 2005; 115(6):871-80.
207. Fabunmi AA, Oworu JO, Odunaiya NA. Prevalence of musculoskeletal disorders among nurses in University College Hospital, Ibadan. West Afr J Nurs. 2008; 19(1):21-25.
208. de Castro AB, Cabrera SL, Gee GC, Fujishiro K, Tagalog EA. Occupational health and safety issues among nurses in the Philippines. Workplace Health Saf. 2009; 57(4):149-57.
209. Karahan A, Kav S, Abbasoglu A, Dogan N. Low back pain: prevalence and associated risk factors among hospital staff. J Adv Nurs. 2009; 65(3):516-24.
210. Mehrdad R, Dennerlein JT, Haghighat M, Aminian O. Association between psychosocial factors and musculoskeletal symptoms among Iranian nurses. Am J Ind Med. 2010; 53(10):1032-9.
211. Tinubu BMS, Mbada CE, Oyeyemi AL, Fabunmi AA. Work-Related Musculoskeletal Disorders among Nurses in Ibadan, South-west Nigeria: a cross-sectional survey. BMC Musculoskelet Disord. 2010; 11:12.
212. Arsalani N, Fallahi-Khoshknab M, Josephson M, Lagerström M. Musculoskeletal disorders and working conditions among Iranian nursing personnel. Int J Occup Saf Ergon. 2014; 20(4):671-80.
213. Barzideh M, Choobineh AR, Tabatabaee HR. Job stress dimensions and their relationship to musculoskeletal disorders in Iranian nurses. Work 2014; 47(4):423-9.
214. Munabi IG, Buwembo W, Kitara DL, Ochieng J, Mwaka ES. Musculoskeletal disorder risk factors among nursing professionals in low resource settings: a cross-sectional study in Uganda. BMC Nurs. 2014; 13(1):1-8.
215. Yasobant S, Rajkumar P. Work-related musculoskeletal disorders among health care professionals: A cross-sectional assessment of risk factors in a tertiary hospital, India. Indian J Occup Environ Med. 2014; 18(2):75-81.

216. Abaraogu UO, Ezema CI, Nwosu CK. Job stress dimension and work-related musculoskeletal disorders among southeast Nigerian physiotherapists. Int J Occup Saf Ergon. 2017; 23(3):404-9.
217. Amin NA, Quek KF, Oxley JA, Noah R, Nordin R. Emotional distress as a predictor of work-related musculoskeletal disorders in Malaysian nursing professionals. Int J Occup Environ Med. 2018; 9(2):69-78.
218. Dlungwane T, Voce A, Knight S. Prevalence and factors associated with low back pain among nurses at a regional hospital in KwaZulu-Natal, South Africa. Health SA Gesondheid. 2018; 23(0):a1028. doi:10.4102/hsag.v23i0.1082.
219. Ike E, Olawumi J. The prevalence, risk factors and coping measures of back pain among nurses in Federal Medical Centre, Abeokuta, Ogun state, Nigeria. Int J Caring Sci. 2018; 11(2):955-68.
220. Luan HD, Hai NT, Xanh PT, et al. Musculoskeletal disorders: prevalence and associated factors among district hospital nurses in Haiphong, Vietnam. Biomed Res Int. 2018:e1-e9. doi:10.1155/2018/3162564.
221. Dong H, Zhang Q, Liu G, Shao T, Xu Y. Prevalence and associated factors of musculoskeletal disorders among Chinese healthcare professionals working in tertiary hospitals: a cross-sectional study. BMC Musculoskelet Disord. 2019; 20:175.
222. Baykal U, Seren S, Sokmen S. A description of oncology nurses' working conditions in Turkey. Eur J Oncol Nurs. 2009; 13(5):368-75.
223. Agrawal A, Bhatt N, Kk S, et al. Prevalence of allergy to latex gloves among dental professionals in Udaipur, Rajasthan, India. Oral Health Prev Dent. 2010; 8(4):345-50.
224. Amarasekera M, Rathnamalala N, Samaraweera S, Jinadasa M. Prevalence of latex allergy among healthcare workers. Int. J Occup Med Environ Health. 2010; 23(4):391-6.
225. Phaswana SM, Naidoo S. The prevalence of latex sensitisation and allergy and associated risk factors among healthcare workers using hypoallergenic latex gloves at King Edward VIII Hospital, KwaZulu-Natal South Africa: a cross-sectional study. BMJ Open. 2013; 3:e002900.
226. Supapvanich C, Povey AC, de Vocht F. Respiratory and dermal symptoms in Thai nurses using latex products. Occup. Med. 2013; 63(6):425-8.
227. Köse S, Mandiracioğlu A, Tatar B, Gül S, Erdem M. Prevalence of latex allergy among healthcare workers in Izmir (Turkey). Cent Eur J Public Health 2014; 22(4):262-5.
228. Supapvanich C, Povey A, de Vocht F. Latex sentization and risk factors in female nurses in Thai governmental hospitals. Int J Occup Med Environ Health. 2014; 27(1):93-103.

229. Abbasi K, Hazrati M, Mohammadbeigi A, et al. Protection behaviors for cytotoxic drugs in oncology nurses of chemotherapy centers in Shiraz hospitals, South of Iran. Indian J Med Paediatr Oncol. 2016; 37(4):227-31.
230. Elshaer N. Adverse health effects among nurses and clinical pharmacists handling antineoplastic drugs: adherence to exposure control methods. J Egypt Public Health Assoc. 2017; 92(3):144-55.
231. Alehashem M, Baniasadi S. Important exposure controls for protection against antineoplastic agents: highlights for oncology health care workers. Work. 2018; 59(1):165-72.
232. Bayraktar-Ekincioglu A, Korubük G, Demirkan K. An evaluation of chemotherapy drug preparation process in hospitals in Turkey – A pilot study. J Oncol Pharm Pract. 2018; 24(8):563-73.
233. Aluko OO, Adebayo AE, Adebisi TF, et al. Knowledge, attitudes and perceptions of occupational hazards and safety practices in Nigerian healthcare workers. BMC Res Notes. 2016; 9:71.
234. Tait FN, Mburu C, Gikunju J. Occupational safety and health status of medical laboratories in Kajiado County, Kenya. Pan Afr Med J. 2018; 29:65-81.
235. Lee R. Occupational transmission of bloodborne diseases to healthcare workers in developing countries: meeting the challenges. J Hosp Infect. 2009; 72(4):285-91.
236. Garner JS. Guideline for isolation precautions in hospitals. Infect Cont Hosp Epidemiol. 1996; 17(1):54-80.
237. Menzies D, Joshi R, Pai M. Risk of tuberculosis infection and disease associated with work in health care settings Int J Tuberc Lung Dis. 2007; 11(6):593-605.
238. Jesudas CD, Thangakunam B. Tuberculosis risk in health care workers. Indian J Chest Dis Allied Sci. 2013; 55(3):149-54.
239. Lanctôt N, Guay S. The aftermath of workplace violence among healthcare workers: a systematic literature review of the consequences. Aggress Violent Behav. 2014; 19(5):492-501.
240. Maslach C, Jackson SE, Leiter MP. Maslach burnout inventory manual. 4th ed. Menlo Park, CA: Mind Garden Inc; 2016.
241. McHugh MD, Kutney-Lee A, Cimiotti JP, Sloane DM, Aiken LH. Nurses' widespread job dissatisfaction, burnout, and frustration with health benefits signal problems for patient care. Health Aff. 2011; 30(2):202-10.

242. World Health Organization. Health workforce requirements for universal coverage and the sustainable development goals. Geneva: WHO; 2016.
243. Andersson GB. Epidemiological features of chronic low-back pain. Lancet. 1999; 354(9178):581-5.
244. Vieira ER, Schneider P, Guidera C, Gadotti IC, Brunt D. Work-related musculoskeletal disorders among physical therapists: a systematic review. J Back Musculoskelet Rehabil. 2016; 29(3):417-28.
245. Epstein S, Sparer EH, Tran BN, et al. Prevalence of work-related musculoskeletal disorders among surgeons and interventionalists: a systematic review and meta-analysis. JAMA Surg. 2018; 153(2):e174947.
246. Sakzewski L, Naser-ud-Din S. Work-related musculoskeletal disorders in dentists and orthodontists: a review of the literature. Work. 2014; 48(1):37-45.
247. McDiarmid MA. Advocating for the health worker. Ann Glob Health. 2019; 85(1):16.
248. Carey RN, Driscoll TR, Peters S, et al. Estimated prevalence of exposure to occupational carcinogens in Australia (2011–2012). Occup Environ Med. 2014; 71(1):55-62.
249. Fritschi L, Crewe J, Darcey E, et al. The estimated prevalence of exposure to asthmagens in the Australian workforce, 2014. BMC Pulm Med. 2016; 16:48.
250. Lewkowski K, Heyworth JS, Li IW, et al. Exposure to noise and ototoxic chemicals in the Australian workforce. Occup Environ Med. 2019; 76(5):341-8.
251. Crewe J, Carey R, Glass D, et al. A comprehensive list of asthmagens to inform health interventions in the Australian workplace. Aust N Z J Public Health. 2016; 40(2):170-3.
252. Vyskocil A, Leroux T, Truchon G. Effect of chemical substances on hearing: interactions with noise. Montreal, Quebec: IRSST; 2012.
253. Johnson A, Morata T. Occupational exposure to chemicals and hearing impairment. The Nordic Expert Group for Criteria Documentation of Health Risks from Chemicals and The Dutch Expert Committee on Occupational Standards. Sweden: University of Gothenburg,; 2010.
254. Campo P, Maguin K, Gabriel S, et al. Combined exposure to noise and ototoxic substances. Luxembourg: EU-OSHA European Agency for Safety and Health at Work; 2009.
255. Australian Bureau of Statistics. Socio-economic indexes for areas 2006. Canberra: ABS; 2008.
256. Australian Bureau of Statistics. Australian standard geographical classification. Canberra: ABS; 2011.

257. Australian Bureau of Statistics. Australian and New Zealand Standard Classification of Occupations 1220.0 - ANZSCO Version 1.2. Canberra, Australia: ABS; 2013.
258. Australian Bureau of Statistics. Healthcare and Social Assistance our largest industry [Internet]. Canberra: Australian Bureau of Statistics; 2017 [Available from: https://www.abs.gov.au/ausstats/abs@.nsf/mediareleasesbyReleaseDate/B611DFF5E8590F8ACA2581BF001F743B.
259. Pukkala E, Martinsen JI, Lynge E, et al. Occupation and cancer–follow-up of 15 million people in five Nordic countries. Acta Oncol. 2009; 48(5):646-790.
260. Pechter E, Davis LK, Tumpowsky C, et al. Work-related asthma among health care workers: surveillance data from California, Massachusetts, Michigan, and New Jersey, 1993–1997. Am J Ind Med. 2005; 47(3):265-75.
261. Abdolell M, LeBlanc M, Stephens D, Harrison R. Binary partitioning for continuous longitudinal data: categorizing a prognostic variable. Stat Med. 2002; 21(22):3395-409.
262. Delclos GL, Gimeno D, Arif AA, Benavides FG, Zock J-P. Occupational exposures and asthma in health-care workers: comparison of self-reports with a workplace-specific job exposure matrix. Am J Epidemiol. 2009; 169(5):581-7.
263. Keegel G, MacFarlane, Nixon, LaMontagne. Provision of control measures for exposure of the hands to wet-working conditions in Australian workplaces. Int J Occup Env Health. 2012; 18(4):312-9.
264. Centers for Disease Control and Prevention. Guideline for hand hygiene in health-care settings: recommendations of the healthcare infection control practices. Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. MMWR Recomm Rep. 2002; 51:1-45.
265. Australian Bureau of Statistics. Australian labour market statistics, Oct 2010: Shift workers. Canberra: Australian Bureau of Statistics; 2011.
266. Ward EM, Germolec D, Kogevinas M, et al. Carcinogenicity of night shift work. Lancet Oncol. 2019; 20(8):1058-9.
267. Barnes-Farrell JL, Davies-Schrils K, McGonagle A, et al. What aspects of shiftwork influence off-shift well-being of healthcare workers? Appl Ergon. 2008; 39(5):589-96.
268. Pietroiusti A, Neri A, Somma G, et al. Incidence of metabolic syndrome among night-shift healthcare workers. Occup Environ Med. 2010; 67(1):54-57.
269. Messing K, Dumais L, Courville J, Seifert AM, Boucher M. Evaluation of exposure data from men and women with the same job title. J Occup Med. 1994; 36(8):913-7.

270. Eng A, Mannetje At, McLean D, et al. Gender differences in occupational exposure patterns. Occup Environ Med. 2011; 68(12):888-94.

271. Walton A, Rogers B. Workplace hazards faced by nursing assistants in the United States: a focused literature review. Int J Environ Res Public Health. 2017; 14:544.

272. Bureau of Labor Statistics. Occupational outlook handbook: fastest growing occupations [Internet]. Washington DC: U.S. Department of Labor; 2018 [Available from: https://www.bls.gov/ooh/fastest-growing.htm.

273. Quinn MM, Markkanen PK, Galligan CJ, et al. Occupational health of home care aides: results of the safe home care survey. Occup Environ Med. 2016; 73(4):237-45.

274. Parks CG, Cooper GS, Nylander-French LA, et al. Comparing questionnaire-based methods to assess occupational silica exposure. Epidemiology. 2004; 15(4):433-41.

275. Bureau of Labor Statistics. Table II. Numbers of nonfatal occupational injuries and illnesses by industry and case types, 2012 [Internet]. 2013 [Available from: https://www.bls.gov/iif/oshwc/osh/os/ostb3583.pdf.

276. Safe Work Australia. Australian Work Health and Safety Strategy 2012–2022 [Internet]. 2012 [Available from: https://www.safeworkaustralia.gov.au/about-us/australian-work-health-and-safety-strategy-2012-2022.

277. Tipayamongkholgul M, Luksamijarulkul P, Mawn B, Kongtip P, Woskie S. Occupational hazards in the Thai healthcare sector. New Solut. 2016; 26(1):83-102.

278. Brower PS, Attfield MD. Reliability of reported occupational history information for US coal miners, 1969–1977. Am J Epidemiol. 1998; 148(9):920-6.

279. Nieuwenhuijsen M. Design of exposure questionnaires for epidemiological studies. Occup Environ Med. 2005; 62(4):272-80.

280. Steege AL, Boiano JM, Sweeney MH. NIOSH health and safety practices survey of healthcare workers: training and awareness of employer safety procedures. Am J Ind Med. 2014; 57(6):640-52.

281. Thinley S, Tshering P, Wangmo K, et al. Health systems in transition : the Kingdom of Bhutan health system review. Regional Office for South-East Asia: WHO; 2017.

282. McHugh ML. Interrater reliability: the kappa statistic. Biochemia Medica. 2012; 22(3):276-82.

283. Meadows KA. So you want to do research? 5: Questionnaire design. Br J Community Nurs. 2003; 8(12):562-70.

284. Teschke K. Exposure surrogates: job-exposure matrices, self-reports, and expert evaluations. In: Nieuwenhuijsen MJ, editor. Exposure assessment in occupational and environmental epidemiology: Oxford Scholarship Online; 2003. p. 119-32.

285. Ikin JF, Fritschi L, Sim MR. Reproducibility of survey results from a study of occupation-related respiratory health in the aluminum industry. Appl Occup Environ Hyg. 2002; 17(11):774-82.

286. Touvier M, Méjean C, Kesse-Guyot E, et al. Comparison between web-based and paper versions of a self-administered anthropometric questionnaire. Eur J Epidemiol. 2010; 25(5):287-96.

287. Le TT, Tran TT, Ho HT, Vu AT, Lopata AL. Prevalence of food allergy in Vietnam: comparison of web-based with traditional paper-based survey. World Allergy Organ J. 2018; 11:16.

288. Mutepfa MM, Tapera R. Traditional survey and questionnaire platforms. In: Pranee L, editor. Handbook of Research Methods in Health Social Sciences: Springer Singapore; 2019. p. 541-58.

289. Giovannetti E, Sigloch S. An internet periphery study: network centrality and clustering for mobile access in Bhutan. Telecomm Policy. 2015; 39(7):608-22.

290. McColl E, Jacoby A, Thomas L, et al. Design and use of questionnaires: a review of best practice applicable to surveys of health service staff and patients. Health Technol Assess. 2001; 5(5):1-256.

291. Beaton DE, Bombardier C, Guillemin F, Ferraz MB. Guidelines for the process of cross-cultural adaptation of self-report measures. Spine. 2000; 25(24):3186-91.

292. Perneger TV, Courvoisier DS, Hudelson PM, Gayet-Ageron A. Sample size for pre-tests of questionnaires. Qual Life Res. 2015; 24(1):147-51.

293. Department of Labour and Human Resources. Profile on the occupational health and safety of Bhutan. Thimphu: MoLHR; 2012.

294. Rai R, El-Zaemey S, Dorji N, Fritschi L. Reliability and validity of an adapted questionnaire assessing occupational exposures to hazardous chemicals among healthcare workers in Bhutan. Int J Occup Environ Med. 2020; (Submitted).

295. Fritschi L, Sadkowsky T, Glass DC. OccIDEAS: web-based assessment of occupational agent exposure. Int J Epidemiol. 2020; 49(2):376-9.

296. International Labour Office. International Standard Classification of Occupations: ISCO-08. Geneva: ILO; 2012.

297. Rai R, Fritschi L, Carey RN, et al. The estimated prevalence of exposure to carcinogens, asthmagens, and ototoxic agents among healthcare workers in Australia. Am J Ind Med. 2020:1-10.
298. Saito R, Virji MA, Henneberger PK, et al. Characterization of cleaning and disinfecting tasks and product use among hospital occupations. Am J Ind Med. 2015; 58(1):101-11.
299. Donnay C, Denis M-A, Magis R, et al. Under-estimation of self-reported occupational exposure by questionnaire in hospital workers. Occup Environ Med. 2011; 68(8):611-7.
300. Mirabelli MC, Holt SM, Cope JM. Anatomy laboratory instruction and occupational exposure to formaldehyde. Occup Environ Med. 2011; 68(5):375-8.
301. Wangdi TD. Cancer care in Bhutan. Bhutan Health Journal. 2018; 4(1):I.
302. Le Moual N, Zock J-P, Dumas O, et al. Update of an occupational asthma-specific job exposure matrix to assess exposure to 30 specific agents. Occup Environ Med. 2018; 75(7):507-14.
303. Lillienberg L, Andersson E, Janson C, et al. Occupational exposure and new-onset asthma in a population-based study in Northern Europe (RHINE). Ann Occup Hyg. 2013; 57(4):482-92.
304. Pape K, Svanes C, Sejbæk CS, et al. Parental occupational exposure pre-and post-conception and development of asthma in offspring. Int J Epidemiol. 2020; 49(6):1856-69.
305. Dumas O, Le Moual N, Lowe AJ, et al. Influence of childhood asthma and allergies on occupational exposure in early adulthood: a prospective cohort study. Int J Environ Res Public Health. 2019; 16(12):2163.
306. Skaaby S, Flachs EM, Lange P, et al. Occupational exposures and exacerbations of asthma and COPD- a general population study. PloS ONE. 2020; 15(12):e0243826.
307. Lillienberg L, Dahlman-Höglund A, Schiöler L, Torén K, Andersson E. Exposures and asthma outcomes using two different job exposure matrices in a general population study in northern Europe. Ann Occup Hyg. 2014; 58(4):469-81.
308. Henneberger PK, Kurth LM, Doney B, Liang X, Andersson E. Development of an asthma-specific job exposure matrix for use in the United States. Ann Work Expo Health. 2020; 64(1):82-95.
309. Kauppinen TP, Mutanen PO, Seitsamo JT. Magnitude of misclassification bias when using a job-exposure matrix. Scand J Work Environ Health. 1992; 18:105-12.

310. Peters S, Vermeulen R, Cassidy A, et al. Comparison of exposure assessment methods for occupational carcinogens in a multi-centre lung cancer case–control study. Occup Environ Med. 2011; 68(2):148-53.
311. Florath I, Glass DC, Rhazi MS, Parent M-E, Fritschi L. Inter-rater agreement between exposure assessment using automatic algorithms and using experts. Ann Work Expo Health. 2019; 63(1):45-53.
312. Pronk A, Stewart PA, Coble JB, et al. Comparison of two expert-based assessments of diesel exhaust exposure in a case–control study: programmable decision rules versus expert review of individual jobs. Occup Environ Med. 2012; 69(10):752-8.
313. Benke G, Sim M, Fritschi L, et al. Comparison of occupational exposure using three different methods: hygiene panel, job exposure matrix (JEM), and self reports. Appl Occup Environ Hyg. 2001; 16(1):84-91.
314. Offermans NS, Vermeulen R, Burdorf A, et al. Comparison of expert and job-exposure matrix-based retrospective exposure assessment of occupational carcinogens in the Netherlands Cohort Study. Occup Environ Med. 2012; 69(10):745-51.
315. Ho Y, Wang Y, Loh E, Tam K. Antiseptic efficacies of waterless hand rub, chlorhexidine scrub, and povidone-iodine scrub in surgical settings: a meta-analysis of randomized controlled trials. J Hosp Infect. 2019; 101(4):370-9.
316. Vandenplas O, Larbanois A, Vanassche F, et al. Latex-induced occupational asthma: time trend in incidence and relationship with hospital glove policies. Allergy. 2009; 64(3):415-20.
317. Rantanen J, Lehtinen S, Valenti A, Iavicoli S. Occupational health services for all. A global survey on OHS in selected countries of ICOH members. Rome: ICOH:2017.
318. Raulf M. Current state of occupational latex allergy. Curr Opin Allergy Clin Immunol. 2020; 20(2):112-6.
319. Benke G, Sim MR, McKenzie DP, et al. Comparison of first, last, and longest-held jobs as surrogates for all jobs in estimating cumulative exposure in cross-sectional studies of work-related asthma. Ann Epidemiol. 2008; 18(1):23-7.
320. Baris D, Armstrong BG. Exposure to magnetic fields estimated from last job held in an electrical utility in Québec, Canada: a validation study. Occup Environ Med. 1996; 53(5):334-8.
321. Wang F, Zhang L, Zhang Y, et al. Meta-analysis on night shift work and risk of metabolic syndrome. Obes Rev. 2014; 15(9):709-20.

322. Fuller C, Michie S, Savage J, et al. The Feedback Intervention Trial (FIT)—improving hand-hygiene compliance in UK healthcare workers: a stepped wedge cluster randomised controlled trial. PloS ONE. 2012; 7(10):e41617.
323. Spruce L. Back to basics: environmental cleaning hazards. AORN J. 2017; 106(5):424-32.

Appendices

Appendix A: Approval from the Human Research Ethics Office, Curtin University (Chapter 5)

Curtin University

Research Office at Curtin

GPO Box U1987
Perth Western Australia 6845

Telephone +61 8 9266 7863
Facsimile +61 8 9266 3793
Web research.curtin.edu.au

11-Dec-2018

Name: Lin Fritschi
Department/School: School of Public Health
Email: Lin.Fritschi@curtin.edu.au

Dear Lin Fritschi

RE: Ethics Office approval
Approval number: HRE2018-0778

Thank you for submitting your application to the Human Research Ethics Office for the project **Identifying occupational hazards among healthcare workers in Australia and Bhutan**.

Your application was reviewed through the Curtin University Negligible risk review process.

The review outcome is: **Approved**.

Your proposal meets the requirements described in the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research (2007).*

Approval is granted for a period of one year from **11-Dec-2018** to **10-Dec-2019**. Continuation of approval will be granted on an annual basis following submission of an annual report.

Personnel authorised to work on this project:

Name	Role
Fritschi, Lin	CI
Rai, Rajni	Student
El-Zaemey, Sonia	Co-Inv

Approved documents:

Document

Standard conditions of approval

1. Research must be conducted according to the approved proposal
2. Report in a timely manner anything that might warrant review of ethical approval of the project including:

- proposed changes to the approved proposal or conduct of the study
- unanticipated problems that might affect continued ethical acceptability of the project
- major deviations from the approved proposal and/or regulatory guidelines
- serious adverse events

3. Amendments to the proposal must be approved by the Human Research Ethics Office before they are implemented (except where an amendment is undertaken to eliminate an immediate risk to participants)
4. An annual progress report must be submitted to the Human Research Ethics Office on or before the anniversary of approval and a completion report submitted on completion of the project
5. Personnel working on this project must be adequately qualified by education, training and experience for their role, or supervised
6. Personnel must disclose any actual or potential conflicts of interest, including any financial or other interest or affiliation, that bears on this project
7. Changes to personnel working on this project must be reported to the Human Research Ethics Office
8. Data and primary materials must be retained and stored in accordance with the Western Australian University Sector Disposal Authority (WAUSDA) and the Curtin University Research Data and Primary Materials policy
9. Where practicable, results of the research should be made available to the research participants in a timely and clear manner
10. Unless prohibited by contractual obligations, results of the research should be disseminated in a manner that will allow public scrutiny; the Human Research Ethics Office must be informed of any constraints on publication
11. Approval is dependent upon ongoing compliance of the research with the Australian Code for the Responsible Conduct of Research, the National Statement on Ethical Conduct in Human Research, applicable legal requirements, and with Curtin University policies, procedures and governance requirements
12. The Human Research Ethics Office may conduct audits on a portion of approved projects.

Special Conditions of Approval
None.

This letter constitutes low risk/negligible risk approval only. This project may not proceed until you have met all of the Curtin University research governance requirements.

Should you have any queries regarding consideration of your project, please contact the Ethics Support Officer for your faculty or the Ethics Office at hrec@curtin.edu.au or on 9266 2784.

Yours sincerely

Amy Bowater
Ethics, Team Lead

Appendix B: Approval from the Research Ethics Board of Health, Ministry of Health, Bhutan (Chapter 6)

དཔལ་ལྡན་འབྲུག་གཞུང་།
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ཐིམ་ཕུག

ROYAL GOVERNMENT OF BHUTAN
MINISTRY OF HEALTH
RESEARCH ETHICS BOARD OF HEALTH
THIMPHU : BHUTAN
P.O. BOX : 726

Ref. No. REBH/Approval/2018/090 1st February 2019

REBH APPROVAL LETTER (valid through 31/01/2020)

PI: : 1. Rajni Rai **Institute:** Curtin University, Perth, Western Australia	**Study Title:** Identifying occupational hazards among healthcare workers in Australia and Bhutan

Co-Investigator(s): 1. Professor Lin Fritschi, 2. Dr. Sonia El-Zaemey, Curtin University
3. Dr. Nidup Dorji, KGUMSB

Proponent of the study: Individuals

Mode of Review:
Initial Review : ✔ *Expedited Review*
Resubmission Review : ✔ *Expedited Review*

Date of continuing review: *31/01/*2020

Note: Please submit continuing review report along with application form AF/01/015/05 at least seven days before the date of continuing review. If the study is completed then please submit final report of the study.

List of document(s) approved:
Protocol : Version No. 2
Informed Consent Form : Version No. 1
Tools (Questionnaire/forms/guides/etc) : Version No. 2

Conditions for Approval:

1. *This approval is granted for the scientific and ethical soundness of the study. The PI shall be responsible to seek all other clearances/approvals required by law/policy including permission from the study sites before conducting the study.*
2. *Report serious adverse events to REBH within 10 working days after the incident and unexpected events should be included in the continuing review report or the final report.*
3. *No biological material shall be used for other research purpose beyond which is specified in this protocol.*
4. *Any new research study with stored biological material from this study will need a new approval from the REBH before study begins.*
5. *Any changes to the proposal or to the attachments (informed consent and research tools such as forms) shall be approved by REBH before implementation.*
6. *Final report of the study shall be submitted to REBH at the end of the study for review and protocol file closure.*

(Dr. Neyzang Wangmo)
Chairperson, REBH

For further information please contact: *REBH Secretary:* at *Tel: +975-2-322602* or email at msgurung@health.gov.bt or tashidema@health.gov.bt

Appendix C: Approval from the Human Research Ethics Office, Curtin University (Chapter 6)

Curtin University

Research Office at Curtin

GPO Box U1987
Perth Western Australia 6845

Telephone +61 8 9266 7863
Facsimile +61 8 9266 3793
Web research.curtin.edu.au

22-Feb-2019

Name: Lin Fritschi
Department/School: Epidemiology and Biostatistics
Email: Lin.Fritschi@curtin.edu.au

Dear Lin Fritschi

RE: Reciprocal ethics approval
Approval number: HRE2019-0079

Thank you for your application submitted to the Human Research Ethics Office for the project Identifying occupational hazards among healthcare workers in Australia and Bhutan.

Your application has been approved by the Curtin University Human Research Ethics Committee (HREC) through a reciprocal approval process with the lead HREC.

The lead HREC for this project has been identified as Research Ethics Board of Health, Ministry of Health, Royal Government of Bhutan.

Approval number from the lead HREC is noted as 2018/090.

The Curtin University Human Research Ethics Office approval number for this project is **HRE2019-0079**. Please use this number in all correspondence with the Curtin University Ethics Office regarding this project.

Approval is granted for a period of one year from **22-Feb-2019** to **31-Jan-2020**. Continuation of approval will be granted on an annual basis following submission of an annual report.

Personnel authorised to work on this project:

Name	Role
Fritschi, Lin	Supervisor
El-Zaemey, Sonia	Co-Inv
Rai, Rajni	Student
Dorji, Nidup	Co-Inv

You must comply with the lead HREC's reporting requirements and conditions of approval. You must also:

- Keep the Curtin University Ethics Office informed of submissions to the lead HREC, and of the review outcomes for those submissions
- Conduct your research according to the approved proposal

- Report to the lead HREC anything that might warrant review of the ethics approval for the project
- Submit an annual progress report to the Curtin University Ethics Office on or before the anniversary of approval, and a completion report on completion of the project. These can be the same reports submitted to the lead HREC.
- Personnel working on this project must be adequately qualified by education, training and experience for their role, or supervised
- Personnel must disclose any actual or potential conflicts of interest, including any financial or other interest or affiliation, that bears on this project
- Data and primary materials must be managed in accordance with the Western Australian University Sector Disposal Authority (WAUSDA) and the Curtin University Research Data and Primary Materials policy
- Where practicable, results of the research should be made available to the research participants in a timely and clear manner
- The Curtin University Ethics Office may conduct audits on a portion of approved projects.

This letter constitutes ethical approval only. This project may not proceed until you have met all of the Curtin University research governance requirements.

Should you have any queries regarding consideration of your project, please contact the Ethics Support Officer for your faculty or the Ethics Office at hrec@curtin.edu.au or on 9266 2784.

Yours sincerely

Amy Bowater
Ethics, Team Lead

Appendix D: Approval from the Research Ethics Board of Health, Ministry of Health, Bhutan (Chapter 7)

དཔལ་ལྡན་འབྲུག་གཞུང་།
གསོ་བ་ལྷན་ཁག
གསོ་བའི་ ཞིབ་འཚོལ་ ཀུན་སྤྱོད་རྣམ་གཞག་ བཀོད་ཚོགས།
ཐིམ་ཕུག

ROYAL GOVERNMENT OF BHUTAN
MINISTRY OF HEALTH
RESEARCH ETHICS BOARD OF HEALTH
THIMPHU : BHUTAN
P.O. BOX : 726

Ref. No. REBH/Approval/2018/090 — 26th August 2019

REBH APPROVAL LETTER (valid through 26th August /2020)

PI: : 1. Rajni Rai **Institute:** Curtin University, Perth, Western Australia	**Study Title:** Identifying occupational hazards among healthcare workers in Australia and Bhutan

Co-Investigator(s): 1. Professor Lin Fritschi, 2. Dr. Sonia El-Zaemey, Curtin University
3. Dr. Nidup Dorji, KGUMSB

Proponent of the study: Individuals

Mode of Review:
Initial Review : ✔ *Expedited Review*
Resubmission Review : ✔ *Expedited Review*
Amendment Review: ✔ *Expedited Review*

Date of continuing review 26th August /2020

Note: Please submit continuing review report along with application form AF/01/015/05 at least seven days before the date of continuing review. If the study is completed then please submit final report of the study.

List of document(s) approved:
Protocol : Version No. 2
Informed Consent Form : Version No. 1
Tools (Questionnaire/forms/guides/etc) : Version No. 3

Conditions for Approval:

1. *This approval is granted for the scientific and ethical soundness of the study. The PI shall be responsible to seek all other clearances/approvals required by law/policy including permission from the study sites before conducting the study.*
2. *Report serious adverse events to REBH within 10 working days after the incident and unexpected events should be included in the continuing review report or the final report.*
3. *No biological material shall be used for other research purpose beyond which is specified in this protocol.*
4. *Any new research study with stored biological material from this study will need a new approval from the REBH before study begins.*
5. *Any changes to the proposal or to the attachments (informed consent and research tools such as forms) shall be approved by REBH before implementation.*
6. *Final report of the study shall be submitted to REBH at the end of the study for review and protocol file closure.*

Wangmo
(Dr. Neyzang Wangmo)
Chairperson, REBH

For further information please contact: *REBH Secretary:* at *Tel: +975-2-322602* or email at msgurung@health.gov.bt or tashidema@health.gov.bt

Appendix E: Approval from the Human Research Ethics Office, Curtin University (Chapter 7)

Curtin University

Research Office at Curtin

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28-Aug-2019

Name: Lin Fritschi
Department/School: Epidemiology and Biostatistics
Email: Lin.Fritschi@curtin.edu.au

Dear Lin Fritschi

RE: Amendment approval
Approval number: HRE2019-0079

Thank you for submitting an amendment request to the Human Research Ethics Office for the project **Identifying occupational hazards among healthcare workers in Australia and Bhutan**.

Your amendment request has been reviewed and the review outcome is: **Approved**

The amendment approval number is HRE2019-0079-02 approved on 28-Aug-2019.

The following amendments were approved:
Ethics approval has been granted from the Research Ethics Board of Health (REBH), Bhutan to conduct the main survey in phase 2 of the research project.

Any special conditions noted in the original approval letter still apply.

Standard conditions of approval

1. Research must be conducted according to the approved proposal
2. Report in a timely manner anything that might warrant review of ethical approval of the project including:
    - proposed changes to the approved proposal or conduct of the study
    - unanticipated problems that might affect continued ethical acceptability of the project
    - major deviations from the approved proposal and/or regulatory guidelines
    - serious adverse events
3. Amendments to the proposal must be approved by the Human Research Ethics Office before they are implemented (except where an amendment is undertaken to eliminate an immediate risk to participants)
4. An annual progress report must be submitted to the Human Research Ethics Office on or before the anniversary of approval and a completion report submitted on completion of the project
5. Personnel working on this project must be adequately qualified by education, training and experience for their role, or supervised
6. Personnel must disclose any actual or potential conflicts of interest, including any financial or other interest or affiliation, that bears on this project
7. Changes to personnel working on this project must be reported to the Human Research Ethics Office
8. Data and primary materials must be retained and stored in accordance with the Western Australian University Sector Disposal Authority (WAUSDA) and the Curtin University Research Data and Primary Materials policy
9. Where practicable, results of the research should be made available to the research participants in a timely and clear manner
10. Unless prohibited by contractual obligations, results of the research should be disseminated in a manner that will allow public scrutiny; the Human Research Ethics Office must be informed of any constraints on publication
11. Ethics approval is dependent upon ongoing compliance of the research with the Australian Code for the Responsible Conduct of Research, the National Statement on Ethical Conduct in Human Research, applicable legal requirements, and with Curtin University policies, procedures

and governance requirements
12. The Human Research Ethics Office may conduct audits on a portion of approved projects.

Should you have any queries regarding consideration of your project, please contact the Ethics Support Officer for your faculty or the Ethics Office at hrec@curtin.edu.au or on 9266 2784.

Yours sincerely

Bowater

Amy Bowater
Ethics, Team Lead

Appendix F: Questionnaire and consent form for survey of healthcare workers in Bhutan (Chapter 7)

Curtin University

A

Informed consent for healthcare workers

Name of principle investigator: Dr. Rajni Rai

Name of organisation: Curtin University, Australia

Name of research project: Identifying occupational hazards among healthcare workers in Australia and Bhutan.

Part I: Information sheet

Introduction: I am Dr. Rajni Rai, a PhD student in Curtin University. I am doing research on chemicals that you are exposed to in your job which may be harmful to you. I am going to provide information about my research and invite you to participate. You can talk to anyone you feel comfortable with about the research before you decide to participate. This consent form may contain words that you may not understand. If so, please ask me to stop as we go through the information and I will explain them to you. You can also ask me any questions that you may have.

Purpose of the research: Healthcare workers are exposed to many chemicals in their workplace that may be harmful to their health. We want to find out what harmful chemicals you are exposed to and what measures you are using to protect yourselves (e.g., gloves, aprons). This information can help us learn how to better protect healthcare workers from these harmful chemicals.

Type of research intervention: This research involves completing a questionnaire that will take about 15-20 minutes.

Participation selection: We are inviting healthcare workers working in JDWNRH, Paro and Wangdue hospitals to participate in this survey.

Voluntary participation: Your participation in this research is entirely voluntary. It is your choice to take part or not. You do not have to agree if you do not want to. If you decide to take part and then change your mind, you can withdraw from the project and any information we have collected from you will be destroyed.

Risks and benefits: There may be no direct benefits to you from participating in this research. However, we hope this project will help promote occupational health and safety among healthcare workers in Bhutan. Apart from giving up your time to complete the questionnaires, we do not expect any other risks or inconveniences associated with taking part in this study.

Reimbursements: There will be no costs to you for taking part in this research and you will not be paid for participating in this project.

Confidentiality: The information that we collect from this research project will be kept private. Any information about you will have a number on it instead of your name. Only the researchers will know what your number is. Electronic data will be password-protected and hard copy data will be in locked storage. It will not be shared with or given to anyone.

Sharing the Results: The information we collect in this study will be kept under secure conditions at Curtin University for 7 years after the research is published, and will then be destroyed. The results of this research may be presented at conferences or published in professional journals. You will not be identified in any results that are published or presented**.**

Who to contact: If you have any further questions about the study, you can contact Dr. Rajni Rai by email at rajni.rai@postgrad.curtin.edu.au or by phone at 17809851, or contact her supervisor Professor Lin Fritschi on lin.fritschi@curtin.edu.au**.** Research Ethics Board of Health (REBH) has approved this study (REBH 2018/090), which is a committee whose task it is to make sure that research participants are protected. If you wish to find about more about the REBH, please contact Mr. Kinley Dorji by email at kdorjee@health.gov.bt or by phone at 17450682/77356213.

If you decide to take part in this research we will ask you to sign the consent form. Signing the consent indicates that you understand what you have read or what has been discussed; and you agree to be in the research project and have your information used as described. Please take your time and ask any questions you have before you decide what to do. You will be given a copy of this information and the consent form to keep.

Part II: Certificate of Consent

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study.

Name of participant___________________________________Signature__________________

Date ___________________________ (Day/month/year)

Statement by the researcher/person taking consent

I have accurately explained the information sheet to the potential participant, and to the best of my ability made sure that the participant understands the following: 1) Participation is voluntary, and 2) Information collected will be confidential. I confirm that the participant was given an opportunity to ask questions about the study, and all questions asked have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Name of researcher taking consent ___________________________Signature________________

Date______________________________ (Day/month/year)

Section A: Demographics

1. **Are you male or female?**
   - ☐ Male
   - ☐ Female
2. **In what year were you born?** ____
3. **Which of the following describes your ethnic group?**
   - ☐ Ngalop
   - ☐ Sharshop
   - ☐ Lotshamp
   - ☐ Others (please specify): ____
4. **What is the highest level of education you have completed?**
   - ☐ Primary school/ High school
   - ☐ Diploma
   - ☐ Bachelor’s degree
   - ☐ Postgraduate degree

Section B: Employment

1. **Which hospital do you currently work in?**
   - ☐ JDWNRH
   - ☐ Wangdue/Bajo hospital
   - ☐ Paro hospital
2. **Which of the following best describes your current occupation?**
   - ☐ Medical doctor
     - ☐ Surgeon
     - ☐ Anaesthesiologist
     - ☐ Others (please specify):_____________________________________
   - ☐ Dental doctor
   - ☐ Clinical officer
   - ☐ Nurse
     - ☐ Clinical nurse
     - ☐ Staff nurse
     - ☐ Nurse Anaesthetist
   - ☐ Medical technologist
     - ☐ Laboratory officer
     - ☐ Pharmacist
     - ☐ Others (please specify): ____________________________________
   - ☐ Medical technician
     - ☐ Laboratory technician
     - ☐ Pharmacy technician
     - ☐ Others (please specify):____________________________________

☐ Health assistant
☐ Support staff
Ward boy/girl
Cleaner
Others (please specify): ____________________________________

3. Which department/ward do you currently work in?

____

4. How long have you been working as a healthcare worker?

☐ Less than 1 years
☐ 1-5 years
☐ 6-10 years
☐ 11-20 years
☐ 21-30 years
☐ More than 30 years

5. What is your current position level/grade? _______________________________

Section C: Latex gloves

1. Do you wear gloves at work?
☐ Yes
☐ No → *GO TO* **SECTION D** *ON* ***PAGE 3***

2. What are the gloves made from?
☐ Latex
☐ Others (please specify): ____
☐ I don't know → Are the gloves stretchy and creamy white in colour?
☐ Yes
☐ No

3. Are the gloves powdered on the inside?

☐ Yes
☐ No

Section D: Sterilization

4. **Do you sterilise instruments or other equipment yourself?**
   - ☐ Yes
   - ☐ No → *GO TO* **SECTION E** *ON* ***PAGE 4***
5. **What sterilisation method is usually used?**
   - ☐ In a solution
   - ☐ In an autoclave or sterilisation unit
   - ☐ None of the above
6. **What chemical is used? Please select all that apply:**
   - ☐ Glutaraldehyde or Cidex
   - ☐ Quaternary ammonia compounds
   - ☐ Formaldehyde or formalin
   - ☐ Others (please specify): _______________________________________
7. **Do you manually pour or drain liquid sterilising agents into trays or processing units?**
   - ☐ Yes
   - ☐ No

The next questions address the use of personal protective equipment (PPE). Depending on your job and exposures, PPE may not be required.

8. **How often do you wear water resistant gown or outer garment while handling sterilising agents?**
   - ☐ Always
   - ☐ Sometimes
   - ☐ Never
9. **How often do you wear protective gloves while handling sterilising agents?**
   - ☐ Always
   - ☐ Sometimes
   - ☐ Never
10. **How often do you wear eye or face protection (e.g., goggles, face shields) while handling sterilising agents? (Do not include personal eye glasses).**
    - ☐ Always
    - ☐ Sometimes
    - ☐ Never
11. **Do you wear any of the following while handling sterilising agents?**
    - ☐ Standard surgical mask
    - ☐ N95 respirator
    - ☐ I do not wear masks or respirators
12. **What are the reason(s) you do not wear personal protective equipment (gloves, gowns, eye or face protection, masks) while handling sterilising agents? Please select all that apply:**
    - ☐ An engineering control (e.g., closed disinfection system) is used
    - ☐ Skin exposure is minimal
    - ☐ Not part of our protocol
    - ☐ Not readily available in the work area

- ☐ No one else who does this work uses them
- ☐ Too uncomfortable or difficult to use
- ☐ Others (please specify): ______________________________________
- ☐ I always wear personal protective equipment

13. When was the last time you received training on safe handling of sterilising agents?

- ☐ Within the past 12 months
- ☐ More than 12 months
- ☐ I never received training

14. Does your hospital/department have standard operating procedures for safe handling of sterilising agents?

- ☐ Yes
- ☐ No
- ☐ I don't know

Section E: Dental

15. Do you work in the Dental department?

- ☐ Yes
- ☐ No → *GO TO* **SECTION F** *ON* ***PAGE 5***

16. Do you manufacture crowns, false teeth or bridges?

- ☐ Yes → Do you do this in an enclosed box or system?
  - ☐ Yes
  - ☐ No
- ☐ No

17. Do you take or work with dental impressions?

- ☐ Yes → Are the dental impressions made from epoxy resins?
  - ☐ Yes
  - ☐ No
- ☐ No

18. Do you perform endodontic treatment?

- ☐ Yes → Do you use sodium hypochlorite (bleach)?
  - ☐ Yes
  - ☐ No
- ☐ No

The next questions address the use of personal protective equipment (PPE). Depending on your job and exposures, PPE may not be required.

19. Do you wear any of the following while manufacturing false teeth or bridges, taking dental impressions, or performing endodontic treatment?

- ☐ Standard surgical mask
- ☐ N95 respirator
- ☐ I do not wear masks or respirators

20. What are the reason(s) you do not wear masks while manufacturing false teeth or bridges, taking dental impressions, or performing endodontic treatment? Please select all that apply:

- ☐ Not part of our protocol
- ☐ Not readily available in the work area
- ☐ No one else who does this work uses them
- ☐ Too uncomfortable or difficult to use
- ☐ Others (please specify): ____
- ☐ I always wear masks

Section F: Laboratory

21. Do you work in a laboratory?
- ☐ Yes
- ☐ No → *GO TO* **SECTION G** *ON* ***PAGE 7***

22. Do you use methylene blue or aniline blue to stain tissue?
- ☐ Yes
- ☐ No

23. Do you use any of the following? Please select all that apply:
- ☐ Xylene
- ☐ Toluene
- ☐ Formaldehyde
- ☐ Benzene
- ☐ Ammonia or ammonium compounds
- ☐ Trichloroethylene
- ☐ None of the above

24. Do you handle or come into contact with any of the following acids? Please select all that apply:
- ☐ Chromic acid
- ☐ Sulfuric/sulfur dioxide acid
- ☐ Glacial acetic acid
- ☐ Hydrochloric acid
- ☐ Peroxyacetic or peracetic acid
- ☐ None of the above

25. What do you usually clean your glassware with? Please select all that apply:
- ☐ Alcohol
- ☐ Chromic acid
- ☐ Detergent
- ☐ Aqua regia
- ☐ Others (please specify): ____

The next questions address the use of personal protective equipment (PPE). Depending on your job and exposures, PPE may not be required.

26. How do you usually handle laboratory chemicals?
- ☐ In a fume hood
- ☐ In a sealed box with manipulation tool
- ☐ Others (please specify): ____

27. How often do you wear water resistant gown or outer garment while handling laboratory chemicals?
- ☐ Always

- ☐ Sometimes
- ☐ Never

28. How often do you wear protective gloves while handling laboratory chemicals?
- ☐ Always
- ☐ Sometimes
- ☐ Never

29. How often do you wear eye or face protection (e.g., goggles, face shield) while handling laboratory chemicals? (Do not include personal eye glasses)
- ☐ Always
- ☐ Sometimes
- ☐ Never

30. Do you wear any of the following while handling laboratory chemicals?
- ☐ Standard surgical mask
- ☐ N95 respirator
- ☐ I do not wear masks or respirators

31. What are the reason(s) you do not wear personal protective equipment (gowns. gloves, eye or face protection, masks) while handling laboratory chemicals? Please select all that apply:
- ☐ An engineering control (e.g., fume hood) is used
- ☐ Skin exposure is minimal
- ☐ Not part of our protocol
- ☐ Not readily available in the work area
- ☐ No one else who does this work uses them
- ☐ Too uncomfortable or difficult to use
- ☐ Others (please specify): ______________________________________
- ☐ I always wear personal protective equipment

32. When was the last time you received training on safe handling of laboratory chemicals?
- ☐ Within the past 12 months
- ☐ More than 12 months
- ☐ I never received training

33. Does your hospital/department have standard operating procedures for safe handling of laboratory chemicals?
- ☐ Yes
- ☐ No
- ☐ I don’t know

Section G: Suturing and antiseptics

34. Do you perform sutures?
- ☐ Yes
- ☐ No → *GO TO* **SECTION H** *ON* ***PAGE 8***

35. Do you use glues for suturing?
- ☐ Yes → Do you use cyanoacrylate super glue?
  - ☐ Yes
  - ☐ No
- ☐ No

36. Do you apply antiseptics?

- ☐ Yes → Do you apply chlorhexidine (Savlon)?
  - ☐ Yes
  - ☐ No
- ☐ No

Section H: Surgery

37. Do you work in the operation theatre (OT)?

- ☐ Yes
- ☐ No → *GO TO* **SECTION I** *ON* ***PAGE 9***

38. Do you handle or come in contact with bone cement?

- ☐ Yes
- ☐ No

39. Do you operate diathermy equipment or work within one and a half meters of diathermy equipment?

- ☐ Yes
- ☐ No

The next questions address the use of control measures and personal protective equipment (PPE). Depending on your job and exposures, PPE may not be required.

40. Local Exhaust Ventilation (LEV) captures and removes the contaminants at the point where they are being produced, such as a portable smoke evacuator or a flexible tube connected to a room (wall) suction system. LEV does not include blood suction canister systems. How often was LEV used while you worked within one and a half meters of the source of surgical smoke during diathermy?

- ☐ Always
- ☐ Sometimes
- ☐ Never

41. What are the reason(s) LEV was not always used during diathermy? Please select all that apply:

- ☐ General room ventilation was sufficient to dissipate smoke plume
- ☐ Used a different system (e.g., blood suction canister) to remove the smoke
- ☐ Exposure was minimal
- ☐ Not part of our protocol
- ☐ Not readily available in the work area
- ☐ No one else who does this work uses them
- ☐ Too difficult to use
- ☐ Too bulky or noisy
- ☐ Others (please specify): ______________________________________

42. How often do you wear N95 respirators during diathermy?

- ☐ Always
- ☐ Sometimes
- ☐ Never

43. What are the reason(s) you do not wear N95 respirators during diathermy? Please select all that apply:

- ☐ An engineering control (e.g., local exhaust ventilation system) is used
- ☐ Exposure is minimal
- ☐ Not part of our protocol
- ☐ Not readily available in the work area
- ☐ No one else who does this work uses them
- ☐ Too uncomfortable or difficult to use
- ☐ Others (please specify): ______________________________________
- ☐ I always wear a N95 respirator

44. When was the last time you received training on addressing hazards of surgical smoke?

- ☐ Within the past 12 months
- ☐ More than 12 months
- ☐ I never received training

45. Does your hospital/department have standard operating procedures for addressing hazards of surgical smoke?

- ☐ Yes
- ☐ No
- ☐ I don't know

Section I: Anaesthetic gases

46. Do you administer anaesthetic gases to patients?

- ☐ Yes
- ☐ No → *GO TO* **SECTION J** *ON **PAGE 11***

47. How often do you use a waste gas scavenging system (e.g., patient nasal mask with scavenging, local exhaust hood places near the patient's mouth) when you administer anaesthetic gases?

- ☐ Always
- ☐ Sometimes
- ☐ Never

48. When administering anaesthetic gases to patients, how often do you check anaesthesia machines, breathing circuits, and other components for leaks?

- ☐ Always
- ☐ Sometimes
- ☐ Never

49. When administering anaesthetic gases to patients, how often do you start the anaesthetic gas flow after delivery mask or airway device is applied?

- ☐ Always
- ☐ Sometimes
- ☐ Never

50. When administering anaesthetic gases to patients, how often do you turn off the anaesthetic gas flow before turning off the flow of carrier gas to the breathing system?

- ☐ Always
- ☐ Sometimes
- ☐ Never

51. When administering anaesthetic gases to patients, how often do you mainly use high flow anaesthesia (3-6L/min of fresh gas)?

- ☐ Always
- ☐ Sometimes
- ☐ Never

52. Do you personally fill anaesthesia vaporizers?

- ☐ Yes
- ☐ No

53. When filling anaesthesia vaporizers, which system do you use?

- ☐ A "key filler" or other closed system
- ☐ A "funnel fill" system (also called "pour fill" or "screw cap fill" system)

54. When was the last time you received training on safe handling of anaesthetic gases?

- ☐ Within the past 12 months
- ☐ More than 12 months
- ☐ I never received training

55. Does your hospital/department have standard operating procedures for safe handling of anaesthetic gases?

- ☐ Yes
- ☐ No
- ☐ I don't know

Section J: Antineoplastic drugs

56. Do you administer or compound antineoplastic drugs?

- ☐ Yes
- ☐ No → *GO TO* **SECTION K** *ON* ***PAGE 13***

57. Do you administer antineoplastic drugs?

- ☐ Yes → While administering antineoplastic drugs, which of the following do you use? Please select all that apply
  - ☐ Closed-system transfer device (e.g., PhaSeal)
  - ☐ Luer-Lock fittings for all needle-less systems, infusions, and pumps
  - ☐ A needle-less system
  - ☐ None of the above
- ☐ No

58. Do you compound antineoplastic drugs?

- ☐ Yes → While compounding antineoplastic drugs, which of the following do you use:
  - ☐ A room or area dedicated to the preparation of these agents
  - ☐ A biological safety cabinet

☐ An isolator
☐ Others (please specify): ______________________________________
☐ None of the above

☐ No

59. Do you prime IV tubing for antineoplastic drugs?

☐ Yes → How do you prime the IV tubing? Please select all that apply:
☐ With antineoplastic agent
☐ With diluents (i.e., another liquid other than antineoplastic agent)

☐ No

The next questions address the use of personal protective equipment (PPE). Depending on your job and exposures, PPE may not be required.

60. How often do you wear a non-absorbent gown with closed front and tight cuffs while administering/compounding antineoplastic agents?

☐ Always
☐ Sometimes
☐ Never

61. Have you taken home any clothing that came into contact with antineoplastic agents?

☐ Yes
☐ No
☐ I don't know

62. How often do you wear gloves while administering/compounding antineoplastic agents?

☐ Always
☐ Sometimes
☐ Never

63. When wearing gloves, how often do you wear two pairs (i.e., double gloves)?

☐ Always
☐ Sometimes
☐ Never

64. How often do you wash hands after removing gloves?

☐ Always
☐ Sometimes
☐ Never

65. How often do you wear eye or face protection (e.g., goggles, face shield) while administering/compounding antineoplastic agents? (Do not include personal eye glasses)

☐ Always
☐ Sometimes
☐ Never

66. Do you wear any of the following while administering/compounding antineoplastic agents? Please select all that apply:

☐ Standard surgical mask
☐ N95 respirator
☐ I do not wear masks or respirators

67. **What are the reason(s) you do not wear personal protective equipment (gowns, gloves, eye or face protection, masks) while administering/compounding antineoplastic agents? Please select all that apply:**
    - ☐ An engineering control (e.g., closed-system drug transfer device) was used
    - ☐ Exposure is minimal
    - ☐ Not part of our protocol
    - ☐ Not readily available in the work area
    - ☐ No one else who does this work uses them
    - ☐ Too uncomfortable or difficult to use
    - ☐ Cross-contamination to other areas is not a concern
    - ☐ Others (please specify): ______________________________________
    - ☐ I always wear personal protective equipment
68. **When was the last time you received training on safe handling of antineoplastic drugs?**
    - ☐ Within the past 12 months
    - ☐ More than 12 months
    - ☐ I never received training
69. **Does your hospital/department have standard operating procedures for safe handling of antineoplastic drugs?**
    - ☐ Yes
    - ☐ No
    - ☐ I don’t know

Section K: Cleaning

70. **Is one of your tasks to clean the work place?**
    - ☐ Yes
    - ☐ No → *Thank you for participating in the survey*
71. **Do you handle or come in contact with any of the following cleaning agents while you are at work? Please select all that apply:**
    - ☐ Bleach
    - ☐ Ammonium solutions/Quaternary ammonium compounds
    - ☐ Disinfectants (e.g., Dettol)
    - ☐ Chlorhexidine (Savlon)
    - ☐ White spirits, mineral turpentine or mineral spirits
    - ☐ None of the above
72. **Do you use any of the following acid-based products? Please select all that apply:**
    - ☐ Drain cleaner, please specify the brand name: __________________________
    - ☐ Other acid cleaners (please specify): ___________________________________
    - ☐ No, I do not use any

The next questions address the use of personal protective equipment (PPE). Depending on your job and exposures, PPE may not be required.

73. **How often do you wear protective gloves while handling cleaning agents?**
    - ☐ Always
    - ☐ Sometimes
    - ☐ Never

74. **How often do you use goggles while handling cleaning agents? (Do not include personal eye glasses)**
    - ☐ Always
    - ☐ Sometimes
    - ☐ Never
75. **Do you wear any of the following while handling cleaning agents? Please select all that apply:**
    - ☐ Standard surgical mask
    - ☐ N95 respirator
    - ☐ I do not wear masks or respirators
76. **What are the reason(s) you do not wear personal protective equipment while handling cleaning agents? Please select all that apply:**
    - ☐ Exposure is minimal
    - ☐ Not part of our protocol
    - ☐ Not readily available in the work area
    - ☐ No one else who does this work uses them
    - ☐ Too uncomfortable or difficult to use
    - ☐ Others (please specify): ______________________________________
    - ☐ I always wear personal protective equipment
77. **When was the last time you received training on safe handling of cleaning agents?**
    - ☐ Within the past 12 months
    - ☐ More than 12 months
    - ☐ I never received training
78. **Does your hospital/department have standard operating procedures for safe handling of cleaning agents?**
    - ☐ Yes
    - ☐ No
    - ☐ I don't know

Thank you for participating in the survey.

Appendix G: Co-authors' approval to include papers in thesis

From: Lin Fritschi <lin.fritschi@curtin.edu.au>
Sent: 29 March 2021 12:56
To: Rajni Rai <rajni.rai@curtin.edu.au>
Subject: RE: Permission to include co-authored papers in my PhD Thesis

Dear Rajni
I give you permission to include the four papers that I have co-authored in your PhD thesis
Lin

Lin Fritschi
MBBS, FAFPHM, PhD, FAAHMS
John Curtin Distinguished Professor
School of Public Health
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Tel | +61 8 9266 9476

Email | lin.fritschi@curtin.edu.au
Web | www.curtin.edu.au

From: sonia el-zaemey <sonia.elzaemey@yahoo.com>
Sent: 29 March 2021 08:48
To: Rajni Rai <rajni.rai@curtin.edu.au>
Subject: Re: Permission to include co-authored papers in my PhD Thesis

I Sonia El-Zaemey give my permission to include any papers with my involvement in your PhD thesis.

29th March 2021

To whom it may concern

I, Nidup Dorji (PhD), give my permission to include any papers generated with my involvement with your PhD thesis. I can be contacted if there are any further clarifications required from my side.

Sincerely

Nidup Dorji (PhD)
Faculty of Nursing and Public Health
Khesar Gyalpo University of Medical Sciences of Bhutan
Thimphu, Bhutan.

E-mail: nidupdorji@fnph.edu.bt

From: Deborah Glass <deborah.glass@monash.edu>
Sent: 12 March 2021 11:17
To: Rajni Rai <rajni.rai@curtin.edu.au>
Subject: Re: Permission to include the article titled "The estimated prevalence of exposure to carcinogens, asthmagens, and ototoxic agents among healthcare workers in Australia" in Rajni Rai's Thesis

I , Deborah Glass, give Rajni Rai permission to include the article titled "The estimated prevalence of exposure to carcinogens, asthmagens, and ototoxic agents among healthcare workers in Australia" published in the American Journal of Industrial Medicine, of which I am co-author, in her PhD thesis
Deborah Glass

From: kate lewkowski <kate.lewkowski@gmail.com>
Sent: 12 March 2021 11:14
To: Rajni Rai <rajni.rai@curtin.edu.au>
Subject: Re: Permission to include the article titled "The estimated prevalence of exposure to carcinogens, asthmagens, and ototoxic agents among healthcare workers in Australia" in Rajni Rai's Thesis

Hi Rajni,
I give you permission to include the article titled "The estimated prevalence of exposure to carcinogens, asthmagens, and ototoxic agents among healthcare workers in Australia" in your PhD thesis.
Yours sincerely,
Kate Lewkowski

From: Renee Carey <renee.carey@curtin.edu.au>
Sent: 12 March 2021 12:46
To: Rajni Rai <rajni.rai@curtin.edu.au>
Subject: RE: Permission to include the article titled "The estimated prevalence of exposure to carcinogens, asthmagens, and ototoxic agents among healthcare workers in Australia" in Rajni Rai's Thesis

I, Renee Carey, give Rajni Rai permission to include the article titled "The estimated prevalence of exposure to carcinogens, asthmagens, and ototoxic agents among healthcare workers in Australia" published in the *American Journal of Industrial Medicine*, of which I am a co-author, in her PhD thesis.

12/03/2021

Kind regards,
Renee

From: Bir Doj Rai <birdoj_rai@yahoo.com>
Sent: 13 March 2021 10:36
To: Rajni Rai <rajni.rai@curtin.edu.au>
Subject: Re: Permission to include the article titled "Exposure to Occupational Hazards among Health Care Workers in Low- and Middle-Income Countries: A Scoping Review" in Rajni Rai's thesis

Hi Rajni,
I give my consent as that follows:

I, Mr. Bir Doj Rai offer my permission to Rajni Rai, to include the article with following details in her PhD thesis. I do so as a co-author of the article.
Title: Exposure to Occupational Hazards among Health Care Workers in Low- and Middle-Income Countries: A Scoping Review.
Publisher: International Journal of Environmental Research and Public Health

Dr. Bir Doj Rai
RLDC, Wangduephodrang
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Appendix H: Paper 1 (Chapter 3)

International Journal of
Environmental Research and Public Health

MDPI

Review

Exposure to Occupational Hazards among Health Care Workers in Low- and Middle-Income Countries: A Scoping Review

Rajni Rai [1,*], Sonia El-Zaemey [1], Nidup Dorji [2], Bir Doj Rai [3] and Lin Fritschi [1]

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Abstract: Health care workers are exposed to numerous workplace hazards. The implementation of safety measures in high-income countries has largely mitigated these risks. However, in many low- and middle- income countries (LMICs), resources to institute safety measures are lacking, increasing the risk of occupational exposures to these hazards. The aim of this scoping review is to map and synthesize the available research on occupational hazards among health care workers in LMICs, identify research gaps and inform policy. Searches for relevant articles were conducted in five electronic databases using a broad range of search terms. The inclusion criteria were: quantitative observational or experimental studies which examined exposure to one or more occupational hazards among health care workers in a LMCI; and the article was published in English in a peer-reviewed journal. A total of 99 studies met the inclusion criteria, and data were extracted from these studies. Large proportions of health care workers in LMICs were exposed to biological hazards (bloodborne pathogens, tuberculosis), psychosocial hazards (workplace violence, burnout, job dissatisfaction), ergonomic hazards (musculoskeletal complaints), and chemical hazards (exposure to latex and antineoplastic drugs). The implementation of risk reduction strategies was suboptimal. The majority of the literature was on biological hazards (48%), and research on other hazards was limited in comparison. Occupational safety needs to become a priority public health issue to protect health care workers in LMICs. More research is needed to understand the magnitude of the problem in these countries.

Keywords: occupational hazards; health care workers; low- and middle-income countries

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Citation: Rai, R.; El-Zaemey, S.; Dorji, N.; Rai, B.D.; Fritschi, L. Exposure to Occupational Hazards among Health Care Workers in Low- and Middle-Income Countries: A Scoping Review. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2603. https://doi.org/10.3390/ijerph18052603

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1. Introduction

Health care workers are at potential risk of harm from exposure to numerous hazardous agents encountered in their workplace [1]. The most recent and visible example is the ongoing COVID-19 pandemic, which has showcased the vulnerability of health care workers and demonstrated the importance of ensuring their safety [2].

In addition to exposures to emerging diseases, health care workers are routinely exposed to other infectious agents such as tuberculosis, influenza, HIV, and Hepatitis B, which have been the primary focus of research and safety programs [3]. Health care workers are also exposed to various chemical hazards and agents that have been linked to long-term adverse health effects. Chemicals used in health care settings such as ethylene oxide, formaldehyde, and antineoplastic drugs have been linked to cancers and adverse reproductive outcomes [4–6]. Exposure to latex and cleaning and disinfecting agents has been associated with occupational asthma among health care workers [7,8]. Musculoskeletal disorders and injuries, and various psychosocial hazards such as workplace violence, stress, and burnout are other well-recognised occupational hazards among health care workers [9–11].

Recognising these risks, safety measures and standards to protect health care workers have been instituted in high-income countries and have largely succeeded in mitigating these hazards [12]. However, in many low- and middle-income countries (LMICs), occupational health and safety is often neglected [13]. These deficiencies in occupational health have been attributed to a lack of political commitment, insufficient resources, poor data collection systems, and weak enforcement of regulations. Occupational health research has shown that providing a safe work environment increases organizational commitment and worker retention [14]. Poor working conditions and threats to health have been reported to contribute to problems in recruitment and retention of health care workers in LMICs, augmenting the issue of health care worker shortages in these countries [15].

In order to institute any prevention and safety intervention, it is important to understand the magnitude of the problem. The majority of the literature on occupational hazards in health care workers has originated in high-income countries, and research from LMICs on this topic is reported to be limited [16]. Findings from studies conducted in high-income countries cannot be generalised to LMICs because exposures in LMICs are likely to be different from high-income countries due to differences in legislation and regulations, health care systems, work practices and the availability of control measures. There is a need to determine the scope and volume of available research conducted on this topic in LMICs and to identify any research gaps. Apart from a narrative literature review conducted in 2016, which was limited in scope and included only 46 studies, there are no other reviews available on this topic [16].

Scoping reviews have been described by Arksey and O'Malley as those which "aim to map rapidly the key concepts underpinning a research area and the main sources and types of evidence available, and can be undertaken as standalone projects in their own right, especially where an area is complex or has not been reviewed comprehensively before" [17]. A revised definition of scoping reviews was proposed by Daudt et al. as "scoping studies aim to map the literature on a particular topic or research area and provide an opportunity to identify key concepts, gaps in literature; and types and sources of evidence to inform practice, policymaking, and research" [18]. Therefore, a scoping review was conducted to map and synthesize the available research on exposure to occupational hazards among health care workers in LMICs, to identify any research gaps and to inform policy to improve the safety of health care workers.

2. Methods

This review was conducted according to the methodological framework for scoping reviews outlined by Arksey and O'Malley [17], Levac et al. [19], Colquhan et al. [20], and The Joanna Briggs Institute [21]. It is reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) [22]. It was guided by the research question 'What is known from the existing literature about exposure to occupational hazards among health care workers in LMICs?'

2.1. Search Strategy

The key terms relating to the research question were identified as follows: 'health care workers', 'health workers', 'health personnel', 'health professionals', 'nurses', 'doctors', 'laboratory workers' 'occupational hazards', 'occupational risks', 'occupational diseases', 'occupational health', 'occupational injuries', 'occupational accidents', 'low-and-middle-income countries', 'low-income countries', and 'developing countries'. The search strategy was developed by the research team in consultation with an academic librarian. Using these key terms and their associated mapped subject headings and MeSH terms, searches were conducted in the electronic databases MEDLINE, Scopus, CINAHL, Embase, and PsycINFO till 1 May 2020 (Table S1. Search strategy for Medline (Ovid) (date of search: 1 May 2020)). Original peer-reviewed articles in the English language were the only limits applied to the searches to maintain a breadth of coverage. Bibliographies of the included studies were also checked to ensure that all relevant studies had been included in the review. Grey literature was not included.

2.2. Study Selection

Studies were selected based on the following inclusion criteria: (1) participants were health care workers as classified by the World Health Organization (WHO) [23], (2) the study was conducted in a low- and middle- (both lower- and upper-) income country as classified by the World Bank classification of countries, 2020 [24], (3) the study topic was on exposure to occupational hazards, (4) the type of study was a quantitative observational or experimental study, and (5) the article was published in English in a peer-reviewed journal. Studies were excluded if they were qualitative in design, case series or case reports, reviews, conference presentations or dissertations. The only exception to the application of the selection criteria was on studies on tuberculosis. For tuberculosis, since a systematic review on tuberculosis among health care workers in LMICs had been published in 2006 [25], only studies conducted after this period on this topic were included. Studies on night shift work were also excluded.

After removing duplicates, one reviewer (RR) assessed the articles by titles and abstracts and applied the inclusion and exclusion criteria to select the full-text articles to be retrieved. Any uncertainties related to study selection at this stage was discussed with the research team till a consensus was reached. Full-text articles were then screened independently by two reviewers (RR and SE-Z) to finalize their inclusion in the review. Any disagreement regarding the determination of study inclusion in the review at this stage was resolved by consulting a third reviewer (LF). Manual searches of the reference lists of included studies were also conducted.

2.3. Charting of the Data

Data were extracted from the studies and charted on a table by one reviewer (RR). This included author, year of publication, country of study origin, aims, study population and sample size, study design and methodology, and key findings. A second reviewer (LF) then extracted data from ten randomly selected studies using the data charting form to ensure that the data extraction approach was consistent with the research question and study aims.

2.4. Collating and Summarising the Results

The study characteristics, which included the year of publication, study design and methodology, location, participant characteristics, the topic researched, and the study outcomes, were first tabulated. This was performed to provide a descriptive numerical summary of the studies included in the review. A thematic analysis was then carried out, and the studies were sorted into occupational hazards groups based on the WHO classification of occupational hazards in health care workers [26]. These two steps assisted in identifying the dominant areas of research, their location and methodology and any research gaps. The findings are then described as a narrative review.

3. Results

The database searches identified 609 articles, with a further 37 articles identified from a search of reference lists (Figure 1). After removing duplicates, 330 articles were screened by titles followed by abstract examinations of 141 articles. The review of abstracts resulted in 110 articles for full-text examination, of which 99 articles met the inclusion criteria and were included in the review.

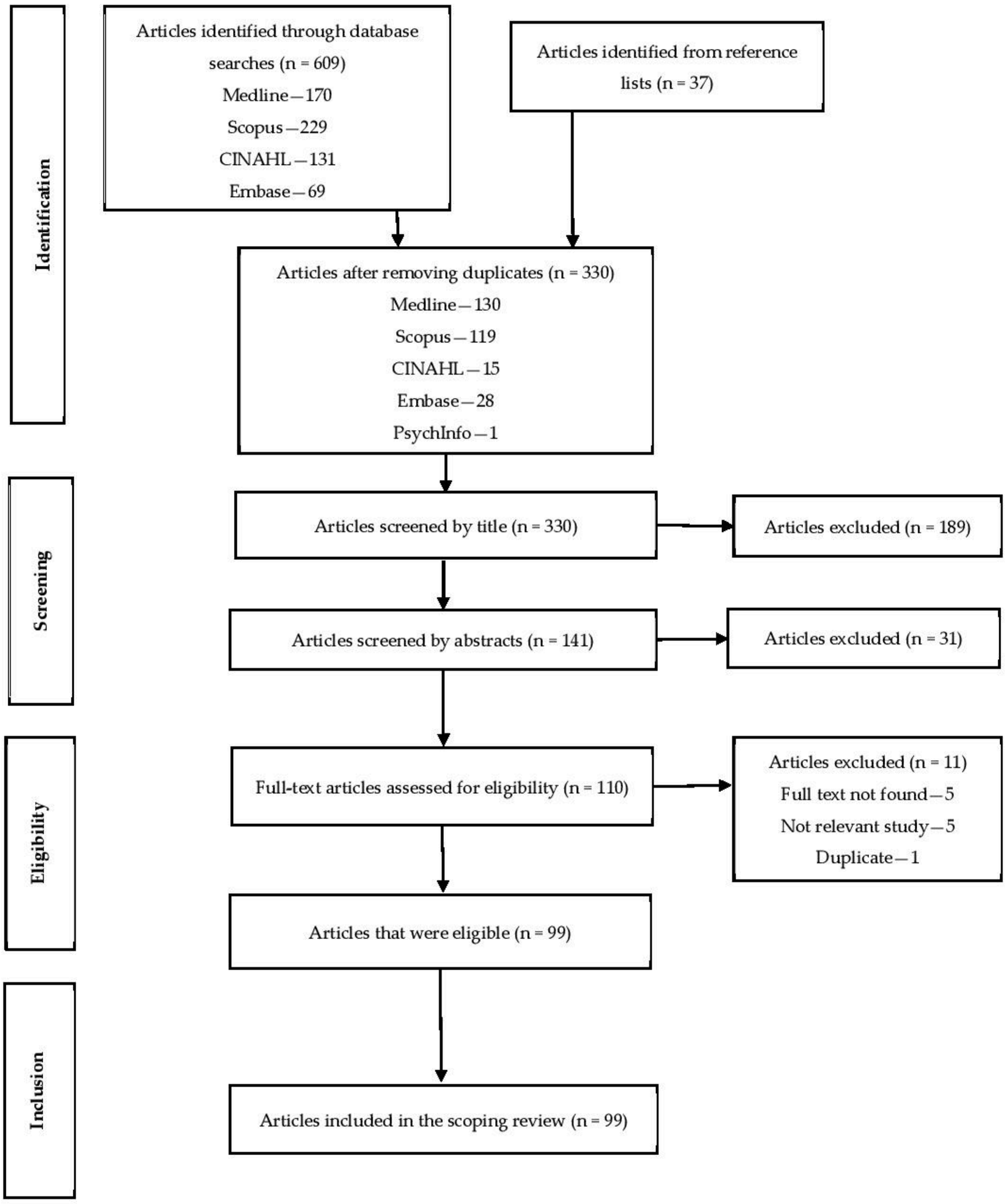

Figure 1. Flow chart illustrating the scoping review study selection process.

The majority of the studies (34 of 99) were conducted in the Sub-Saharan African region (according to the World Bank regions), were cross-sectional in design (82), and participants were all health care workers (51) (Figure 2). Fifty one studies were conducted in district/state hospitals and primary care centres, and 48 were conducted in tertiary care centres. The included studies were published after 1991, with six studies published in the 1990s, 31 studies published between 2001 and 2010, and 62 studies between 2011 and 2020 (Figure 3).

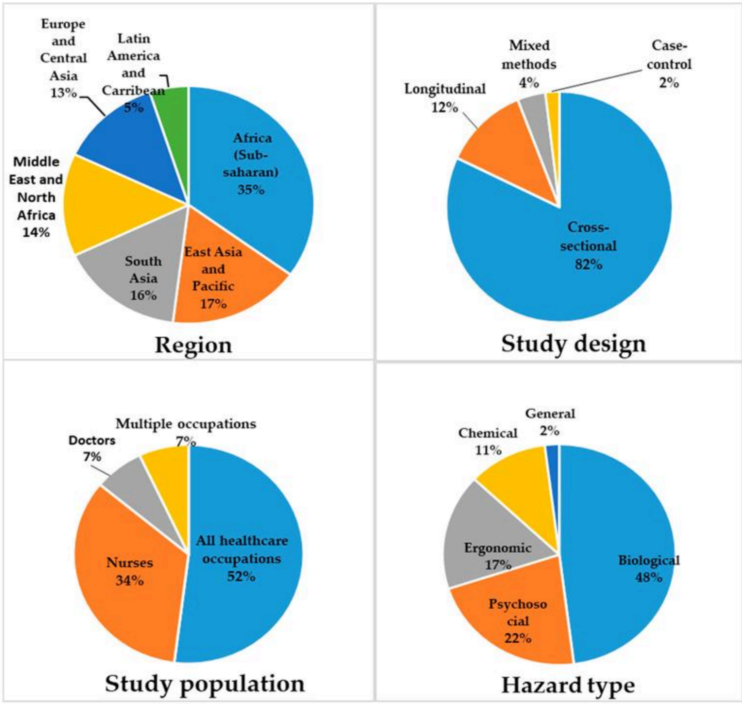

Figure 2. Characteristics of studies.

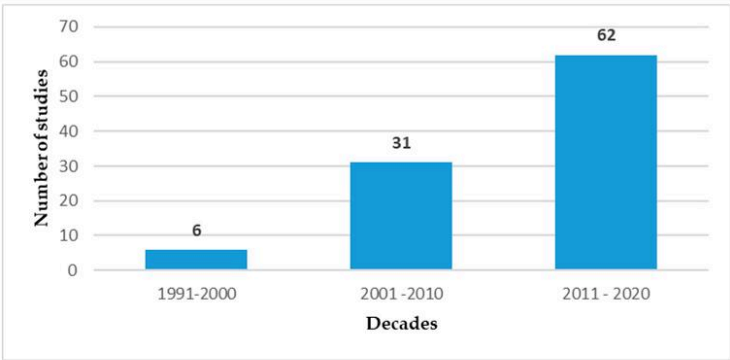

Figure 3. Number of studies by a decade of publication.

Almost half the studies (47) were on biological hazards, 22 studies were on psychosocial hazards, 17 were on ergonomic hazards, and 11 were on chemical hazards (Figure 2). In addition, there were two studies that investigated the different types of occupational hazards in general. Among the studies on biological hazards, the majority (38/47) examined exposure to bloodborne pathogens and nine studies (after 2006) examined exposure to tuberculosis (Table 1). Among the studies on psychosocial hazards, 12 studies examined workplace violence and safety climate, six studies examined the prevalence of burnout and its risk factors and four studies examined work environment and job satisfaction (Table 2). The studies on ergonomic hazards mainly investigated the prevalence of musculoskeletal complaints and their risk factors (Table 3). Among the studies on chemical hazards, six studies examined exposure to latex, and five examined exposure to antineoplastic drugs (Table 4).

Table 1. The characteristics of the studies (n = 47) on exposure to biological hazards (arranged in chronological order according to the year of publication).

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
				I. Bloodborne Pathogens			
Cavalcante et al. [27]	1991	Occupational risk of acquiring HIV	Brazil	651 health care workers from a teaching hospital	Prospective	Health care workers who reported accidental exposures to infective material from AIDS patients to the Infection Control Committee (n = 247) and those who had other risks of infection but no occupational exposures (n = 404) were interviewed and blood was collected for HIV testing at baseline, 90, 180 and 360 days later (for health care workers who reported accidents).	247 health care workers reported 338 accidents and of these 115 were followed up for more than 6 months and 132 were lost to follow up. None tested positive for HIV. 50% of exposures occurred through needlestick or sharp injuries, 22% through contact of blood on mucous membranes, 28% through exposures to urine, faeces or cerebrospinal fluid from AIDs patients. The highest frequencies of injuries were reported by nurses, followed by physicians, laundry and housekeeping personnel and laboratory workers. Of the 404 health care workers with no occupational exposures, 6 were positive and had confirmed risk factors for HIV transmission.
Adegboye et al. [28]	1994	Needlestick and sharp object injuries and accidents; awareness of the risk of occupational exposure to HIV	Nigeria	474 health care workers working in a university hospital complex, who were occupationally exposed to blood	Cross-sectional	Questionnaires on needlestick and sharp injuries in the past year and on knowledge on HIV transmission.	27% of health care workers reported at least one needlestick injury in the past year. Circumstances resulting in needlestick injuries were unexpected patient movement (29%), handling or disposal of used needles (23%), needle recapping (18%), accidental stick by a colleague (18%), and needle disassembly (10%). 15% reported at least one sharp object injury in the past year and this most commonly involved broken glass from patient specimen containers (39%).The highest frequencies of injuries were reported by dental staff and surgeons. Almost all participants were aware of the risk of occupational exposure to HIV.

Table 1. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Olubuyide [29]	1996	Contact with HIV and Hepatitis B (HBV)-positive patients and needlestick injuries	Nigeria	149 resident doctors in a teaching hospital in Nigeria	Cross-sectional	Questionnaire asking about contact with HIV/HBV patients, needlestick injuries, and precautions used. No time period was reported.	93% reported contact with HIV/HBV patients, 9% had needlestick injuries (presumably lifetime) and 54% used universal precautions when performing procedures.
Gumodoka et al. [30]	1997	Injuries and use of personal protective equipment (PPE) to protect from HIV	United Republic of Tanzania	403 health care workers from nine hospitals in the Mwanza region	Mixed methods	Questionnaires on the use of PPE and needlestick injuries and splashes. Observations and interviews were carried out in different sections of the hospitals to determine general hygiene practices.	Prick and splash incidents were reported frequently (at least 5 pinprick accidents and nine splashes per health care worker per year). The general hygiene measures to reduce the risk of HIV was not sufficient and PPE was not used consistently.
Khuri-Bulos et al. [31]	1997	Needlestick and sharp injuries	Jordan	248 health care workers working in a tertiary care hospital	Prospective	Surveillance of sharps injuries over a 3 year period. Health care workers who reported sharps injuries during this period completed a questionnaire. Serum samples were collected at baseline and 6 months later to be tested for Hepatitis B, C and HIV.	Over the 3 year period, 248 health care workers reported needlestick injuries. Highest frequencies were reported by nurses (34.6%). The total average annual rate was 82:1000 health care workers per year. Only a minority of health care workers submitted a serum sample.
Gounden and Moodley [32]	2000	Injuries and use of personal protective equipment to protect from HIV	South Africa	265 health care workers from a tertiary care hospital	Mix of retrospective and prospective	Health care workers were interviewed over a period of one year.	13% reported accidental injuries with HIV-positive patients. The highest frequencies of injuries were among registrars. Compliance with universal precautions was suboptimal. 48% of the participants on post-exposure prophylaxis (PEP) did not complete their regimen; the side effects of PEP was reported as the main reason for discontinuation.

Table 1. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Phipps et al. [33]	2002	Needlestick injuries; and knowledge, attitudes and practices	China	441 nurses working in 3 tertiary care hospitals in Hunan Province	Cross-sectional	Questionnaire on needlestick injuries in the past year, Hepatitis B knowledge and immunization status, and work practices.	82% of the nurses reported experiencing a needlestick injury in the past year. These injuries occurred most frequently when separating a needle and syringe, recapping a needle, transporting needles for disposal, and giving injections. Only 8% reported the injuries to an authority. The majority never wore gloves when drawing blood, giving an injection or starting an intravenous line. 29% were not vaccinated against Hepatitis B.
Talaat et al. [34]	2003	Needlestick injuries and Hepatitis B vaccination status	Egypt	1485 health care workers from health facilities in 2 governorates (Nile Delta and Upper Egypt)	Cross-sectional	Questionnaire on needlestick injuries and Hepatitis B vaccination status.	36.6% reported at least one needlestick injury in the past 3 months. Two-hand recapping was the most common behaviour associated with needlestick injury. 15.8% reported being fully vaccinated against Hepatitis B; vaccination rates were lowest among housekeeping personnel.
Kermode et al. [35]	2005	Needlestick injuries	India	266 health care workers from 7 rural health settings (hospitals with attached community health projects) in north India	Cross-sectional	Questionnaire on needlestick or sharps injuries in the past week, past year, and over the working lifetime.	63% reported at least 1 needlestick injury in the last year and 73% over their working lifetime. Doctors and nurses were more likely to be exposed than student nurses and laboratory workers.
Kermode et al. [36]	2005	Compliance with universal precautions (UP)	India	266 health care workers from 7 rural health settings (hospitals with attached community health projects) in north India	Cross-sectional	Questionnaire on 12 behaviours related to the practice of UP.	Compliance with UP was not optimal. Compliance with UP was associated with being in the job for a longer period, knowledge of bloodborne pathogen transmission, perceiving fewer barriers to safe practice and strong commitment to workplace safety climate.

Table 1. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Nsubuga and Jaakkola [37]	2005	Needlestick and sharps injuries and risk factors	Uganda	526 midwives and nurses in a tertiary care hospital in Kampala	Cross-sectional	Questionnaire on needlestick injuries and risk factors.	57% reported a needlestick injury in the last year and 82% in their entire career. The risk factors identified were lack of training, working for more than 40 h/week, recapping needles, and not using gloves when handling needles. Lack of training was the strongest predictor.
Obi et al. [38]	2005	Needlestick injuries and splashes, and use of personal protective equipment (PPE)	Nigeria	264 surgeons from five tertiary health institutions in Southeast Nigeria	Cross-sectional	Questionnaire on needlestick injuries and splashes in the last 5 years, use of PPE, and attitudes towards care of HIV-infected patients.	40.2% reported a needlestick injury and 26% reported blood splashes in the past five years. The highest frequencies were reported in resident surgeons. All wore protective aprons, 65.2% used double gloves and 30.3% used goggles during surgical procedures. 83% had some reservations about treating HIV-positive patients.
Chelenyane and Endacott [39]	2006	Infection control practices	Botswana	22 health care workers from two referral hospitals emergency departments	Mixed methods	Questionnaire with multiple choice and open ended questions.	The majority of participants reported compliance with universal precautions. Barriers to compliance were lack of appropriate facilities, shortage of equipment and materials, inadequate staffing, and lack of training programs.
Akinleye and Omokhodion [40]	2008	Needlestick injuries and work practices	Nigeria	270 primary health care workers from two urban and three rural local government areas	Cross-sectional	Questionnaire on needlestick injuries in the past year and work practices.	32% reported a needlestick injury in the past year. Compliance with the use of gloves and hand washing were greater among rural than urban health workers.
Okeke et al. [41]	2008	Needlestick injuries and Hepatitis B vaccination status	Nigeria	346 medical students in a tertiary institute	Cross-sectional	Questionnaire on needlestick injuries and splashes, and Hepatitis B vaccination status	48% reported a previous needlestick injury and 27.7% reported being vaccinated against Hepatitis B.

Table 1. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Taegtmeyer et al. [42]	2008	Needlestick injuries (NSIs) and safety practices	Kenya	650 health care workers from 11 health facilities in Thika District	Prospective	Questionnaires and semi-structured interviews; together with an intervention of introduction of biosafety measures, vaccination, and post-exposure prophylaxis (PEP). Surveys were conducted at baseline and at one year.	The incidence of NSIs was 0.97 per health care worker per year. After the institution of biosafety measures, there was a significant reduction in injuries, an increase in the health care workers accessing HIV testing and in the uptake of Hepatitis B vaccination uptake, but the uptake of PEP was low.
Chen et al. [43]	2009	Sharp object injuries	China	831 health care workers from 9 hospitals in Fujian, who worked in departments with a high risk of occupational exposures to blood	Cross-sectional	Questionnaire on sharp object injuries in the past year.	86.2% of the health care workers reported a sharps injury on the job and 71.3% said that it had occurred in the past year. Nurses reported the highest frequencies of injuries, followed by surgeons, anaesthetists, and laboratory workers. Disposable syringes caused most of the injuries.
Simon [44]	2009	Needlestick injuries	India	50 nurses in a super-speciality tertiary care hospital in Delhi	Cross-sectional	Questionnaire on needlestick injuries, and knowledge and practices on needlestick injuries.	70% had sustained a needlestick injury during their career, and of these the majority (71%) did not report it. There was a lack of awareness on prevention and management of NSIs.
Chakravarthy et al. [45]	2010	Sharps injuries, and blood and body fluid exposure incidents	India	265 health care workers who reported sharps injuries and accidental blood and body fluid exposures to the Infection Control Committee of 4 tertiary referral hospitals	Retrospective review of data from sharp injury, and blood and body fluid exposure reports	Data were obtained from sharps injuries, and blood and body fluid exposures reports that were reported to the Infection Control Committees of the 4 hospitals. Data collection period ranged from 6 to 26 months.	243 sharps injuries and 22 incidents of blood and body fluids exposures were reported in the cumulated 50 months of study. The highest frequencies of injuries were reported by nurses and housekeeping staff. The majority of the injuries were caused by disposable needles.

Table 1. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Yacoub et al. [46]	2010	Needlestick injuries and Hepatitis B vaccination status	Syria	321 health care workers from three tertiary care hospitals in Aleppo	Cross-sectional	Questionnaire on needlestick injuries and Hepatitis B vaccination status. Blood was collected to test for Hepatitis B (HBsAg).	76.6% reported at least one needlestick injury in the past year. Anaesthesiology technicians, doctors, nurses, and housekeeping had the greatest exposure risks. 56.1% reported being fully vaccinated against Hepatitis B; vaccination rates were lowest among housekeeping personnel. 2.8% tested positive for HBsAg.
Sangwan et al. [47]	2011	Needlestick injuries and splashes	India	70 health care workers in a tertiary care hospital	Cross-sectional	Questionnaire on needlestick injuries and splashes in the past year, and reasons for not using PPE.	71.43% reported a needlestick injury in the past year. The most frequent reasons for not using PPE were in emergencies and other co-workers not using them. Only 34% reported that adequate PPE was always provided.
Irmak [48]	2012	Needlestick and sharps injuries	Turkey	143 nurses working patient care in a state hospital	Cross-sectional	Questionnaire on needlestick and sharps injuries in the past year.	30.1% of the nurses reported at least one sharp object injury in the past year. The use of syringe needles was the most common cause of injury. 16.3% of the nurses were not wearing gloves when they sustained the injury.
Nasim et al. [49]	2012	Safe work practices and use of personal protective equipment	Pakistan	1782 laboratory technicians from public sector hospitals and private hospital laboratories throughout Pakistan	Cross-sectional	Questionnaire on safe and unsafe work practices, and the use of personal protective equipment.	31.9% did not use any kind of personal protective equipment, 46% reported reusing syringes, 43.2% regularly recapped needles after use, 67.2% said that standard operating procedures were not available, and 84.2% had no formal biosafety training.
Omorogbe et al. [50]	2012	Injection safety practices and use of PPE	Nigeria	122 nurses from 6 mission hospitals in Benin city	Cross-sectional	Questionnaire adapted from the WHO injection safety assessment tool and observation of practices.	55.8% reported recapping of needles and only 3.3% said that they regularly used gloves when giving injections.

Table 1. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Phillips et al. [51]	2012	Needlestick and sharps injuries	Zambia	442 health care workers from five health facilities in Lusaka and Livingstone	Cross-sectional	Questionnaire on needlestick and sharps injuries in the past year.	The annual average sharps injury rate was 1.3 injuries/worker. The highest frequencies were reported by nurses and service workers. Syringe needles accounted for the majority of the injuries. 88% reported the availability of PPE, but only 8% were fully vaccinated against Hepatitis B.
Sethi et al. [52]	2012	Compliance with infection control practices	Uganda	183 health care workers from a referral hospital in Kampala	Cross-sectional	Questionnaire on hand hygiene, barrier protection, and contact precautions.	68.9% reported using gloves as barrier protection. Universal precautions were not always followed. The reasons for suboptimal infection control practices were lack of time and lack of resources.
Abkar et al. [53]	2013	Unsafe injection practices	Yemen	127 health care workers from two hospitals and 6 rural health centres	Cross-sectional	Questionnaire and observation of injection practices.	There were several unsafe practices, particularly the recapping of needles after use, which occurred in 61.1% and 36.8% of the observations in the hospitals and health centres, respectively.
Afridi et al. [54]	2013	Needlestick injuries, Hepatitis B vaccination status and infection control measures	Pakistan	497 health care workers from two tertiary care hospitals in Karachi	Cross-sectional	Questionnaire on needlestick injuries, Hepatitis B vaccination status and infection control measures.	64% reported needlestick injuries during their career. Working for more than 5 years and working as a nurse were the factors associated with an increased risks. Injecting medicine, drawing blood, and two hand recapping of needles were the practices associated with needlestick injuries. 34% reported being vaccinated against Hepatitis B. Infection control measures were inadequate.

Table 1. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Rajkumari et al. [55]	2014	Needlestick injuries and splashes	India	356 health care workers who reported sharps injuries and splashes in a tertiary hospital in New Delhi	Prospective	Surveillance of sharps injuries over a 2 years 5 months period. Health care workers who reported sharps injuries during this period completed a questionnaire. Blood samples were collected at baseline and 6 months later to be tested for Hepatitis B, C and HIV.	Highest frequencies of sharps injuries were reported by doctors (36.2%), followed by nurses (14.6%) and hospital waste disposal staff (7.6%). There was no seroconversion among the exposed health care workers. The majority (85.1%) of the injuries reported were from sharps (as compared to splashes). Only 55.3% were using PPE during the time of exposure.
Bekele et al. [56]	2015	Needlestick injury reporting and attitudes	Ethiopia	340 health care workers from four hospitals of Bale zone	Cross-sectional	Questionnaire on needlestick injury reporting and attitudes.	98.2% were aware of the risks of needlestick injuries.58.7% of needlestick injuries were not reported. The main reasons for not reporting were time constraints, sharps that caused the injury were not used by patients, the source patient did not have diseases of concern, and lack of knowledge of reporting.
Priya et al. [57]	2015	Needlestick injuries and splashes	India	105 health care workers who reported sharps injuries and accidental blood and body fluid exposures to the anti-retroviral therapy centre of a tertiary care hospital	Retrospective review of data from sharp injury, and blood and body fluid exposure reports	Data from three years were obtained from sharps injuries, and blood and body fluid exposures reports that were reported to the Anti-retroviral therapy centre of a tertiary care hospital.	105 health care workers reported an occupational exposure to blood and body fluids. The highest frequencies were reported by interns. Needlestick injuries were the commonest type of exposure (85%), followed by mucous membrane splash (13%) and exposure on intact skin (2%). The practices that resulted in exposures were blood withdrawal (45.7%), during surgical procedures (24.7%) and disposal of sharps (23%).

Table 1. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Sabermoghaddam et al. [58]	2015	Needlestick injuries and splashes	Iran	371 health care workers from 6 government hospitals in the Northern Khorasan province	Cross-sectional	Questionnaire on needlestick injuries and splashes in the past year.	44% reported a sharp object injury and 31% reported contact with blood and body fluids in the past year. 91% reported always using a safety box to deposit used needles, 35.9% reported washing their hands before and after examining patients, 41.5% reported using gloves, 58% had attended training on safe handling of sharps. 52% of those who were injured did not report the injury.
Türe et al. [59]	2016	Needlestick injuries and splashes, and risk factors	Turkey	166 health care workers who reported sharps injuries and accidental blood and body fluid exposures to the Infection Control Committee of a tertiary care hospital	Retrospective review of data from sharp injuries, and blood and body fluid exposure reports	Data were obtained from sharps injuries, and blood and body fluid exposure reports that were reported to the Infection Control Committee. Data collection period was from August 2011 to June 2013.	166 health care workers reported an occupational exposure to blood and body fluids. The occupational exposure incidence was 2.18 exposures/person-year. The highest frequencies of injuries were reported by nurses and cleaning staff. Having heavy workloads and long working hours increased the risk of exposures whereas increased work experience decreased the risk of exposures.
Konlan et al. [60]	2017	Hepatitis B vaccination status and practices to reduce occupational exposures	Ghana	108 nurses from two hospitals within the Tamale metropolis	Cross-sectional	Questionnaire on Hepatitis B vaccination status and practices to reduce occupational exposures to Hepatitis B.	64.8% said that they reported occupational exposures to Hepatitis B. 33.3% reported receiving 3 doses of Hepatitis B vaccination. Compliance with precautions to reduce occupational exposures was suboptimal.
Matsubara et al. [61]	2017	Needlestick and sharps injuries and risk factors	Lao PDR	623 health care workers from 4 tertiary care hospitals in Vientiane Capital	Cross-sectional	Questionnaire on needlestick injuries over their entire career, and in the past 6 months, and injection practices based on the World Health Organization questionnaire on injection practices.	11.4% reported a needlestick injury in the past 6 months and 42.1% in their entire career. The highest frequencies were reported by surgeons, dentists and cleaners. The injuries were caused by percutaneous injections (17.9%), suturing needles (17.0%), intravenous line insertion (17.0%), recapping needles (13.2%), disposal (10.4%), and others (24.5%). Protective factors for needlestick injuries identified were adequate availability of needles and syringes, and adequate training.

Table 1. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Geberemariyam et al. [62]	2018	Needlestick injures and infection control practices	Ethiopia	648 health care workers with direct involvement in patient care in public health care facilities in one district	Cross-sectional	Questionnaire on needlestick injuries and infection control practices.	Only 36.3% reported safe infection prevention practices. Life-time prevalence of needlesticks and blood or body fluid exposure 32.4% and 39.0%, respectively, with 24.8% of them having >1 injuries. Exposures occurred mostly during intravenous catheter insertion, suturing, and recapping of needles. Factors associated with better infection control practices were profession, service years, presence of infection prevention committee and guideline, and ever taking training.
Mandić et al. [63]	2018	Needlestick injuries and splashes	Serbia	5247 health care workers who routinely worked with blood from 17 general hospitals in Serbia	Cross-sectional	Questionnaire on needlestick injuries and splashes over their entire career and in the last year.	39% reported an exposure to blood and body fluids in the past year and 66% over their entire career. The prevalence of needlestick injuries occurring in the last year was equal among genders, but it was more prevalent in women during the entire career. The highest frequencies were reported in nurses.
Hebo et al. [64]	2019	Exposure to blood and body fluids, practices of standard precautions and seroprevalance of Hepatitis B and C	Ethiopia	240 health care workers from Jimma University Medical Center	Cross-sectional	Questionnaires on exposure to blood and body fluids and use of standard precautions. Blood was collected and tested for Hepatitis B and C.	60% reported being ever exposed and 43% reported exposure in the past year to blood and body fluids through accidental splashes and sharps injuries. 2.5% of the samples was positive for HBsAg and 0.42% for anti-HCV antibodies. Only 42.6% had good practices of standard precautions.
				II. Tuberculosis (TB)			
Lien et al. [65]	2009	Prevalence of latent TB and risk factors	Vietnam	150 health care workers from a TB hospital and 150 from a non-TB hospital in Hanoi	Cross-sectional	Questionnaire on occupational history; interferon-gamma release assay (IGRA), QuantiFERON-TB Gold In-Tube assay and one- and two-step tuberculin skin tests (TSTs) for TB infection.	Prevalence of TB infection was 47.3%, 61.1% and 66.3% as estimated by IGRA, one- and two-step TST, respectively. Working in a TB hospital, increasing age, lower education levels, and higher body mass index were associated with increased risk of IGRA positivity.

Table 1. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Mathew et al. [66]	2013	TB among health care workers	India	101 health care workers with TB (cases) and 101 without TB in a tertiary care hospital in Vellore	Nested case–control	Questionnaire on occupational history and non-occupational exposure to TB.	Rate of active pulmonary TB was 314 per 100,000 person-years, which was 1.86 times higher than that of the general population. Body mass index <19 kg/m^2, having frequent contact with patients, and working in the medical wards or microbiology laboratories were independently associated with increased risk of TB
Wei et al. [67]	2013	Prevalence of latent TB infection (LTBI)	China	210 health care workers in a chest hospital in Harbin	Prospective	Questionnaire on occupational history; participants were tested with two interferon-gamma release assays (QuantiFERON-TB Gold In-Tube assay (GFT-GIT) and A.TB) and TST. Participants were observed for 2 years to check for the development of active tuberculosis.	Prevalence of LTBI was 76.5% by QFT-GIT, 65.7% by A.TB and 97.6% by TST, which was higher than that reported in the general population. Working as a nurse and age > 30 years were independently associated with increased risk of LTBI.
Whitaker et al. [68]	2013	Prevalence and risk of latent TB infection (LTBI)	Georgia	319 health care workers in Georgia	Prospective longitudinal	Questionnaire, and tests for LTBI using the TST and QuantiFERON-TB Gold In-Tube Assay (QFT-GIT). The tests were repeated 6–26 months after baseline.	Prevalence at baseline was 67% by TST and 46% by QFT-GIT. Health care workers (HCWs) working in TB health care facilities had a higher prevalence of positive TST and QTF-GIT. Frequent contact with TB patients was associated with increased risk of QTF-GIT positivity only and increasing age was associated with increased risk of positivity of both tests. The conversions rates were high at 22.8/100 person-years (QTF-GIT) and 17.1/100 person-years (TST). Female HCWs had a decreased risk of TST conversion and older HCWs had an increased risk of QTF-GIT conversion.

Table 1. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Tudor et al. [69]	2014	TB incidence and risk factors	South Africa	1313 health care workers from 3 district hospitals in KwaZulu-Natal	Retrospective	Occupational health medical records of 1313 health care workers were reviewed during the period of January 2006 and December 2010.	The TB incidence rate was 1958/100,000 person-years, which was two-fold greater than in the general population. An increased incidence of TB was seen in those working in TB wards, paediatric wards, outpatient departments and stores/workshops. Health care workers living with HIV had a greater incidence of TB.
El-Sokkary et al. [70]	2015	Latent TB infection (LTBI) prevalence and risk factors	Egypt	132 health care workers from a chest Hospital in Zagazig city	Cross-sectional	Questionnaire and tests for LTBI using the TST and QuantiFERON-TB Gold In-Tube Assay (QFT-GIT).	Prevalence was 28.8% by QFT-GIT and 59.1% by TST. Being a nurse, working >10 years, smoking and diabetes were significantly associated with risk of LTBI.
Tudor et al. [71]	2016	Occupational risk factors for TB	South Africa	145 health care workers (54 cases, 91 controls) from 3 district hospitals in KwaZulu-Natal	Case control	Cases were identified from the occupational health medical records between January 2006 and December 2010.	Health care workers with HIV and those who spent time working in areas with tuberculosis patients were at an increased risk of TB.
He et al. [72]	2017	Pulmonary tuberculosis status among health care workers as diagnosed with low-dose CT	China	1012 health care workers from the Beijing Chest Hospital	Retrospective	Health examination data of 1012 health care workers which included low-dose lung CT examinations from January 2012 to November 2015 were analysed.	The incidence and prevalence rates of active TB were >2.8 times and >4.1 times greater than that of the general population of China. The majority (78.9%) of the health care workers with active TB worked in high-risk areas such as TB wards, outpatient clinics and radiology departments.
Erawati and Andriany [73]	2020	Latent TB infection (LTBI) prevalence and risk factors	Indonesia	195 health care workers from 34 primary health centres in Semarang	Cross-sectional	Questionnaire and tests for LTBI using QuantiFERON-TB Gold In-Tube Assay (QFT-GIT).	Prevalence of LTBI was 23.6%. Health care workers with comorbidities were at increased risk of LTBI.

Notes: HIV—Human Immunodeficiency Virus, AIDS—Acquired Immunodeficiency Syndrome, HBV—Hepatitis B Virus, HCV—Hepatitis C Virus, PPE—personal protective equipment, PEP—post-exposure prophylaxis, UP—universal precaution, NSI—needlestick injury, HBsAg—Hepatitis B surface Antigen, TB—tuberculosis, IGRA—interferon-gamma release assay, TST—tuberculin skin test, LTBI—latent tuberculosis infection. Mixed-methods studies refers to studies with qualitative and quantitative components.

Table 2. The characteristics of the studies (n = 22) on exposure to psychosocial hazards (arranged in chronological order according to the year of publication).

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
I. Workplace Violence							
Kisa et al. [74]	2002	Sexual harassment and work productivity	Turkey	215 nurses from two hospitals in Turkey	Cross-sectional	Questionnaires on sexual harassment and work performance.	73% reported being sexually harassed. The main perpetrators were physicians and patients, and these incidents occurred more commonly in the in-patient clinics. 45% reported a decline in work productivity following the incidents.
Kamchuchat et al. [75]	2008	Workplace violence	Thailand	545 nurses working in a general hospital in southern Thailand	Mixed methods	Questionnaire modified from one developed by the Joint Program on Workplace Violence in the Health Sector and key informant interviews (n = 17).	The 12-month prevalence was 38.9% for verbal abuse, 3.1% for physical abuse and 0.7% for sexual harassment. The main perpetrators of verbal and physical abuse were patients and their family, while co-workers were the main perpetrators for sexual harassment. Younger age and working in high-risk areas (out-patient unit, emergency units, operating theatre, medical and surgical units) were associated with an increased risk of violence.
Aydin et al. [76]	2009	Workplace violence	Turkey	522 general practitioners from 48 cities	Cross-sectional	Questionnaire on workplace violence.	82.2% reported experiencing violence at work. Verbal abuse was the most common (89.3%), followed by physical violence (7.9%), economic (1.7%) and sexual violence (1.1%). Verbal and sexual violence was more common in women and physical and economic violence more common in men. Patients and their relatives was the most common source (91.1%).
Gimeno et al. [77]	2010	Prevalence of verbal abuse and its association with safety climate at work	Costa Rica	625 health care workers working in 10 public hospitals in Costa Rica	Cross-sectional	Questionnaires on safety climate and verbal abuse.	83.9% of the participants reported low safety climate levels. Prevalence of verbal abuse from all sources was 78.2%, with the most common being abuse from co-workers and patients. The odds of experiencing verbal abused increased with lower levels of safety climate.

Table 2. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Atan et al. [78]	2012	Workplace violence	Turkey	441 nurses from 6 university hospitals	Cross-sectional	Questionnaires on workplace violence in the past year.	60.8% reported some form of workplace violence, 59.4% verbal violence and 16.6% physical violence. The sources for verbal violence were patients (47.4%), visitors (39.5%), and health staff (10.7%) and for physical violence were patients (14.3%), visitors (5.0%) and health staff (0.5%). Of those who experienced violence, 42.9% reported a negative impact on their physical and/or psychological health and 42.9% reported a negative impact on work performance.
Khademloo et al. [79]	2013	Prevalence of physical and verbal abuse	Iran	271 nurses from 5 hospitals in the north of Iran	Cross-sectional	Questionnaire on physical and verbal abuse experienced in the last year (Staff Observation Scale Revised (SOAS-R)).	95.9% reported verbal abuse; the sources were patients (30.3%), family members (53.4%), and co-workers (16.1%). 29.1% reported physical abuse; the sources were patients (44.3%) and family members (55.6%).
da Silva et al. [80]	2015	Workplace violence and its association with depression	Brazil	2940 primary health care workers from 66 health centres in Sao Paolo	Cross-sectional	Questionnaire on workplace violence (adapted from a WHO questionnaire on domestic violence), and depression and depressive symptoms (Brazilian version of the nine-item Patient Health Questionnaire).	The frequencies of violence experienced at work were: insults (44.9%), witnessing violence (29.5%), threats (24.8%), and physical aggression (2.3%). Exposure to violence was positively associated with depressive symptoms and probable major depression.
Baig et al. [81]	2018	Prevalence of workplace violence	Pakistan	822 health care workers from hospitals, non-government organizations and ambulance services in Karachi	Mixed methods	Questionnaires on workplace violence; and 42 in-depth interviews and 17 focus group discussions.	33.5% had experienced violence in the past year. Verbal violence was more common (30.5%) than physical violence (14.6%). The main source was from people who accompanied patients (58.1%). The main perceived causes of violence were failure to meet the expectations of patients, communication gaps, poor quality of services, inadequate security in facilities, heavy workloads, and lack of training to respond to violence.

Table 2. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Zhao et al. [82]	2018	Prevalence of workplace violence and association with mental health	China	886 nurses from 8 tertiary hospitals in Heilongjiang Province	Cross-sectional	Questionnaires on workplace violence (Workplace Violence Scale), anxiety (Self-rating Anxiety Scale) and depression (Self-rating Depression Scale).	67.2% reported workplace violence. Workplace violence was positively associated with anxiety and depression. Service years played a moderating role in the relationship between workplace violence and anxiety, and gender played a moderating role in the association between workplace violence and depression.
Abate et al. [83]	2019	Workplace violence and associated factors	Ethiopia	435 health care workers from a tertiary care mental hospital in Addis Ababa	Cross-sectional	ILO/ICN/WHO/PSI Workplace Violence in the Health Sector Country Case Study Questionnaire.	62.1% reported verbal violence, 36.8% physical violence and 21.8% sexual harassment. Age > 31 years and contact with patients were the associated factors.
Yenealem et al. [84]	2019	Prevalence and risk factors for violence at work	Ethiopia	531 health care workers from Gondar city	Cross-sectional	Questionnaires adapted from the ILO/ICN/WHO/PSI Workplace Violence in the Health Sector Country Case Study Questionnaire.	58.2% reported experiencing some form of violence, of which 53.1% reported verbal abuse, 22% physical attacks, and 7.2% sexual harassment. Working in emergency departments, working in shifts, having less work experience and being a nurse was associated with an increased risk of violence.
Hacer and Ali [85]	2020	Workplace violence and its association with burnout	Turkey	310 physicians from Ordu province	Cross-sectional	Questionnaires on workplace violence and the Maslach Burnout Inventory.	93.2% reported experiencing verbal violence, 86.1% psychological violence and 22.6% physical violence. The most common source of violence were patients and their relatives. Emotional exhaustion and depersonalization scores were significantly higher in those who had experienced violence.
				II. Burnout			
Ashkar et al. [86]	2009	Prevalence of burnout	Lebanon	155 resident doctors from 2 tertiary care hospitals in Beirut	Cross-sectional	Questionnaires on occupational history and the Maslach Burnout Inventory for Health Service Workers.	80% reported high levels of burnout in at least one domain. Prevalence according to subscales was: high levels of emotional exhaustion (EE)—67.7%, high depersonalisation (DP) scores—47.1% and low levels of personal accomplishment (PA)—23.9%. Working > 80 h/week, experiencing a major stress, getting > eight calls per month, and being female increased the risk of burnout

Table 2. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Ayala and Carnero [87]	2013	Demographic and occupational determinants of burnout	Peru	93 nurses working in acute and critical care departments in a referral military hospital in Lima	Cross-sectional	Questionnaires on occupational history and the Maslach Burnout Inventory.	Higher emotional exhaustion scores were associated with having children and inversely associated with time working in the current department. Higher depersonalisation scores were associated with being single and working in the emergency room or intensive care unit. Higher personal achievement scores were associated with having children.
Zubairi and Noordin [88]	2016	Prevalence of burnout and risk factors	Pakistan	82 resident doctors working in a university hospital in Karachi	Cross-sectional	Questionnaires on occupational history and the Maslach Burnout Inventory	74.4% reported high levels of burnout on at least one subscale, and 12.2% reported burnout on all the three subscales. Prevalence according to subscales was: high levels of EE—60%, high DP scores—38% and low levels of PA—32%. Workload dissatisfaction, length of working hours, relationship with co-workers and lack of autonomy were associated with an increased risk of burnout
Colindres et al. [89]	2018	Association of psychosocial work environment, burnout and compliance with infection control measures	Ecuador	333 nurses in four acute care facilities in Ecuador	Cross-sectional	Questionnaires on effort-reward imbalance, burnout (Copenhagen Burnout Inventory scale) and infection control compliance (modified Johns Hopkins University. School of Hygiene and Public Health Safety Climate Questionnaire).	21% of nurses experienced effort reward imbalance and 35.8% had work-related burnout. 44.2% reported adhering to infection control practices. Increased effort-reward imbalance was associated with an increased risk of burnout. Burnout was independently associated with decreased adherence to infection control practices.
Khan et al. [90]	2019	Job stress and burnout	Pakistan	447 anaesthesiologists from tertiary hospitals in Lahore and Karachi	Cross-sectional	Questionnaires on occupational history and the Maslach Burnout Inventory.	39.4% showed moderate to high levels emotional exhaustion, 68.4% moderate to high levels of depersonalization, and 50.3% moderate to high levels of burnout in personal achievements. Working in Lahore, > 2 nights on call per week, and > 40 h/week work inside the operating room were associated with burnout.

Table 2. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Mumbwe et al. [91]	2020	Prevalence of burnout	Zambia	160 anaesthesia providers (physicians and non-physicians) in Zambia	Cross-sectional	Questionnaires on occupational history and the Maslach Burnout Inventory.	Burnout was seen in 51.3% of participants. Prevalence according to subscales was: high levels of EE—66.3%, high DP scores—45% and low levels of PA—23.8%. Not being a physician and not having the right team to work with were significantly associated with burnout.
III. Work Environment and Job Satisfaction							
Li et al. [92]	2009	Psychosocial work environment and intention to leave	China	3088 nurses from 12 hospitals participated in the baseline study and 1521 in the one-year follow-up study	Longitudinal	Copenhagen Psychosocial Questionnaires.	Prevalence of intention to leave was 16.26% at baseline, and at one-year follow up, the incidence rate was 14.46%. Increased emotional demand, decreased workplace commitment, decreased meaning of work, and decreased job satisfaction were associated with intention to leave.
Ayamolowo et al. [93]	2013	Work environment and job satisfaction	Nigeria	161 nurses working in public primary health care facilities in Ekiti State	Cross-sectional	Questionnaires assessing work environment (adapted from the World Health Professions Alliance checklist on environment for health care professionals) and job satisfaction (Minnesota Satisfaction Questionnaire (MSQ).	44% of the nurses perceived their work environment to be of average quality and 31% as high quality. A majority (67.1%) of nurses reported low degrees of job satisfaction. There was a positive correlation between overall work environment and job satisfaction.
Ogunlade and Ogun-fowokan. [94]	2014	Nurses' experiences and satisfaction with night shift work	Nigeria	186 nurses who did a roster including night shift in 2 tertiary hospitals in Ile-Ife	Cross-sectional	Questionnaires assessing experiences and satisfaction during night shift work.	Overall, 55.4% were fairly satisfied with their night shifts as compared to 1.6% who were very satisfied and 43.0% who were satisfied. Inadequate staffing and equipment for protection from hazards were the factors that contributed to the low satisfaction with night shifts.
Ayalew and Workineh [95]	2019	Job satisfaction and associated factors	Ethiopia	220 nurses from public health facilities in Bahir Dar city	Cross-sectional	Questionnaire on job satisfaction using the Job satisfaction scale and Minnesota Questionnaire.	43.6% were satisfied with their job. Advancement, recognition and work security were positively associated with job satisfaction.

Note: Mixed-methods studies refers to studies with qualitative and quantitative components.

Table 3. The characteristics of the studies (n = 17) on exposure to ergonomic hazards (arranged in chronological order according to the year of publication).

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Smith et al. [96]	2004	Musculoskeletal complaints (MSCs) and psychosocial risk factors	China	282 nurses from a tertiary care hospital in Shijiazhuang city	Cross-sectional	Standardized Nordic Questionnaire.	Prevalence of MSCs in the past 12 months was 70%. The most common site was the lower back (56%) followed by the neck (45%), shoulder (40%) and upper back (37%). High mental pressure, limited work support and performing boring and tedious tasks were associated with increased risk of MSCs.
Tezel [97]	2005	Musculoskeletal complaints (MSCs)	Turkey	120 nurses from 4 hospitals in Ezrurum	Cross-sectional	Standardized Nordic Questionnaire.	90% reported at least one MSC in the past 6 months. Low-back pain was the most common (69%), followed by neck (54%) and shoulder (46%) pain.
Fabunmi et al. [98]	2008	Prevalence of musculoskeletal disorders (MSD)	Nigeria	214 nurses in a university hospital in Ibadan	Cross-sectional	Standardized Nordic Questionnaire.	90.7% reported experiencing MSDs in the past 12 months. Low-back pain was the most common (78%). Job inexperience, volume and type of work were the predisposing factors.
de Castro et al. [99]	2009	Work-related injuries and back pain	Philippines	690 nurses from 13 regions of the Philippines who were attending the Philippines Nurses Association annual national convention	Cross-sectional	Questionnaires on work related injuries/illness, reporting behaviour, and safety concerns.	38.6% reported experiencing at least one occupational injury/illness in the past year and 78.2% reported experiencing back pain. Most of the injuries were not reported. The most frequent safety concerns reported were stress and overwork.
Karahan et al. [100]	2009	Prevalence of low-back pain and risk factors	Turkey	1600 health care workers from 6 hospitals in 4 Turkish cities	Cross-sectional	Questionnaires on back pain and occupational history.	61.3% reported at least one occurrence of low-back pain within the last 12 months. Age, female gender, smoking, occupation as a nurse, work stress and heavy lifting were associated with increased risks.

Table 3. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Mehrdad et al. [101]	2010	Musculoskeletal symptoms and association with psychosocial factors	Iran	317 nurses from the Emam hospital in Tehran	Cross-sectional	Standardized Nordic Questionnaire and General Nordic questionnaire on psychosocial work environment.	95% reported complaints in at least one body site in the past 12 months. Low back was the most common site (73.2%). Higher levels of stress was associated with increased risk of musculoskeletal complaints.
Tinubu et al. [102]	2010	Work-related musculoskeletal disorders (WMSDs) and risk factors	Nigeria	128 nurses from 3 hospitals in Ibidan	Cross-sectional	Standardized Nordic Questionnaire.	78% reported WMSDs in at least one body site in the past 12 months. WMSDs occurred mostly in low back (44.1%), neck (28.0%), and knees (22.4%). Working in the same position for long periods, lifting/transferring patients, bending or twisting, and handling many patients were the commonest risk factors.
Arsalani et al. [103]	2014	Prevalence of musculoskeletal disorders (MSD) and risk factors	Iran	520 nurses working in 10 university hospitals in Tehran	Cross-sectional	Standardized Nordic Questionnaire and psychosocial working conditions from the Copenhagen Psychosocial Questionnaire.	88% reported experiencing MSDs in the past 12 months, with the most common body regions being the lower back (65.3%), knees (56.2%) and neck (49.8%). Physical and psychosocial work demands and low control over their work, which lead to work-related stress, increased the risk of MSDs. Participants also reported inflexible work schedule, poor quality of devices for transferring patients, overexertion and job dissatisfaction.
Barzideh et al. [104]	2014	Prevalence of musculoskeletal disorders (MSD) and risk factors	Iran	385 nurses working in 14 educational hospitals	Cross-sectional	Standardized Nordic questionnaire and Job Content Questionnaire.	89.9% reported experiencing MSDs in the last 12 months. Lower back pain was the most common (61.8%). High psychological and physical job demands and low decision latitude were associated with increased risks.
Munabi et al. [105]	2014	Prevalence of musculoskeletal disorders (MSD) and risk factors	Uganda	741 nurses from 5 hospitals in Uganda	Cross-sectional	Questionnaire adapted from the Standardized Nordic and standardized Dutch Musculoskeletal questionnaires.	80.8% had experienced MSDs in the last 12 months. Low-back pain was the most common (61.9%). Working in a bent or twisted position, mental exhaustion and being absent from work for more than 6 months were associated with an increased risk.

Table 3. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Yasobant and Rajkumar [106]	2014	Work-related musculoskeletal disorders (WMSDs), and risk factors	India	140 health care workers from a tertiary care hospital in Chennai	Cross-sectional	Standardized Nordic Musculoskeletal Questionnaire.	50.7% reported symptoms in at least one body site in the past 12 months. Low back was the most common site (45.7%). Working in the same position for long periods, working in awkward and cramped positions, and performing repetitive tasks were the commonest risk factors.
Abaraogu et al. [107]	2017	Work-related musculoskeletal disorders (WMSDs) and job stress	Nigeria	126 physiotherapists from hospitals in five states	Cross-sectional	Standardized Nordic Musculoskeletal Questionnaire and Job Content Questionnaire.	82.1% reported symptoms in at least one body site in the last 12 months. Low back was the most common site (57.8%). There were high levels of stress in most of the job dimensions. However, no specific domains of job stress dimensions were associated with WMSDs.
Amin et al. [108]	2018	Prevalence of self-perceived emotional distress and musculoskeletal disorders (MSD)	Malaysia	376 nurses working in public hospitals in the Klang valley	Cross-sectional	Standardized Nordic Musculoskeletal Questionnaire and short version of the Depression, Anxiety, and Stress Scale.	73.1% had experienced MSDs in the last 12 months and neck was the most common site (48.9%). 75% reported emotional distress. Stress and anxiety were significantly associated with an increased risk of MSDs.
Dlungwane et al. [109]	2018	Low-back pain and risk factors	South Africa	242 nurses from a regional hospital in KwaZulu-Natal	Cross-sectional	Questionnaire on back pain and risk factors.	The point prevalence of low-back pain was 59%. Frequent bending, maintaining prolonged positions and transferring patients were the risk factors.
Ike and Olawumi [110]	2018	Back pain and risk factors	Nigeria	228 nurses working in a medical centre in Abeokuta	Cross-sectional	Questionnaire on back pain and risk factors.	The point prevalence of back pain was 39%. Maintaining a particular position for long periods and lifting patients were common risk factors.
Luan et al. [111]	2018	Prevalence of musculoskeletal disorders (MSD) and risk factors	Vietnam	1179 nurses working in 15 district hospitals in Haiphong	Cross-sectional	Standardized Nordic Questionnaire.	74.7% reported symptoms of MSDs in the last 12 months. Low back and neck were the most common sites (44.4% and 44.1%). Age, history of musculoskeletal disease, anxiety and absenteeism in the workplace were risk factors.

Table 3. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Dong et al. [112]	2019	Prevalence of musculoskeletal disorders (MSD) and risk factors	China	14,720 health care workers from 8 tertiary hospitals in Shandong Province	Cross-sectional	Questionnaire incorporating the Standardized Nordic Musculoskeletal and the Dutch Musculoskeletal Questionnaires.	91.2% reported symptoms in at least one body site in the last 12 months. Low back was the most common site (72.8%). MSDs were associated with increased work load, psychological fatigue, mental stress and certain ergonomic factors (bending, twisting).

Table 4. The characteristics of the studies (n = 11) on exposure to chemical hazards and occupational hazards in general (n = 2) (arranged in chronological order according to the year of publication).

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
I. Chemical Hazards							
Baykal et al. [113]	2009	Working conditions and safe handling practices of antineoplastic drugs	Turkey	171 nurses who worked in oncology units and administered antineoplastic drugs in nine hospitals in Istanbul	Cross-sectional	Questionnaires on working conditions and safe handling practices of antineoplastic drugs were distributed.	94.7% of the nurses reported wearing gloves, 89.5% wore masks, 52.0% wore gowns and 18.7% wore goggles. 40.4% reported preparing drugs in a biological safety cabinet, 37.4% said that they prepared the drugs in the nurses' office and 15.8% said that they prepared the drugs in a room that was also used for other purposes such as meals.
Agrawal et al. [114]	2010	Exposure to latex and latex allergy	India	163 dental professionals working in Udaipur city	Cross-sectional	Questionnaires on latex glove use and symptoms of latex allergy.	16% reported allergy symptoms to latex gloves. 81.6% wore gloves for >5 h a day. The number of years of latex gloves use was significantly associated with allergic symptoms.
Amarasekera et al. [115]	2010	Exposure to latex and latex allergy	Sri-Lanka	325 health care workers in a tertiary care hospital	Cross-sectional	Questionnaires latex gloves use and symptoms of latex allergy.	16.3% reported latex allergy symptoms. 49.2% wore gloves for >1 h a day and 44.2% handled other rubber products at work. Longer duration of working as a health care worker and using gloves for >1 h/day were the risk factors associated with allergic symptoms.

Table 4. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Phaswana and Naidoo [116]	2013	Prevalence of latex sensitization and allergy with the use of hypoallergenic powder and lightly powdered latex gloves	South Africa	501 health care workers (337 who used latex gloves and 164 administration staff who did not use latex gloves) in a tertiary care hospital in KwaZulu-Natal	Cross-sectional	Questionnaires on latex glove use and symptoms of latex allergy. Skin prick tests were conducted for latex sensitization.	Prevalence of latex sensitisation and allergy in exposed workers was 7.1% and 5.9%, respectively; and in unexposed workers it was 3.1% and 1.8%. Work-related allergy symptoms were significantly higher in exposed workers. A dose-response relationship was observed for powdered latex gloves.
Supapvanich et al. [117]	2013	Exposure to latex and latex allergy	Thailand	899 nurses from three hospitals in Thailand	Cross-sectional	Questionnaires on respiratory and dermal symptoms that were attributed to latex gloves use.	18% reported symptoms attributable to latex gloves use. Dermal symptoms were more frequently reported, particularly itchy skin and rash. Using >15 pairs of powdered latex gloves/day, using chlorhexidine and being an operating theatre nurse were the risk factors associated dermal symptoms.
Köse et al. [118]	2014	Exposure to latex and latex sensitization	Turkey	1115 health care workers from an education and research hospital in Izmir	Cross-sectional	Questionnaires on latex gloves use and symptoms of latex allergy. Blood was tested for latex-specific IgE levels.	Prevalence of latex sensitization was 4.2%. Latex allergy was more common in nurses.
Supapvanich et al. [119]	2014	Exposure to latex and latex sensitization	Thailand	363 nurses from two tertiary hospitals in Southern Thailand	Cross-sectional	Questionnaires on use of latex gloves and symptoms related to latex use. Latex sensitization was confirmed by detecting anti-latex IgE antibodies using a solid phase immunoassay.	The prevalence of latex sensitization was 4.4%. The prevalence of latex sensitization was higher in hospitals where gloves with higher protein levels were used.

Table 4. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
Abbasi et al. [120]	2016	Safe handling practices of anti-neoplastic drugs	Iran	86 nurses who worked in oncology units and administered antineoplastic drugs from six centres of chemotherapy in Shiraz	Cross-sectional	Questionnaires on the safe handling practices were distributed. Observation of work practices was performed using a check list.	Only about half of the nurses used personal protective equipment (PPE) during the administration of the drugs, and only about 5% used PPE during the administration and disposal of the drugs. Biological safety cabinets were used in all the hospitals and clinics included in the study.
Elshaer [121]	2017	Adherence to control measures used for handling of antineoplastic drugs	Egypt	54 nurses and clinical pharmacists who were exposed to ADs and 54 who were not exposed, working in oncology centres in Alexandria city.	Cross-sectional	Questionnaires on adverse health effects and control measures were distributed. Nurses and clinical pharmacists who were exposed to ADs were compared to those who were not exposed.	Biological safety cabinets and ventilation devices were used by pharmacists but not by nurses. Significantly higher percentages of pharmacists reported safe handling practices and the use of PPE as compared to nurses. There was no medical surveillance program in the workplace.
Alehashem and Baniasadi [122]	2018	Safe-handling practices of antineoplastic drugs and control measures	Iran	14 oncology health care workers filled 224 questionnaires in a tertiary care centre	Cross-sectional	7–8 health care workers worked in the Oncology ward every day. They filled the questionnaire on safe handling practices for six weeks or 30 working days.	20.56% reported carrying out drug preparations without any personal protective equipment. All preparations of antineoplastic drugs were reported to be performed in a biological safety cabinet.
Bayraktar-Ekincioglu et al. [123]	2018	Practices and safety measures when handling antineoplastic drugs	Turkey	40 hospital pharmacists who handled chemotherapy from Turkey	Cross-sectional	Questionnaires on chemotherapy drug preparation processes and knowledge on the safety measures.	The majority (42.5%) reported using automated chemotherapy units and 30% prepared the drugs manually. The reported practices were not always consistent with published recommendations: use of double glove (63.6%), glasses (62.2%), hair cap (66.7%), foot covers (32.3%), masks (89.1%), coat (92.1%), closed-system drug transfer set (70.6%), and biological safety cabinet (91.7%).

Table 4. *Cont.*

Authors	Year	Topic	Origin	Participants	Type of Study	Methods	Findings
				II. Occupational Hazards (General)			
Aluko et al. [124]	2016	Compliance with control measures	Nigeria	290 health care workers in Osun state	Cross-sectional	Questionnaires on knowledge on occupational hazards and their control practices.	Participants were knowledgeable about the various types of occupational hazards (biological, chemical, physical, and ergonomic). Regarding control practices, 96.2% wore gloves and 77.2 practiced correct body posturing during clinical procedures, 93.8% reported safe disposals, and 62.4% were immunized against Hepatitis B. Only 52.1% always complied with standard procedures and the main reasons for non-compliance were lack of safety equipment and time constrains.
Tait et al. [125]	2018	Biological, chemical, and physical hazards in medical laboratories	Kenya	204 laboratory workers in 108 medical laboratories in Kajiado county	Cross-sectional	Questionnaires on biological, chemical and physical hazards.	65.6% were exposed to 1 + biological hazard, 38.2% handled un-labelled and un-marked chemicals; and 49.5% reported laboratory equipment dangerously placed. There were a large number of other risks. Strong correlations between protective measures within individuals. Control measures reported were occupational health and safety training and supervising staff (98%), proper medical waste containers (92.6%), first aid safety equipment (36.8%), chemical hygiene plans (25%) and chemical hoods (19.1%).

Note: PPE—personal protective equipment.

4. Discussion

This study aimed to map and synthesize the available research on occupational hazards among health care workers in LMICs. The research conducted on this topic is quite substantial as evidenced by the 99 articles included in this review. However, half of these studies were on biological hazards, and research on the other types of hazards was minimal in comparison. The findings of this review also show that research on occupational hazards in LMICs has increased considerably in the last decade, perhaps indicating an increasing recognition of occupational health and safety of health care workers in these countries.

4.1. Biological Hazards

4.1.1. Bloodborne Pathogens

The majority of the literature on biological hazards was on the occupational transmission of bloodborne pathogens, such as Hepatitis B, HIV, and Hepatitis C, through needlestick/sharps injuries and splash accidents. Health care workers from LMICs are at increased risk of transmission of bloodborne pathogens because of the high population prevalence of these diseases and the fact that safety measures to reduce these risks are inadequate [126].

The prevalence of needlestick injuries was variably reported in the studies included in this review, with some studies reporting prevalence in the past year, some over the entire career and a few reporting it in the past 3 months, 6 months and 5 years. The prevalence of needlestick injuries in the past year was reported in 12 studies and showed a wide variation, ranging from 27% in a study conducted in Nigeria to 82% in a study conducted in China [28,33,35,37,40,43,46–48,58,63,64]. The prevalence of needlestick injuries over the entire career was reported in nine studies and ranged from 32.4% in a study conducted in Ethiopia to 86.2% in a study from China [35,37,43,44,54,61–64]. The incidence of needlestick injuries was reported in two studies. A study conducted in Kenya reported an incidence rate of 0.97 needlestick injuries per health care worker per year [42] and a study from Turkey reported an incidence of 2.18 exposures/person-years [59].

Needlestick injuries were more common than accidental splashes [38,45,55,57,58], and syringes caused most of the needlestick injuries [43,45,48,51]. The highest frequencies of injuries were reported by nurses, doctors (mainly surgeons and interns), dental personnel, and cleaners [27,28,31,32,43,45,46,48,51,55,57,59,61,63]. The risk factors for injuries were lack of training, heavy workloads, long working hours, not using gloves, recapping of needles, and using syringes frequently [37,43,48,51,59].

Various risk reduction strategies have been recommended to decrease occupational exposures to bloodborne pathogens, such as the use of standard precautions, vaccination against Hepatitis B, and post-exposure prophylaxis (PEP) for Hepatitis B and HIV [127]. Compliance with standard precautions for infection control was suboptimal as reported in a number of studies from various countries [29,30,32,33,36,38,47–50,52,54,58,60,64,124,125]. Barriers to compliance reported were shortage of equipment, inadequate staffing, and lack of training [39]. Unsafe injection practices such as recapping of needles and reusing syringes were also prevalent [28,34,49,50,53,54]. Most of the needlestick injuries were not reported and treated [33,44,56,58]. There were seven studies that reported on Hepatitis B vaccination status. The vaccination status (completed 3 doses of vaccine) was low in most of the studies ranging from 8% to 56.1% [34,41,46,51,54,60], except for a study conducted in China (71%) [33]. Among all health care workers, vaccination rates were lowest in housekeeping personnel [34,46]. There were only three studies that examined post-exposure prophylaxis for HIV and these studies reported a low uptake of PEP by health care workers and that almost half of those who started PEP discontinued the treatment due to side effects of the drugs [27,32,42]. There were no studies reporting the use of HBV immunoglobulin for post-exposure prophylaxis for HBV infection, which could be due to its unavailability in LMICs [34].

Taken together, the findings of this review show that needlestick and splash injuries are prevalent in LMICs and risk reduction strategies to protect health care workers from these infections are suboptimal.

4.1.2. Tuberculosis

A systematic review on tuberculosis among health care workers in LMICs published in 2006 reported a high occupational risk of tuberculosis, with a latent tuberculosis infection (LTBI) prevalence of 54% (range 33% to 79%), an incidence of 0.5% to 14.3% per year, and an attributable risk due to nosocomial exposure from 25 to 5361 per 100,000 per year [25]. As with transmission of bloodborne infections, health care workers in LMIC are at an increased risk of exposure to tuberculosis due to high population tuberculosis rates and limited resources to institute control practices [128]. As compared to high-income countries where there are strict infection control practices to protect health care workers, even basic infection control strategies to reduce transmission in health care facilities in LMICs are lacking and tuberculosis control is mainly focused on case detection and treatment [128,129].

This present review included studies conducted after 2006, and found that occupational tuberculosis transmission is still a significant problem in LMICs. The prevalence of LTBI as reported by five studies in this review ranged from 23.6% to 76.5% when assessed using interferon-gamma release assays (IGRAs), and from 59.1% to 97.6% when assessed with tuberculin skin tests (TSTs) [65,67,68,70,73]. IGRAs are newer tests that use antigens that are more specific and hence are less likely to be affected by previous BCG vaccination status and non-tuberculosis mycobacterial infection, which are the drawbacks of TSTs [129]. In the systematic review, only one study had used IGRAs to detect LTBI prevalence. There was one study in this present review that reported the incidence rates of LTBI test conversion, a prospective study conducted in Georgia from 2009 to 2011, which reported conversion rates of 17.1 per 100 person-years for TST and 22.8 per 100 person years for IGRAs [68].

There were four studies examining active tuberculosis among health care workers in this review [66,69,71,72]. A study conducted in India reported a pulmonary tuberculosis incidence rate of 314 per 100,000 person-years among health care workers and that this was 1.86 times higher than that of the general population [66]. Another study conducted in South Africa reported a tuberculosis incidence rate of 1985 per 100,000 person-years among health care workers, which was double the incidence of tuberculosis in the general population [69]. A study conducted in China used low-dose lung CT examinations to detect active tuberculosis, and reported that the incidence and prevalence rates of active tuberculosis in health care workers were >2.8 times and >4.1 times greater than that of the general population, respectively [72].

The risk factors for acquiring tuberculosis identified in this review were working in high-risk areas (tuberculosis facilities/wards, medical wards, outpatient departments, microbiology laboratories, radiology departments), belonging to certain occupation groups (nurses, microbiology laboratory technicians, and radiology technicians), working for >10 years, increasing age, and having co-morbidities such as diabetes and HIV [65–73].

In summary, the prevalence and incidence of LTBI in health care workers in LMICs is very high and active tuberculosis among health care workers is approximately two times higher than that of the general population.

4.2. Psychosocial Hazards

4.2.1. Workplace Violence

The majority of studies on psychosocial hazards in this review were on workplace violence. Workplace violence has been reported as a significant problem in the health care sector throughout the world [10]. In this review, the prevalence of experiencing some form of violence in the workplace was high and ranged from 60.8% to 82.2% [76,78,82]. The prevalence varied depending on the specific type of violence measured (e.g., physical, verbal, sexual). Verbal abuse was the most common type of violence experienced by health care workers, with a prevalence ranging from 30.5% to 95.9% [75–81,83–85]. The prevalence of physical abuse ranged from 2.3% to 36.8% [75,76,78–81,83–85] and that of sexual harassment ranged from 0.7% to 21.8% [75,76,83,84]. Patients and their families were the most commonly reported perpetrators of verbal and physical abuse, while co-workers and patients were the most commonly reported perpetrators of sexual harassment [74–79,81,85]. The risk factors for workplace violence identified in this review were working in certain high-risk areas (out-patient departments, emergency departments, operation theatres and in-patient clinics), lower safety climate levels at work, working in shifts, having heavy workloads and younger age [74,75,77,81,84].

Being a victim of workplace violence can result in a range of negative consequences (psychological, physical, emotional, social, work functioning, quality of care, and financial) [130]. Five studies included in this review reported on the consequences and associations of workplace violence [74,78,80,82,85]. Three studies reported on psychological consequences, where exposure to workplace violence was associated with anxiety, depressive symptoms and major depression, and burnout [80,82,85]. Two studies reported on work functioning consequences and found that almost half (42.9% and 45%) of the participants who experienced workplace violence reported a decline in work productivity [74,78].

4.2.2. Burnout

Burnout, as described by Maslach et al. [131], comprises of three dimensions: emotional exhaustion, depersonalization, and low personal accomplishment. Health care workers are known to be at an increased risk of burnout due to the inherent nature of their job which exposes them to high levels of emotional and psychological stress [11]. Burnout has been found to be associated with absenteeism, high turnover rates, low morale, and decrease in the quality of care.

Four of the six studies included in this review examined burnout among doctors (residents and anaesthesiologists) [86,88,90,91] and two studies examined it in acute and critical care nurses [87,89]. These studies reported a high prevalence of burnout. The prevalence of high levels of burnout in at least one dimension ranged from 51.3% to 80% [86,88,91]. Emotional exhaustion, depersonalization, and low personal accomplishment prevalence ranged from 39.4% to 67.7%, 38% to 68.4%, and 23.8% to 50.3%, respectively [86,88,90,91]. The work-related risk factors for burnout identified in this review were long working hours, experiencing a major stress at work, not having the right team to work with, lack of autonomy at work, and negative psychosocial work environments (as measured by perceived effort-reward imbalance). Personal risk factors were reported by only two studies and these included female gender, being single and having children [86,87]. Only one study reported on the consequences of burnout and this study found that burnout was independently associated with decreased adherence to infection control practices [89].

4.2.3. Work Environment and Job Satisfaction

Two studies included in this review examined job satisfaction and work environment among nurses and reported that more than fifty percent of the nurses (56.4% to 67.1%) were not satisfied with their jobs and only 31% perceived their work environment to be of high quality [93,95]. Advancement in the job, recognition, work security and a good work environment were the factors that were reported to be positively associated with job satisfaction. One study examining nurses' satisfaction with night shift work reported that only 43% of these nurses were satisfied with their night shifts, and the factors associated with the low levels of satisfaction were inadequate staffing and inadequate equipment for protection from hazards [94]. A longitudinal study conducted in China examined psychosocial work environment and intention to leave among nurses and reported a 16.3% prevalence of intention to leave and an incidence rate of 14.5% [92]. Increased emotional demands, decreased workplace commitment, decreased meaning of work and decreased job satisfaction were the factors reported to be associated with intention to leave.

The delivery of quality health care depends largely on the quality of staff delivering these services [132]. Satisfied workers are known to be more efficient and productive, thus contributing to the provision of better quality services. Job dissatisfaction, on the other hand, is associated with absenteeism and higher employee turnover rates. Providing a good work environment is a key factor in improving employee job satisfaction, organizational commitment and intention to remain [14].

In summary, the prevalence of verbal and physical abuse, and burnout were reported as being extremely high in these studies. In addition, satisfaction with work was low. These factors impact on retention of health care workers which is particularly important in the context of LMICs since these countries already face a shortage of health care workers [133].

4.3. Ergonomic Hazards

Musculoskeletal disorders are a common cause for work-related disability and absenteeism, resulting in substantial financial consequences in the form of workers' compensation and medical expenditure [134]. Health care worker are at an increased risk of musculoskeletal disorders and there is an extensive body of literature from high-income countries examining these disorders among different occupation groups within the health care sector (nurses, surgeons, physical therapists, dentists) [9,135–137].

The studies on ergonomic hazards included in this review examined prevalence and risk factors of musculoskeletal disorders among health care workers. Thirteen studies examined musculoskeletal disorders using the Nordic Musculoskeletal Questionnaire, mainly among nurses (10/13 studies) [96–98,101–104,106–108,111,112], and four studies examined only low-back pain [99,100,109,110]. The prevalence of musculoskeletal complaints in at least one body site in the past twelve months was reported in 12 studies and ranged from 50.7% to 95%. The most commonly reported body site for these complaints was the lower back (35.3% to 78.2%). The prevalence reported for the other regions of the body ranged from 28% to 49.8% for the neck, 23.5% to 52.1% for the shoulders, 20.7% to 54% for the upper back and 11% to 68.7% for the knees. There was only one study that examined work-related injuries, in which 38.6% of the nurses in the study reported experiencing at least one work-related injury in the past twelve months [99].

The occupational physical risk factors for musculoskeletal complaints identified in this review were working in the same position for prolonged periods, working in a bent or twisted position, lifting and transferring patients, handling many patients, and performing repetitive tasks [102,106,112]. The occupational psychosocial risk factors for musculoskeletal complaints identified were high levels of stress, anxiety, mental exhaustion, limited support in the workplace, low decision latitude, increased workload, monotonous work, job inexperience, and absenteeism [96,98,101,104,108,111,112].

In summary, there were few studies of musculoskeletal disorders among LMIC health care workers, and they found a very high prevalence of musculoskeletal complaints in at least one body site. There was a lack of studies on work-related injuries.

4.4. Chemical Hazards

The studies on chemical hazards in this review mainly examined exposure to latex and latex allergy. Three studies examined the prevalence of latex allergy symptoms among health care workers and reported a prevalence ranging from 16% to 18% [114,115,117]. The occupational risk factors for latex allergy reported in these studies were the number of years using latex gloves, using latex gloves for >1 h per day, using >15 pairs of powdered gloves per day, longer duration of working as a health care worker, using chlorhexidine and working as an operation theatre nurse. Two studies conducted in Turkey and Thailand examining the prevalence of latex sensitization by measuring latex-specific IgE antibody levels reported a prevalence of 4.2% and 4.4%, respectively, and that the prevalence was higher in hospitals where gloves with higher protein levels were used [118,119].

The use of less allergenic alternatives such as powder-free latex gloves and nitrile gloves has been recommended to control latex exposures among health care workers [12].

A study conducted in South Africa examined the prevalence of latex allergy and sensitization after the introduction of hypoallergenic powder-free and lightly powdered latex gloves [116]. The prevalence of latex allergy and sensitization reported in this study was 5.9% and 7.1%, respectively. The authors concluded that health care workers using hypoallergenic powder-free latex gloves were at risk of developing latex sensitization and recommended that a cost-effective alternative that eliminated latex from the health care environment was required in resource poor countries.

Five studies included in this review examined exposure to antineoplastic drugs, mainly safe handling practices, and reported that adherence to control measures was suboptimal. A study conducted in Egypt reported a lack of medical surveillance programs and training, inadequate handling practices, and low usage of personal protective equipment [121]. Two studies conducted in Turkey found that only about 40% of participants used biological safety cabinets and that personal protective equipment was not used consistently [113,123]. Two studies conducted in Iran reported that antineoplastic drug handling practices were not always consistent with published recommendations [120,122].

Few studies have been conducted on the many chemical hazards in health care work. The only studies which could be found examined exposure to latex and antineoplastic drugs and there were no studies on other chemicals such as cleaning products, disinfectants and diathermy smoke.

Health care workers can also be exposed to physical hazards such as radiation, noise, and slips and falls [12]. However, this review did not identify any studies on exposure to these types of hazards from LMICs.

4.5. Implications

This scoping review has revealed that health care workers in LMICs are exposed to a wide range of occupational hazards and that risk reduction strategies and safety measures are inadequately implemented, mainly due to equipment and human resource limitations. To protect health care workers in these countries, first and foremost, occupational health and safety needs to be prioritised. This requires political commitment from governments to increase investments in occupational health and safety programs. Additionally, although development and public health agencies have promoted the importance of health care workers by including the health care workforce as an essential component of sustainable development, these agencies have focused mainly on increasing the numbers and competency of health care workers [138]. There is a need for these agencies to equally address the underlying reasons for health care workers' migration, death and illness in LMICs and to advocate for the provision of safer workplaces for health care workers in these countries.

It is encouraging that research on occupational hazards among health care workers in LMICs has increased considerably in the past decade. However, the majority of the studies in this review were cross-sectional and some of them were of low quality (quality was not an exclusion criteria). In future, larger, more well-designed and prospective studies need to be conducted to make a convincing case for prioritising occupational health and safety of health care workers in these countries. In addition, the majority of the studies were on biological hazards and there were very few studies assessing exposure to chemical hazards. This is as expected since the risks from biological hazards are more apparent in LMICs where the population rates of infectious diseases are high. However, health care workers are also routinely exposed to chemicals that have been linked to chronic diseases such as cancer and asthma. More research is required in this area from LMICs.

4.6. Strengths and Limitations of the Review

To our knowledge, this review on exposure to occupational hazards among health care workers is the most comprehensive to date. It was based on a rigorous, systematic search strategy across five large databases with no date restrictions using strict methodological inclusion criteria.

Although this review has provided an overall synopsis of occupational hazards in health care workers in LMICs, there are some limitations to this study. First, the quality of the included studies was not assessed, so the review is inclusive of all articles irrespective of their quality. Second, only articles published in English were included, which might have resulted in the omission of data published in other languages. Thirdly, there is a possibility that all data may not have been captured by the search strategy, particularly if the articles were published in journals not indexed in Medline. Lastly, this review also excluded night shift work, which is an important occupational risk for health care workers. Despite these limitations, this review provides a comprehensive overview of the hazards encountered in the workplace by health care workers in LMICs.

5. Conclusions

Large proportions of health care workers in LMICs are occupationally exposed to a wide range of hazards. Safety measures and risk reduction strategies in these countries are suboptimal, mainly due to resource limitations. Health care workers need to be protected from occupational hazards because these hazards have the potential to cause diseases and injuries and can adversely impact the retention of health care workers and the quality of care provided. Health care worker retention is of particular importance in LMICs since these countries already face a shortage of health care workers. Political commitment towards making occupational health and safety a priority public health issue is necessary to ensure the safety of health care workers in LMICs. Although research on occupational hazards among health care workers in these countries has increased considerably in the last decade, most of this work is on biological hazards. More research is needed on the other types of occupational hazards.

Supplementary Materials: The following are available online at https://www.mdpi.com/1660-4601/18/5/2603/s1, Table S1: Search strategy for Medline (Ovid) (date of search: 1 May 2020).

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References

1. Vecchio, D.; Sasco, A.J.; Cann, C.I. Occupational risk in health care and research. *Am. J. Ind. Med.* **2003**, *43*, 369–397. [CrossRef] [PubMed]
2. The Lancet. COVID-19: Protecting health-care workers. *Lancet* **2020**, *395*, 922. [CrossRef]
3. McDiarmid, M.A. Hazards of the health care sector: Looking beyond infectious disease. *Ann. Glob. Health* **2014**, *80*, 315–319. [CrossRef]
4. Coggon, D.; Harris, E.; Poole, J.; Palmer, K. Mortality of workers exposed to ethylene oxide: Extended follow up of a British cohort. *Occup. Environ. Med.* **2004**, *61*, 358–362. [CrossRef]
5. Ratner, P.A.; Spinelli, J.J.; Beking, K.; Lorenzi, M.; Chow, Y.; Teschke, K.; Le, N.D.; Gallagher, R.P.; Dimich-Ward, H. Cancer incidence and adverse pregnancy outcome in registered nurses potentially exposed to antineoplastic drugs. *BMC Nurs.* **2010**, *9*, 15. [CrossRef]
6. Vaughan, T.L.; Stewart, P.A.; Teschke, K.; Lynch, C.F.; Swanson, G.M.; Lyon, J.L.; Berwick, M. Occupational exposure to formaldehyde and wood dust and nasopharyngeal carcinoma. *Occup. Environ. Med.* **2000**, *57*, 376–384. [CrossRef]
7. Arif, A.A.; Delclos, G.L. Association between cleaning-related chemicals and work-related asthma and asthma symptoms among healthcare professionals. *Occup. Environ. Med.* **2012**, *69*, 35–40. [CrossRef] [PubMed]

8. Trapé, M.; Schenck, P.; Warren, A. Latex gloves use and symptoms in health care workers 1 year after implementation of a policy restricting the use of powdered gloves. *Am. J. Infect. Control* **2000**, *28*, 352–358. [CrossRef] [PubMed]
9. Davis, K.G.; Kotowski, S.E. Prevalence of musculoskeletal disorders for nurses in hospitals, long-term care facilities, and home health care: A comprehensive review. *Hum. Factors* **2015**, *57*, 754–792. [CrossRef]
10. Phillips, J.P. Workplace violence against health care workers in the United States. *N. Engl. J. Med.* **2016**, *374*, 1661–1669. [CrossRef] [PubMed]
11. Maslach, C. *Burnout: The Cost of Caring*; Malor Books: Cambridge, MA, USA, 2003.
12. National Institute of Occupational Health and Safety. *State of the Sector: Healthcare and Social Assistance*; Centers for Disease Control and Prevention: Atlanta, GA, USA, 2009.
13. Nuwayhid, I.A. Occupational health research in developing countries: A partner for social justice. *Am. J. Public Health* **2004**, *94*, 1916–1921. [CrossRef]
14. Ingersoll, G.L.; Olsan, T.; Drew-Cates, J.; DeVinney, B.C.; Davies, J. Nurses' job satisfaction, organizational commitment, and career intent. *J. Nurs. Admin.* **2002**, *32*, 250–263. [CrossRef]
15. Liese, B.; Dussault, G. *The State of the Health Workforce in Sub-Saharan Africa: Evidence of Crisis and Analysis of Contributing Factors*; The World Bank: Washington, DC, USA, 2004.
16. Owie, H.; Apanga, P. Occupational health hazards prevailing among healthcare workers in developing countries. *J. AIDS Clin. Res.* **2016**, *7*, 596.
17. Arksey, H.; O'Malley, L. Scoping studies: Towards a methodological framework. *Int. J. Soc. Res. Methodol.* **2005**, *8*, 19–32. [CrossRef]
18. Daudt, H.M.; van Mossel, C.; Scott, S.J. Enhancing the scoping study methodology: A large, inter-professional team's experience with Arksey and O'Malley's framework. *BMC Med. Res. Methodol.* **2013**, *13*, 1–9. [CrossRef]
19. Levac, D.; Colquhoun, H.; O'Brien, K.K. Scoping studies: Advancing the methodology. *Implement. Sci.* **2010**, *5*, 69. [CrossRef]
20. Colquhoun, H.L.; Levac, D.; O'Brien, K.K.; Straus, S.; Tricco, A.C.; Perrier, L.; Kastner, M.; Moher, D. Scoping reviews: Time for clarity in definition, methods, and reporting. *J. Clin. Epidemiol.* **2014**, *67*, 1291–1294. [CrossRef]
21. Peters, M.; Godfrey, C.; McInerney, P.; Soares, C.B.; Khalil, H.; Parker, D. *Methodology for JBI Scoping Reviews. The Joanna Briggs Institute Reviewers' Manual 2015*; The Joanna Briggs Institute: Adelaide, Australia, 2015.
22. Tricco, A.C.; Lillie, E.; Zarin, W.; O'Brien, K.K.; Colquhoun, H.; Levac, D.; Moher, D.; Peters, M.D.; Horsley, T.; Weeks, L. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Ann. Intern. Med.* **2018**, *169*, 467–473. [CrossRef] [PubMed]
23. World Health Organization. *Sources and Classification of Health Workforce Statistics*; WHO: Geneva, Switzerland, 2008.
24. World Bank. World Bank Country Classification 2020. Available online: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups (accessed on 17 April 2020).
25. Joshi, R.; Reingold, A.L.; Menzies, D.; Pai, M. Tuberculosis among health-care workers in low-and middle-income countries: A systematic review. *PLoS Med.* **2006**, *3*, e494. [CrossRef]
26. World Health Organization; International Labour Organization. *Caring for Those Who Care: National Programmes for Occupational Health for Health Workers. Policy Brief*; World Health Organization: Geneva, Switzerland, 2020.
27. Cavalcante, N.J.F.; Abreu, E.S.; Fernandes, M.E.L.; Richtmann, R.; Piovesana, M.N.; Yamada, F.T.; Carvalho, E.S. Risk of health care professionals acquiring HIV infection in Latin America. *AIDS Care* **1991**, *3*, 311–316. [CrossRef]
28. Adegboye, A.A.; Moss, G.B.; Soyinka, F.; Kreiss, J.K. The epidemiology of needlestick and sharp instrument accidents in a Nigerian hospital. *Infect. Control Hosp. Epidemiol.* **1994**, *15*, 27–31. [CrossRef]
29. Olubuyide, I. Doctors at risk of hepatitis B and HIV infection from patients in Nigeria. *J. Roy. Soc. Health* **1996**, *116*, 157–160. [CrossRef] [PubMed]
30. Gumodoka, B.; Favot, I.; Berege, Z.; Dolmans, W. Occupational exposure to the risk of HIV infection among health care workers in Mwanza Region, United Republic of Tanzania. *Bull. World Health Organ.* **1997**, *75*, 133–140.
31. Khuri-Bulos, N.A.; Toukan, A.; Mahafzah, A.; Al Adham, M.; Faori, I.; Khader, I.A.; Rumeileh, Z.I.A. Epidemiology of needlestick and sharp injuries at a university hospital in a developing country: A 3-year prospective study at the Jordan University Hospital, 1993 through 1995. *Am. J. Infect. Control* **1997**, *25*, 322–329. [CrossRef]
32. Gounden, Y.P.; Moodley, J. Exposure to human immunodeficiency virus among healthcare workers in South Africa. *Int. J. Gynecol. Obstet.* **2000**, *69*, 265–270. [CrossRef]
33. Phipps, W.; Honghong, W.; Min, Y.; Burgess, J.; Pellico, L.; Watkins, C.W.; Guoping, H.; Williams, A. Risk of medical sharps injuries among Chinese nurses. *Am. J. Infect. Control* **2002**, *30*, 277–282. [CrossRef] [PubMed]
34. Talaat, M.; Kandeel, A.; El-Shoubary, W.; Bodenschatz, C.; Khairy, I.; Oun, S.; Mahoney, F.J. Occupational exposure to needlestick injuries and hepatitis B vaccination coverage among health care workers in Egypt. *Am. J. Infect. Control* **2003**, *31*, 469–474. [CrossRef]
35. Kermode, M.; Jolley, D.; Langkham, B.; Thomas, M.S.; Crofts, N. Occupational exposure to blood and risk of bloodborne virus infection among health care workers in rural north Indian health care settings. *Am. J. Infect. Control* **2005**, *33*, 34–41. [CrossRef] [PubMed]
36. Kermode, M.; Jolley, D.; Langkham, B.; Thomas, M.S.; Holmes, W.; Gifford, S.M. Compliance with Universal/Standard Precautions among health care workers in rural north India. *Am. J. Infect. Control* **2005**, *33*, 27–33. [CrossRef] [PubMed]

37. Nsubuga, F.M.; Jaakkola, M.S. Needle stick injuries among nurses in sub-Saharan Africa. *Trop. Med. Int. Health* **2005**, *10*, 773–781. [CrossRef]
38. Obi, S.; Waboso, P.; Ozumba, B. HIV/AIDS: Occupational risk, attitude and behaviour of surgeons in Southeast Nigeria. *Int. J. STD AIDS* **2005**, *16*, 370–373.
39. Chelenyane, M.; Endacott, R. Self-reported infection control practices and perceptions of HIV/AIDS risk amongst emergency department nurses in Botswana. *Accid. Emerg. Nurs.* **2006**, *14*, 148–154. [CrossRef]
40. Akinleye, A.A.; Omokhodion, F.O. Work practices of primary health care workers in urban and rural health facilities in south-west Nigeria. *Aust. J. Rural Health* **2008**, *16*, 47–48. [CrossRef] [PubMed]
41. Okeke, E.; Ladep, N.; Agaba, E.; Malu, A. Hepatitis B vaccination status and needle stick injuries among medical students in a Nigerian university. *Niger. J. Med.* **2008**, *17*, 330–332. [CrossRef]
42. Taegtmeyer, M.; Suckling, R.; Nguku, P.; Meredith, C.; Kibaru, J.; Chakaya, J.M.; Muchela, H.; Gilks, C. Working with risk: Occupational safety issues among healthcare workers in Kenya. *AIDS Care* **2008**, *20*, 304–310. [CrossRef]
43. Chen, L.; Zhang, M.; Yan, Y.; Miao, J.; Lin, H.; Zhang, Y.; Wang, H.; Du, X.; Li, T. Sharp object injuries among health care workers in a Chinese province. *AAOHN J.* **2009**, *57*, 13–16. [CrossRef]
44. Simon, L.P. Prevention and management of needlestick injury in Delhi. *Br. J. Nurs.* **2009**, *18*, 252–256. [CrossRef]
45. Chakravarthy, M.; Singh, S.; Arora, A.; Sengupta, S.; Munshi, N. The epinet data of four Indian hospitals on incidence of exposure of healthcare workers to blood and body fluid: A multicentric prospective analysis. *Indian J. Med. Sci.* **2010**, *64*, 540–548. [CrossRef]
46. Yacoub, R.; Al Ali, R.; Moukeh, G.; Lahdo, A.; Mouhammad, Y.; Nasser, M. Hepatitis B vaccination status and needlestick injuries among healthcare workers in Syria. *J. Glob. Infect. Dis.* **2010**, *2*, 28–34. [CrossRef] [PubMed]
47. Sangwan, B.; Kotwal, A.; Verma, A. Occupational exposure to blood and body fluids amongst health care workers in a teaching hospital of the armed forces. *Med. J. Armed Forces India* **2011**, *67*, 21–24. [CrossRef]
48. Irmak, Z. Needlestick and sharps injury among nurses at a state hospital in Turkey. *Aust. J. Adv. Nurs.* **2012**, *30*, 48–55.
49. Nasim, S.; Shahid, A.; Mustufa, M.A.; Arain, G.M.; Ali, G.; Taseer, I.-U.-H.; Talreja, K.L.; Firdous, R.; Iqbal, R.; Siddique, S.A.; et al. Biosafety perspective of clinical laboratory workers: A profile of Pakistan. *J. Infect. Dev. Ctries.* **2012**, *6*, 611–619. [CrossRef]
50. Omorogbe, V.E.; Omuemu, V.O.; Isara, A.R. Injection safety practices among nursing staff of mission hospitals in Benin City, Nigeria. *Ann. Afr. Med.* **2012**, *11*, 36–41.
51. Phillips, E.K.; Simwale, O.J.; Chung, M.J.; Parker, G.; Perry, J.; Jagger, J.C. Risk of bloodborne pathogen exposure among Zambian healthcare workers. *J. Infect. Public Health* **2012**, *5*, 244–249. [CrossRef]
52. Sethi, A.K.; Acher, C.W.; Kirenga, B.; Mead, S.; Donskey, C.J.; Katamba, A. Infection Control Knowledge, Attitudes, and Practices among Healthcare Workers at Mulago Hospital, Kampala, Uganda. *Infect Control Hosp. Epidemiol.* **2012**, *33*, 917–923. [CrossRef]
53. Abkar, M.A.A.; Wahdan, I.M.H.; Sherif, A.A.R.; Raja'a, Y.A. Unsafe injection practices in Hodeidah governorate, Yemen. *J. Infect. Public Health* **2013**, *6*, 252–260. [CrossRef]
54. Afridi, A.A.K.; Kumar, A.; Sayani, R. Needle stick injuries-risk and preventive factors: A study among health care workers in tertiary care hospitals in Pakistan. *Glob. J. Health Sci.* **2013**, *5*, 85–92. [CrossRef] [PubMed]
55. Rajkumari, N.; Thanbuana, B.T.; John, N.V.; Gunjiyal, J.; Mathur, P.; Misra, M.C. A prospective look at the burden of sharps injuries and splashes among trauma health care workers in developing countries: True picture or tip of iceberg. *Injury* **2014**, *45*, 1470–1478. [CrossRef] [PubMed]
56. Bekele, T.; Gebremariam, A.; Ahmed, K. Attitude, reporting behavour and management practice of occupational needle stick and sharps injuries among hospital healthcare workers in Bale zone, Southeast Ethiopia: A cross-sectional study. *J. Occup. Med. Toxicol.* **2015**, *10*, 42. [CrossRef]
57. Priya, N.L.; Krishnan, K.U.; Jayalakshmi, G.; Vasanthi, S. An analysis of multimodal occupational exposure leading to blood borne infections among health care workers. *Indian J. Pathol. Microbiol.* **2015**, *58*, 66–68. [CrossRef] [PubMed]
58. Sabermoghaddam, M.; Sarbaz, M.; Lashkardoost, H.; Kaviani, A.; Eslami, S.; Rezazadeh, J. Incidence of occupational exposure to blood and body fluids and measures taken by health care workers before and after exposure in regional hospitals of a developing country: A multicenter study. *Am. J. Infect. Control* **2015**, *43*, 1137–1138. [CrossRef] [PubMed]
59. Türe, Z.; Ulu Kiliç, A.; Cevahir, F.; Altun, D.; Özhan, E.; Alp, E. Predictive factors for percutaneous and mucocutaneous exposure among healthcare workers in a developing country. *J. Epidemiol. Glob. Health* **2016**, *6*, 141–146. [CrossRef] [PubMed]
60. Konlan, K.D.; Aarah-Bapuah, M.; Kombat, J.M.; Wuffele, G.M. The level of nurses' knowledge on occupational post exposure to Hepatitis B infection in the Tamale metropolis, Ghana. *BMC Health Serv. Res.* **2017**, *17*, 1–7. [CrossRef]
61. Matsubara, C.; Sakisaka, K.; Sychareun, V.; Phensavanh, A.; Ali, M. Prevalence and risk factors of needle stick and sharp injury among tertiary hospital workers, Vientiane, Lao PDR. *J. Occup. Health* **2017**, *59*, 581–585. [CrossRef] [PubMed]
62. Geberemariyam, B.S.; Donka, G.M.; Wordofa, B. Assessment of knowledge and practices of healthcare workers towards infection prevention and associated factors in healthcare facilities of West Arsi District, Southeast Ethiopia: A facility-based cross-sectional study. *Arch. Public Health* **2018**, *76*, 69. [CrossRef] [PubMed]
63. Mandić, B.; Mandić-Rajčević, S.; Marković-Denić, L.; Bulat, P. Occupational exposure to blood and bodily fluids among healthcare workers in Serbian general hospitals. *Arh. Hig. Rada Toksikol.* **2018**, *69*, 61–68. [CrossRef] [PubMed]

64. Hebo, H.J.; Gemeda, D.H.; Abdusemed, K.A. Hepatitis B and C viral infection: Prevalence, knowledge, attitude, practice, and occupational exposure among healthcare workers of Jimma University Medical Center, southwest Ethiopia. *Sci. World J.* **2019**, *2019*, 11. [CrossRef]
65. Lien, L.T.; Hang, N.T.L.; Kobayashi, N.; Yanai, H.; Toyota, E.; Sakurada, S.; Huu Thuong, P.; Cuong, V.C.; Nanri, A.; Mizoue, T.; et al. Prevalence and risk factors for tuberculosis infection among hospital workers in Hanoi, Viet Nam. *PLoS ONE* **2009**, *4*, e6798. [CrossRef]
66. Mathew, A.; David, T.; Thomas, K.; Kuruvilla, P.J.; Balaji, V.; Jesudason, M.V.; Samuel, P. Risk factors for tuberculosis among health care workers in South India: A nested case-control study. *J. Clin. Epidemiol.* **2013**, *66*, 67–74. [CrossRef] [PubMed]
67. Wei, Z.; Yang, M.; Quan, B.; Wang, Y.; Wu, Y.; Ji, B. Prevalence of latent tuberculosis infection among healthcare workers in China as detected by two interferon-gamma release assays. *J. Hosp. Infect.* **2013**, *84*, 323–325. [CrossRef]
68. Whitaker, J.; Mirtskhulava, V.; Kipiani, M.; Harris, D.; Tabagari, N.; Kempker, R.; Blumberg, H. Prevalence and incidence of latent tuberculosis infection in Georgian healthcare workers. *PLoS ONE* **2013**, *8*, e58202. [CrossRef]
69. Tudor, C.; Van der Walt, M.; Margot, B.; Dorman, S.E.; Pan, W.K.; Yenokyan, G.; Farley, J.E. Tuberculosis among health care workers in KwaZulu-Natal, South Africa: A retrospective cohort analysis. *BMC Public Health* **2014**, *14*, 891. [CrossRef]
70. El-Sokkary, R.; Abu-Taleb, A.; El-Seifi, O.; Zidan, H.; Mortada, E.; El-Hossary, D.; Farag, S. Assessing the prevalence of latent tuberculosis among health care providers in Zagazig city, Egypt using Tuberculin skin test and Quantiferon-TB gold in-tube test. *Cent. Eur. J. Public Health* **2015**, *23*, 324–330. [PubMed]
71. Tudor, C.; Van der Walt, M.L.; Margot, B.; Dorman, S.E.; Pan, W.K.; Yenokyan, G.; Farley, J.E. Occupational risk factors for tuberculosis among healthcare workers in KwaZulu-Natal, South Africa. *Clin. Infect. Dis.* **2016**, *62*, S255–S261. [CrossRef]
72. He, W.; Chen, B.-D.; Lv, Y.; Zhou, Z.; Xu, J.-P.; Lv, P.-X.; Zhou, X.-H.; Ning, F.-G.; Li, C.-H.; Wang, D.-P. Use of low-dose computed tomography to assess pulmonary tuberculosis among healthcare workers in a tuberculosis hospital. *Infect. Dis. Poverty* **2017**, *6*, 68. [CrossRef]
73. Erawati, M.; Andriany, M. The prevalence and demographic risk factors for latent tuberculosis infection (LTBI) among healthcare workers in Semarang, Indonesia. *J. Multidiscip. Healthc.* **2020**, *13*, 197–206. [CrossRef]
74. Kisa, A.; Dziegielewski, S.F.; Ates, M. Sexual harassment and its consequences: A study within Turkish hospitals. *J. Health Soc. Policy* **2002**, *15*, 77–94. [CrossRef] [PubMed]
75. Kamchuchat, C.; Chongsuvivatwong, V.; Oncheunjit, S.; Yip, T.W.; Sangthong, R. Workplace violence directed at nursing staff at a general hospital in Southern Thailand. *J. Occup. Health* **2008**, *50*, 201–207. [CrossRef]
76. Aydin, B.; Kartal, M.; Midik, O.; Buyukakkus, A. Violence against general practitioners in Turkey. *J. Interpers. Violence* **2009**, *24*, 1980–1995. [CrossRef] [PubMed]
77. Gimeno, D.; Barrientos-Gutiérrez, T.; Burau, K.D.; Felknor, S.A. Safety climate and verbal abuse among public hospital-based workers in Costa Rica. *Work* **2012**, *42*, 29–38. [CrossRef]
78. Atan, Ş.U.; Baysan Arabaci, L.; Sirin, A.; Isler, A.; Donmez, S.; Unsal Guler, M.; Oflaz, U.; Yalcinkaya Ozdemir, G.; Yazar Tasbasi, F. Violence experienced by nurses at six university hospitals in T urkey. *J. Psychiatr. Ment. Health Nurs.* **2013**, *20*, 882–889. [CrossRef] [PubMed]
79. Khademloo, M.; Moonesi, F.S.; Gholizade, H. Health care violence and abuse towards nurses in hospitals in north of Iran. *Glob. J. Health Sci.* **2013**, *5*, 211–216. [CrossRef] [PubMed]
80. Da Silva, A.T.C.; Peres, M.F.T.; de Souza Lopes, C.; Schraiber, L.B.; Susser, E.; Menezes, P.R. Violence at work and depressive symptoms in primary health care teams: A cross-sectional study in Brazil. *Soc. Psychiatry Psychiatr. Epidemiol.* **2015**, *50*, 1347–1355. [CrossRef]
81. Baig, L.A.; Shaikh, S.; Polkowski, M.; Ali, S.K.; Jamali, S.; Mazharullah, L.; Soomro, M.; Kumari, B.; Memon, S.; Maheshwari, G. Violence against health care providers: A mixed-methods study from Karachi, Pakistan. *J. Emerg. Med.* **2018**, *54*, 558–566. [CrossRef] [PubMed]
82. Zhao, S.; Xie, F.; Wang, J.; Shi, Y.; Zhang, S.; Han, X.; Sun, Z.; Shi, L.; Li, Z.; Mu, H.; et al. Prevalence of workplace violence against Chinese nurses and its association with mental health: A cross-sectional survey. *Arch. Psychiatr. Nurs.* **2018**, *32*, 242–247. [CrossRef] [PubMed]
83. Abate, A.; Abebaw, D.; Birhanu, A.; Zerihun, A.; Assefa, D. Prevalence and associated factors of violence against hospital staff at Amanuel Mental Specialized Hospital in Addis Ababa, Ethiopia. *Psychiatry J.* **2019**, *2019*, 11. [CrossRef]
84. Yenealem, D.G.; Woldegebriel, M.K.; Olana, A.T.; Mekonnen, T.H. Violence at work: Determinants & prevalence among health care workers, northwest Ethiopia: An institutional based cross sectional study. *Ann. Occup. Environ. Med.* **2019**, *31*, 8.
85. Hacer, T.Y.; Ali, A. Burnout in physicians who are exposed to workplace violence. *J. Forensic Leg. Med.* **2020**, *69*, 101874. [CrossRef]
86. Ashkar, K.; Romani, M.; Musharrafieh, U.; Chaaya, M. Prevalence of burnout syndrome among medical residents: Experience of a developing country. *Postgrad. Med. J.* **2010**, *86*, 266–271. [CrossRef] [PubMed]
87. Ayala, E.; Carnero, A.M. Determinants of burnout in acute and critical care military nursing personnel: A cross-sectional study from Peru. *PLoS ONE* **2013**, *8*, e54408. [CrossRef]
88. Zubairi, A.J.; Noordin, S. Factors associated with burnout among residents in a developing country. *Ann. Med. Surg.* **2016**, *6*, 60–63. [CrossRef] [PubMed]
89. Colindres, C.V.; Bryce, E.; Coral-Rosero, P.; Ramos-Soto, R.M.; Bonilla, F.; Yassi, A. Effect of effort-reward imbalance and burnout on infection control among Ecuadorian nurses. *Int. Nurs. Rev.* **2018**, *65*, 190–199. [CrossRef] [PubMed]

90. Khan, F.A.; Shamim, M.H.; Ali, L.; Taqi, A. Evaluation of job stress and burnout among anesthesiologists working in academic institutions in 2 major cities in Pakistan. *Anesth. Analg.* **2019**, *128*, 789–795. [CrossRef]
91. Mumbwe, M.C.; McIsaac, D.; Jarman, A.; Bould, M.D. A cross-sectional survey to determine the prevalence of burnout syndrome among anesthesia providers in Zambian hospitals. *Anesth. Analg.* **2020**, *130*, 310–317. [CrossRef]
92. Li, J.; Fu, H.; Hu, Y.; Shang, L.; Wu, Y.; Kristensen, T.S.; Mueller, B.H.; Hasselhorn, H.M. Psychosocial work environment and intention to leave the nursing profession: Results from the longitudinal Chinese NEXT study. *Scand. J. Public Health* **2010**, *38*, 69–80. [CrossRef]
93. Ayamolowo, S.J.; Irinoye, O.; Oladoyin, M.A. Job satisfaction and work environment of primary health care nurses in Ekiti State, Nigeria: An exploratory study. *Int. J. Caring Sci.* **2013**, *6*, 531–542.
94. Ogunlade, O.; Ogunfowokan, A. Clinical nurses' satisfaction with night shift in selected hospitals in Ile-Ife, Osun state, Nigeria. *Int. J. Caring Sci.* **2014**, *7*, 129–139.
95. Ayalew, E.; Workineh, Y. Job satisfaction and associated factors among nurses in Bahir Dar city administrative, North West Ethiopia, 2017. *BMC Res. Notes* **2019**, *12*, 319. [CrossRef]
96. Smith, D.R.; Wei, N.; Zhao, L.; Wang, R.-S. Musculoskeletal complaints and psychosocial risk factors among Chinese hospital nurses. *Occup. Med.* **2004**, *54*, 579–582. [CrossRef] [PubMed]
97. Tezel, A. Musculoskeletal complaints among a group of Turkish nurses. *Int. J. Neurosci.* **2005**, *115*, 871–880. [CrossRef]
98. Fabunmi, A.A.; Oworu, J.O.; Odunaiya, N.A. Prevalence of musculoskeletal disorders among nurses in University College Hospital, Ibadan. *West Afr. J. Nurs.* **2008**, *19*, 21–25.
99. De Castro, A.B.; Cabrera, S.L.; Gee, G.C.; Fujishiro, K.; Tagalog, E.A. Occupational health and safety issues among nurses in the Philippines. *Workplace Health Saf.* **2009**, *57*, 149–157.
100. Karahan, A.; Kav, S.; Abbasoglu, A.; Dogan, N. Low back pain: Prevalence and associated risk factors among hospital staff. *J. Adv. Nurs.* **2009**, *65*, 516–524. [CrossRef]
101. Mehrdad, R.; Dennerlein, J.T.; Haghighat, M.; Aminian, O. Association between psychosocial factors and musculoskeletal symptoms among Iranian nurses. *Am. J. Ind. Med.* **2010**, *53*, 1032–1039. [CrossRef]
102. Tinubu, B.M.S.; Mbada, C.E.; Oyeyemi, A.L.; Fabunmi, A.A. Work-Related Musculoskeletal Disorders among Nurses in Ibadan, South-west Nigeria: A cross-sectional survey. *BMC Musculoskelet. Disord.* **2010**, *11*, 12. [CrossRef] [PubMed]
103. Arsalani, N.; Fallahi-Khoshknab, M.; Josephson, M.; Lagerström, M. Musculoskeletal disorders and working conditions among Iranian nursing personnel. *Int. J. Occup. Saf. Ergon.* **2014**, *20*, 671–680. [CrossRef]
104. Barzideh, M.; Choobineh, A.R.; Tabatabaee, H.R. Job stress dimensions and their relationship to musculoskeletal disorders in Iranian nurses. *Work* **2014**, *47*, 423–429. [CrossRef] [PubMed]
105. Munabi, I.G.; Buwembo, W.; Kitara, D.L.; Ochieng, J.; Mwaka, E.S. Musculoskeletal disorder risk factors among nursing professionals in low resource settings: A cross-sectional study in Uganda. *BMC Nurs.* **2014**, *13*, 7. [CrossRef]
106. Yasobant, S.; Rajkumar, P. Work-related musculoskeletal disorders among health care professionals: A cross-sectional assessment of risk factors in a tertiary hospital, India. *Indian J. Occup. Environ. Med.* **2014**, *18*, 75–81. [CrossRef]
107. Abaraogu, U.O.; Ezema, C.I.; Nwosu, C.K. Job stress dimension and work-related musculoskeletal disorders among southeast Nigerian physiotherapists. *Int. J. Occup. Saf. Ergon.* **2017**, *23*, 404–409. [CrossRef] [PubMed]
108. Amin, N.A.; Quek, K.F.; Oxley, J.A.; Noah, R.; Nordin, R. Emotional distress as a predictor of work-related musculoskeletal disorders in Malaysian nursing professionals. *Int. J. Occup. Environ. Med.* **2018**, *9*, 69–78. [CrossRef]
109. Dlungwane, T.; Voce, A.; Knight, S. Prevalence and factors associated with low back pain among nurses at a regional hospital in KwaZulu-Natal, South Africa. *Health SA Gesondheid* **2018**, *23*, a1028. [CrossRef] [PubMed]
110. Ike, E.; Olawumi, J. The prevalence, risk factors and coping measures of back pain among nurses in Federal Medical Centre, Abeokuta, Ogun state, Nigeria. *Int. J. Caring Sci.* **2018**, *11*, 955–968.
111. Luan, H.D.; Hai, N.T.; Xanh, P.T.; Giang, H.T.; Thuc, P.V.; Hong, N.M.; Khue, P.M. Musculoskeletal disorders: Prevalence and associated factors among district hospital nurses in Haiphong, Vietnam. *Biomed. Res. Int.* **2018**, e1–e9. [CrossRef]
112. Dong, H.; Zhang, Q.; Liu, G.; Shao, T.; Xu, Y. Prevalence and associated factors of musculoskeletal disorders among Chinese healthcare professionals working in tertiary hospitals: A cross-sectional study. *BMC Musculoskelet. Disord.* **2019**, *20*, 175. [CrossRef] [PubMed]
113. Baykal, U.; Seren, S.; Sokmen, S. A description of oncology nurses' working conditions in Turkey. *Eur. J. Oncol. Nurs.* **2009**, *13*, 368–375. [CrossRef]
114. Agrawal, A.; Bhatt, N.; Kk, S.; Singh, K.; Chaudhary, H.; Asawa, K. Prevalence of allergy to latex gloves among dental professionals in Udaipur, Rajasthan, India. *Oral Health Prev. Dent.* **2010**, *8*, 345–350.
115. Amarasekera, M.; Rathnamalala, N.; Samaraweera, S.; Jinadasa, M. Prevalence of latex allergy among healthcare workers. *Int. J. Occup. Med. Environ. Health* **2010**, *23*, 391–396. [CrossRef]
116. Phaswana, S.M.; Naidoo, S. The prevalence of latex sensitisation and allergy and associated risk factors among healthcare workers using hypoallergenic latex gloves at King Edward VIII Hospital, KwaZulu-Natal South Africa: A cross-sectional study. *BMJ Open* **2013**, *3*, e002900. [CrossRef]
117. Supapvanich, C.; Povey, A.C.; de Vocht, F. Respiratory and dermal symptoms in Thai nurses using latex products. *Occup. Med.* **2013**, *63*, 425–428. [CrossRef]

118. Köse, S.; Mandiracioğlu, A.; Tatar, B.; Gül, S.; Erdem, M. Prevalence of latex allergy among healthcare workers in Izmir (Turkey). *Cent. Eur. J. Public Health* **2014**, *22*, 262–265. [CrossRef]
119. Supapvanich, C.; Povey, A.; de Vocht, F. Latex sentization and risk factors in female nurses in Thai governmental hospitals. *Int. J. Occup. Med. Environ. Health* **2014**, *27*, 93–103. [CrossRef]
120. Abbasi, K.; Hazrati, M.; Mohammadbeigi, A.; Ansari, J.; Sajadi, M.; Hosseinnazzhad, A.; Moshiri, E. Protection behaviors for cytotoxic drugs in oncology nurses of chemotherapy centers in Shiraz hospitals, South of Iran. *Indian J. Med. Paediatr. Oncol.* **2016**, *37*, 227–231.
121. Elshaer, N. Adverse health effects among nurses and clinical pharmacists handling antineoplastic drugs: Adherence to exposure control methods. *J. Egypt. Public Health Assoc.* **2017**, *92*, 144–155. [CrossRef]
122. Alehashem, M.; Baniasadi, S. Important exposure controls for protection against antineoplastic agents: Highlights for oncology health care workers. *Work* **2018**, *59*, 165–172. [CrossRef]
123. Bayraktar-Ekincioglu, A.; Korubük, G.; Demirkan, K. An evaluation of chemotherapy drug preparation process in hospitals in Turkey—A pilot study. *J. Oncol. Pharm. Pract.* **2018**, *24*, 563–573. [CrossRef] [PubMed]
124. Aluko, O.O.; Adebayo, A.E.; Adebisi, T.F.; Ewegbemi, M.K.; Abidoye, A.T.; Popoola, B.F. Knowledge, attitudes and perceptions of occupational hazards and safety practices in Nigerian healthcare workers. *BMC Res. Notes* **2016**, *9*, 71. [CrossRef]
125. Tait, F.N.; Mburu, C.; Gikunju, J. Occupational safety and health status of medical laboratories in Kajiado County, Kenya. *Pan Afr. Med. J.* **2018**, *29*, 65–81. [PubMed]
126. Lee, R. Occupational transmission of bloodborne diseases to healthcare workers in developing countries: Meeting the challenges. *J. Hosp. Infect.* **2009**, *72*, 285–291. [CrossRef]
127. Garner, J.S. Guideline for isolation precautions in hospitals. *Infect. Cont. Hosp. Epidemiol.* **1996**, *17*, 54–80. [CrossRef]
128. Menzies, D.; Joshi, R.; Pai, M. Risk of tuberculosis infection and disease associated with work in health care settings. *Int. J. Tuberc. Lung Dis.* **2007**, *11*, 593–605.
129. Jesudas, C.D.; Thangakunam, B. Tuberculosis risk in health care workers. *Indian J. Chest Dis. Allied Sci.* **2013**, *55*, 149–154.
130. Lanctôt, N.; Guay, S. The aftermath of workplace violence among healthcare workers: A systematic literature review of the consequences. *Aggress. Violent Behav.* **2014**, *19*, 492–501. [CrossRef]
131. Maslach, C.; Jackson, S.E.; Leiter, M.P. *Maslach Burnout Inventory Manual*, 4th ed.; Mind Garden Inc.: Menlo Park, CA, USA, 2016.
132. McHugh, M.D.; Kutney-Lee, A.; Cimiotti, J.P.; Sloane, D.M.; Aiken, L.H. Nurses' widespread job dissatisfaction, burnout, and frustration with health benefits signal problems for patient care. *Health Aff.* **2011**, *30*, 202–210. [CrossRef]
133. World Health Organization. *Health Workforce Requirements for Universal Coverage and the Sustainable Development Goals*; WHO: Geneva, Switzerland, 2016.
134. Andersson, G.B. Epidemiological features of chronic low-back pain. *Lancet* **1999**, *354*, 581–585. [CrossRef]
135. Vieira, E.R.; Schneider, P.; Guidera, C.; Gadotti, I.C.; Brunt, D. Work-related musculoskeletal disorders among physical therapists: A systematic review. *J. Back Musculoskelet. Rehabil.* **2016**, *29*, 417–428. [CrossRef]
136. Epstein, S.; Sparer, E.H.; Tran, B.N.; Ruan, Q.Z.; Dennerlein, J.T.; Singhal, D.; Lee, B.T. Prevalence of work-related musculoskeletal disorders among surgeons and interventionalists: A systematic review and meta-analysis. *JAMA Surg.* **2018**, *153*, e174947. [CrossRef]
137. Sakzewski, L.; Naser-ud-Din, S. Work-related musculoskeletal disorders in dentists and orthodontists: A review of the literature. *Work* **2014**, *48*, 37–45. [CrossRef]
138. McDiarmid, M.A. Advocating for the health worker. *Ann. Glob. Health* **2019**, *85*, 16. [CrossRef]

Appendix I: Paper 3 (Chapter 6)

Original Article

Reliability and Validity of an Adapted Questionnaire Assessing Occupational Exposures to Hazardous Chemicals among Health Care Workers in Bhutan

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Abstract

Background: Collection of reliable and valid occupational history data is of utmost importance to assess work-related exposures and their health effects. Few standardized questionnaires are available for the collection of occupational history data in low-and-middle income countries.

Objective: To adapt and test a validated questionnaire developed in the United States by the National Institute of Safety and Health, in order to assess occupational chemical exposures among health care workers in Bhutan.

Methods: The questionnaire was first adapted to suit the Bhutanese context with the advice of an expert review committee. 30 health care workers then completed the questionnaire at baseline and 10–14 days later. Test-retest reliability was assessed by calculating Cohen's κ and percentage agreement.

Results: The questionnaire had high test-retest reliability. Cohen's κ ranged from 0.61 to 1.00, and percentage agreement ranged from 86.7% to 100%. Further adaptations included omitting questions on chemicals not available in Bhutan.

Conclusion: The adapted questionnaire is appropriate for assessing occupational chemical exposures among health care workers in Bhutan.

Keywords: Occupational exposure; Health personnel; Surveys and questionnaires; Advisory committees; Developing countries; Bhutan

Introduction

Health care workers (HCWs) operate in an environment containing numerous hazards that pose daily risks to their health.[1] The health care sector has consistently reported a high prevalence of non-fatal injuries and illnesses in the USA, and Australia.[2,3] With a worldwide population of 56 million HCWs, the health care sector employs 13% of the global workforce.[4] Job growth in this industry

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is expected to increase to meet the rising needs of an aging global population. A substantial population of HCWs will therefore be at risk of harm in the workplace, with the potential to adversely impact the quality of health care services.

Occupational exposures to biological and psychological hazards among HCWs are widely recognized.[5] Less apparent is that the health care environment also contains hazardous chemicals similar to those found in "blue-collar" industries, exposures to which can increase the risk of long-term adverse health outcomes. Exposures to chemicals such as ethylene oxide, formaldehyde, and antineoplastic drugs have been linked to certain types of cancers such as hematological and nasopharyngeal cancers.[6-8] Exposure to latex as well as a number of chemicals in cleaning and disinfecting agents have been associated with work-related asthma among HCWs.[9,10] Chemicals used in hospital laboratories such as toluene, styrene, and xylene have the potential to cause auditory damage and hearing loss.[11]

Research on occupational exposures to hazardous chemicals among HCWs has highlighted these risks, and safety programs and standards have been instituted to ensure the safety of these workers.[12] However, the majority of these studies have been conducted in high-income countries.[5] Very little work has been done on examining these hazards in low- and middle-income countries (LMICs).[13] The limited research in this area from LMICs has mainly examined exposure to latex.[14]

The collection of valid and reliable occupational history data is of utmost importance in estimating occupational exposures and work-related health effects. One way of obtaining this information is through questionnaires, which can collect details to assist in exposure assessment (*eg*, tasks conducted within a job, and use of control measures).[15] Unfortunately, there are very few standardized questionnaires available in this area,[16] especially so for use in LMICs.

The National Institute for Occupational Safety and Health (NIOSH) developed a questionnaire for the Health and Safety Practices Survey of HCWs conducted in the USA in 2011, which aimed to examine safety practices to minimize exposure to hazardous chemicals in the workplace.[17] The questionnaire used in the survey may not be directly applicable for use in LMICs due to differences in legislation, work environments, and safety standards. The objective of this study was therefore to adapt and test this questionnaire for use in Bhutan to assess occupational exposures to asthmagens, carcinogens, and ototoxic chemicals among HCWs.

Materials and Methods

This study was conducted in two stages: (1) the adaptation of the NIOSH questionnaire, and (2) test-retest reliability assessment.

Stage 1: Adaptation of the NIOSH Questionnaire

The NIOSH questionnaire was developed for a Web-based survey of HCWs to examine safety practices to minimize exposure to chemicals in the workplace.[17] The survey instrument contains seven hazard modules and a core module. The core module includes questions about demographics and exposures to other occupational hazards (*eg*, infectious agents). The hazard modules contain questions about frequency and duration of exposures, and work practices and control measures used to minimize exposure to chemicals that are commonly encountered in the health care setting (*ie*, anaesthetic drugs, aerosolized medications, antineoplastic drugs, chemical sterilants, high-level disinfectants, and surgical smoke).

A committee of experts in Bhutan was consulted during the process of questionnaire adaptation. The committee of experts comprised of two senior doctors and a nurse with extensive practical experience within the Bhutanese health care system, and one nurse specialized in occupational health. The NIOSH questionnaire was developed for a high-income country with advanced medical technology and drugs, many of which are not available in Bhutan. The committee was asked whether to retain each question in the instrument to make the questionnaire appropriate for the Bhutanese context. For example, the module on high-level disinfectants in the original questionnaire included questions on the use of manual or automated disinfection systems. The questions on automated disinfection systems were excluded because they were not used in Bhutan. Since the original questionnaire did not include chemicals used in laboratories, dental departments, and for cleaning, questions on these chemicals were adapted from the health care job module in OccIDEAS, a computer application that assesses occupational exposures.[18] OccIDEAS consists of job modules that include questions about various tasks carried out in a particular job, and about control measures that might influence exposure levels. These modules are developed based on evidence from literature and expert opinion.

For the Questionnaire see the Web extra on the Journal Web site

The pre-final version of the modified questionnaire was then reviewed by the experts to assess the validity of the instrument. The experts evaluated whether the items in the questionnaire were relevant to the Bhutanese context, whether the questions were comprehensible to Bhutanese HCWs, and determined the comprehensiveness of the questionnaire. The experts felt that the hard-copy version of the questionnaire would be more acceptable to the population. Based on the experts' review, the final version of the modified questionnaire was consolidated for testing as a hard-copy version in English. Tertiary education in Bhutan is delivered in English,[19] so health professionals have no difficulty with an English-language questionnaire. Questions about the survey instrument (comprehensibility, ease of use, and preferred mode of administration) were also included in the final version to obtain additional feedback from participants.

Questionnaire

Sociodemographic variables such as age, sex, ethnicity, and level of education were collected. For occupational history, participants were asked about the hospital and department they were currently working in, their job title, and the duration of employment as a HCW. Participants were also asked about the tasks that were carried out as part of their job (*eg*, sterilizing instruments, working in the dental department, laboratory or surgery, preparing drugs, suturing, cleaning the workplace, administering antineoplastic drugs and anesthetic gases), and about current work practices and control measures to minimize exposures to chemicals (*eg*, using portable smoke evacuators to remove smoke during diathermy, fume hoods in the laboratory, waste gas scavenging systems to remove waste anesthetic gases, biological safety cabinets while compounding antineoplas-

TAKE-HOME MESSAGE

- Few standardized questionnaires are available to collect occupational history data in low- and middle-income countries (LMICs).
- A questionnaire adapted for use in Bhutan showed good reliability and validity in assessing occupational chemical exposures in health care workers.
- The process of questionnaire adaptation and testing used in this study could assist in developing questionnaires for other LMICs.

Table 1: The list of asthmagens, carcinogens, and ototoxic chemicals assessed in a reliability study in Bhutan

Asthmagens	Carcinogens	Ototoxic chemicals
Acids	Industrial chemicals	Toluene
Ammoniacal compounds	Diethyl/dimethyl sulphate	Styrene
Asthma aldehydes	Epichlorhydrin	p-Xylene
Acrylates	Ethylene oxide	Trichloroethylene
Drugs	Formaldehyde	Ethyl-benzene
Epoxy	Ortho-toluidine	n-Hexane
Industrial cleaning and sterilizing agents		
Latex	Solvents	
Reactive dyes	Alcohol	
Other reactive chemicals	Aliphatic Solvents	
	Benzene	
	Chlorinated Solvents	
	Tetrachloroethylene (Perc)	
	Trichloroethylene	
	Products of combustion	
	Polycyclic aromatic hydrocarbons (PAH)	

tic drugs, and using gloves, water-resistant gowns, masks, and goggles while handling chemicals).

Stage 2: Test-retest Reliability

Participants and Procedure

A targeted convenience sample of 30 HCWs was recruited from three hospitals (a tertiary hospital in Thimphu, and two district hospitals in Wangdue and Paro) located in the western region of Bhutan in April and May, 2019. The state provides free health care services to all citizens as mandated in the Constitution of Bhutan.[19] Therefore, all health care facilities in the country are in the public sector and all health care professionals work in these facilities. The western region of Bhutan has the highest number of HCWs as compared to the eastern and central regions, and half of the hospitals are located in this region.[19]

The eligibility criteria for the study were HCWs who were 18–60 years of age, and currently working in any one of the three hospitals included in the study. Care was taken to include participants from different age groups, varying durations of employment, a range of job titles, and equal sex representation during the recruitment process.

Participants completed the questionnaire at two times—once at baseline (Time 1) and then 10–14 days later (Time 2). This time interval is considered adequate to provide independent observations and to prevent true variations in exposure.[16] Hard-copy questionnaires were personally distributed among the participants and collected when completed. All the questionnaires were self-administered, except for one participant (a hospital cleaner) who completed the questionnaire as an interview conducted in the local language.

Exposure assessment

The data from the questionnaire were entered into OccIDEAS. Based on the participants' responses in the questionnaire, pre-determined algorithms were applied in OccIDEAS to determine exposure to various carcinogens, asthmagens, and ototoxic chemicals (Table 1).[18] The rules in the algorithms were based on evidence from

Table 2: Frequency distribution of demographic characteristics of the sample of health care workers studied

Parameter	n (%)
Sex	
Male	14 (47)
Female	16 (53)
Ethnic group	
Ngalop	5 (17)
Sharshop	12 (40)
Lotshamp	10 (33)
Others	3 (10)
Education	
Primary/High school	4 (13)
Diploma	6 (20)
Bachelor's degree	11 (37)
Postgraduate degree	9 (30)
Hospital	
National Referral hospital, Thimphu	20 (67)
Paro hospital	5 (17)
Wangdue hospital	5 (17)
Current occupation	
Medical doctor	1 (3)
Dental doctor	3 (10)
Nurse	21 (70)
Technologist/technician and support staff	5 (17)
Duration of work as health care worker (yrs)	
<6	8 (27)
6–10	6 (20)
11–20	8 (27)
>21	8 (28)

literature, material safety data sheets, and expert advice from occupational hygienists on the determinants of exposures.

Feed-back on the questionnaire

Participants were asked whether they had difficulties in using the questionnaire and in understanding the questions, and to provide reasons, if so. They were also asked to choose their preferred mode of questionnaire administration (hard-copy or Web-based).

Ethics

Informed written consent was obtained from all participants. The study was approved by the Research Ethics Board of Health, Bhutan, and the Human Research Ethics Committee, Curtin University.

Statistical Analysis

Statistical analyses were carried out using STATA 14 (StataCorp, College Station. TX). Descriptive statistics such as means and frequencies were estimated for sociodemographic variables. Cohen's κ (2 levels) and weighted κ (>2 levels) statistics, and percentages of overall agreement were used to test the reliability of the questionnaire. These were calculated for the questions related to the main tasks (yes/no), for exposures to chemicals (exposed/unexposed), and for specific tasks questions if there were enough responses. Established cut-off values for κ (*ie*, "poor" 0.00–0.20, "fair" 0.21–0.40, "moderate" 0.41–0.60, "strong" 0.61–0.80, and "almost perfect" agreement 0.81–1.00) and percentages of agreement (≥75% was considered "acceptable") were used to determine the adequacy of agreement of the estimates.[20]

Results

Adaptation of the Questionnaire

On advice from the experts, questions on chemicals used in the laboratory, the dental department, and in cleaning, were

Table 3: Test-retest reliability of the questions regarding the main tasks and exposure assessment in health care workers in Bhutan

Main tasks	n (%) answered yes		2×2				Cohen's κ (95% CI)	% agreement
	Time 1	Time 2	YY[a]	YN[b]	NY[c]	NN[d]		
Do you sterilize instruments or other equipment yourself?	4 (13)	2 (7)	2	2	0	26	0.63 (0.19 to 1.00)	93
Do you work in the dental department?	3 (10)	3 (10)	3	0	0	27	1.00	100
Do you work in the pharmacy department?	0 (0)	0 (0)	—	—	—	—	—	—
Do you work in the laboratory	3 (10)	3 (10)	3	0	0	27	1.00	100
Do you perform sutures?	11 (37)	11 (37)	9	2	2	17	0.71 (0.45 to 0.97)	87
Do you work in surgery?	3 (10)	2 (7)	1	2	1	26	0.35 (-0.22 to 0.92)	90
Do you administer antineoplastic drugs?	1 (3)	1 (3)	1	0	0	29	1.00	100
Do you compound antineoplastic drugs?	0 (0)	0 (0)	—	—	—	—	—	—
Do you wear gloves at work?	30 (100)	30 (100)	—	—	—	—	—	—
Is one of your tasks to clean the work place?	18 (60)	17 (57)	17	1	0	12	0.93 (0.80 to 1.00)	97
Do you administer anaesthetic gases to patients?	2 (7)	2 (7)	2	0	0	2	1.00	100
Exposures								
Asthmagens								
Industrial cleaning and sterilizing agents	26 (87)	25 (83)	24	2	1	3	0.61 (0.21 to 1.00)	90
Ammoniacal compounds	10 (33)	10 (33)	9	1	1	19	0.85 (0.65 to 1.00)	93
Ototoxic agents								
P-xylene	12 (40)	11 (37)	10	2	1	17	0.79 (0.56 to 1.00)	90
Toluene	11 (37)	11 (37)	9	2	2	17	0.71 (0. 45 to 0.97)	87
Carcinogens								
Aliphatic solvents	11 (37)	11 (37)	9	2	2	17	0.71 (0.45 to 0.97)	87

[a]Yes/Yes; [b]Yes/No; [c]No/Yes; [d]No/No

retained in the questionnaire. Questions on some chemicals (ethylene oxide, and hydrogen peroxide gas plasma), drugs (aerosolized medicines), and control measures (use of purifying respirators with chemical cartridges, environmental expo-

Table 4: Test-retest reliability of questions on cleaning in Bhutanese health care workers

Question	n (%) Time 1	n (%) Time 2	Weighted Cohen's κ (95% CI)	% agreement
Use bleach for cleaning				
Yes	17 (57)	15 (50)	0.90 (0.89 to 0.93)	95
No	1 (3)	2 (7)		
NA*	12 (40)	13 (43)		
Use chlorhexidine for cleaning				
Yes	8 (27)	10 (33)	0.82 (0.54 to 0.86)	92
No	10 (33)	7 (23)		
NA*	12 (40)	13 (43)		
Use disinfectants for cleaning				
Yes	9 (30)	9 (30)	0.82 (0.78 to 0.93)	92
No	9 (30)	8 (27)		
NA*	12 (40)	13 (43)		
Use spirits for cleaning				
Yes	11 (37)	11 (37)	0.84 (0.74 to 0.89)	92
No	7 (23)	6 (20)		
NA*	12 (40)	13 (43)		
Wear gloves when handling cleaning agents				
Always	12 (40)	13 (43)	0.80 (0.76 to 1.00)	90
Sometimes	6 (20)	4 (13)		
Never	0 (0)	0 (0)		
NA*	12 (40)	13 (43)		
Wear goggles when handling cleaning agents				
Always	1 (3)	0 (0)	0.83 (0.72 to 0.90)	94
Sometimes	7 (23)	11 (37)		
Never	10 (33)	6 (20)		
NA*	12 (40)	13 (43)		

Continued

Table 4: Test-retest reliability of questions on cleaning in Bhutanese health care workers

Question	n (%) Time 1	Time 2	Weighted Cohen's κ (95% CI)	% agreement
Type of mask used when handling cleaning agents				
Standard surgical mask	17 (57)	17 (57)	0.90 (0.82 to 1.00)	95
N95 respirator	0 (0)	0 (0)		
Do not wear mask/respirators	1 (3)	0 (0)		
NA*	12 (40)	13 (43)		
Training received for handling cleaning agents				
Within past 12 months	3 (10)	4 (13)	0.85 (0.80 to 0.88)	94
More than 12 months	5 (17)	5 (17)		
Never received training	10 (33)	8 (27)		
NA*	12 (40)	13 (43)		

*NA: not applicable, did not answer the cleaning questions

sure monitoring, and medical surveillance) were omitted because these were not available in Bhutan. The experts agreed that the adapted questionnaire was comprehensible and comprehensive.

Sample Characteristics

The mean age of participants was 37.5 (SD 8.1, range 24 to 52) years; 53% were female (Table 2). Two-thirds (67%) of the sample reported having a university degree as their highest level of education. A majority of participants (70%) were nurses and two-thirds (67%) of the participants worked in the National Referral Hospital in Thimphu.

Test-retest reliability

The percentages of overall agreement on questions regarding the main tasks carried out between Time 1 and Time 2 were excellent (87%–100%, Table 3). All κ estimates also demonstrated strong or almost perfect agreement (0.63–1.00) on the main tasks carried out, except for the question on surgery which showed fair agreement (κ 0.35).

Participants were exposed to at least one chemical from each of the three categories (carcinogens, asthmagens, and ototoxic agents) of hazardous chemicals assessed (Table 3). The prevalence of exposure to industrial cleaning and sterilizing agents was substantial at both Time 1 (87%) and Time 2 (83%). The percentages of overall agreement on the prevalence of exposures at Time 1 and Time 2 were excellent (87%–93%). The κ estimates also demonstrated strong to almost perfect agreement (0.61–0.85).

The task of cleaning the workplace was reported by almost two-thirds (57%–60%) of the participants (Table 4). The additional questions on cleaning asking about the use of cleaning chemicals, use of personal protective equipment, and training received on handling cleaning agents, showed a high degree of agreement between Time 1 and Time 2. All the κ estimates demonstrated almost perfect agreement (0.80–0.90); the percentages of overall agreement were excellent (90%–95%). Reliability tests were not conducted for the additional questions on the other main tasks due to the low number of responses to these questions.

Feed-back on the Questionnaire from the Participants

A majority of the participants (83%) chose hard-copy as their preferred mode of questionnaire administration. Four (13%) participants reported difficulties in using the questionnaire. One reported the questionnaire was too long and three participants said they found it tedious looking for the next questions after the skip questions (*ie*, if they answered no to the main question regarding a task, they skipped all the subsequent questions on that task and went on to the next main question). Only one participant reported difficulty in understanding the questions. The difficulty reported was on the question asking about whether they worked in surgery. The participant found this confusing as "do you work in surgery?" could mean either operating theatre, surgical ward, or minor surgery.

Discussion

The objective of this study was to adapt and test a validated questionnaire to examine occupational exposures to hazardous chemicals among HCWs in Bhutan since standardized questionnaires suitable for use in LMICs are currently not available. This was achieved by modifying the questionnaire to make it relevant to Bhutan, followed by validation and reliability testing. The adapted questionnaire exhibited good content validity and strong to almost perfect test-retest reliability.

The modification of the questionnaire mainly involved omission and substitution of certain questions to make the questionnaire relevant to the Bhutanese context. The original questionnaire had been developed in a high-income country with advanced medical technology, much of which is not available in low-income countries. Questions on some of these advanced technologies were omitted (*eg*, automated disinfection systems), or substituted with those being used in the country (*eg*, chemotherapy gloves substituted with plain gloves). In addition, questions on laboratory, dental, and cleaning chemicals were adapted from OccIDEAS to make the questionnaire more comprehensive in assessing chemicals that HCWs use in Bhutan. The experts agreed that the modified questionnaire was comprehensible, comprehensive, and relevant to the Bhutanese context.

The reliability of the questionnaire was assessed by test-retest analyses. There was a high degree of agreement on the questions asking about the main tasks carried out. The only exception was the question asking about whether they worked in surgery, which demonstrated fair agreement. This could be because the question was not well understood as stated by one of the participants in the feed-back, who found this question confusing. It is important that words used in the questionnaire are clear and unambiguous for optimum comprehension and accurate interpretation.[21] Therefore, this question was re-worded as "do you work in the operation theatre?" in the final questionnaire to make it clearer. Since the majority of participants reported cleaning the workplace as one of their main tasks, the reliability of the additional questions on cleaning was also assessed. These questions on the use of various chemicals and control measures also demonstrated very strong agreement.

The information gathered from the questionnaires at the two time periods was sufficiently consistent to result in excellent agreement in exposure assessment. Detailed self-reported occupational exposure information gathered from questionnaires has previously been shown to have a high degree of sensitivity[22] and reliability[23]. Using a list of specific agents to prompt recall, asking about agents that can be easily identified, and using familiar terminology (*eg*, using trade names instead of generic names), is known to improve accuracy of exposure assessment when using questionnaires.[22]

The main difficulties reported in using the questionnaire in this study were the length of the questionnaire and the tediousness in looking for the next questions after the skip questions. This is to be expected because the original questionnaire was designed for use as a Web-based survey, where the questions after the skip questions would be presented automatically, and the main questions would help screen the subsequent questions, thus, making the survey shorter. However, as indicated by both the study participants and the expert panel, the hard-copy version was the preferred mode of questionnaire administration in Bhutan. Both on-line and traditional paper-based surveys have been shown to be comparable in terms of reliability and validity,[24,25] and the selection of the most appropriate method depends on factors such as study aims, budget, and geographic area of the research.[26] The preference of the hard-copy version by participants in this study could be because the Web-based version requires an internet connection, access to which might be problematic in a low-income country like Bhutan due to the high costs and poor quality of internet connectivity.[27] So measures to improve the appearance of the questionnaire such as making the skip questions and page numbers more visible by presenting these in colored bold fonts, could assist in improving the usability of the hard-copy questionnaire.[21,28]

Cross-cultural adaptations of questionnaires usually involve translation, review by an expert committee, and pre-testing.[29] There are multiple ethnic groups (three main groups, many tribal groups) in Bhutan, each with their own language and, since English is used as the medium of instruction in all schools and institutions in Bhutan and therefore widely used,[19] administering the questionnaire in English was deemed appropriate, with a provision for the questionnaire to be administered as an interview in the local language when necessary (*eg*, for HCWs with little English proficiency such as cleaners, ambulance drivers). Although the questionnaire was not translated, almost all participants reported no difficulties in understanding the questionnaire endorsing the adequacy of presenting the questionnaire in English to Bhutanese HCWs.

The major limitations of this study were the use of a convenience sample and the small sample size. Although a sample size of 30 is adequate to achieve a power of 80% in detecting a problem with a 5% prevalence,[30] the results of this study, though encouraging, should be interpreted with caution due to non-random selection of the participants. In addition, despite attempts to recruit participants having a range of job titles, the majority were nurses and there was no representation of some job titles such as pharmacists. Furthermore, having the questionnaire only in English requires presenting the questionnaire as an interview in the local language by experienced interviewers to those workers with limited English proficiency, which could affect study resources such as time and costs.

The process of questionnaire adaptation and testing used in this study could assist in developing questionnaires for other LMICs. This process could be useful for countries with similar health care systems and medical technology.

This is one of the few studies testing a questionnaire to examine occupational exposures to chemical hazards in LMICs. The overall findings from this study suggested that the modified questionnaire had good validity and reliability to measure workplace exposures to hazardous chemicals among HCWs in Bhutan. Administering the questionnaire in English, with a provision for interpretation when required, was suitable for Bhutanese HCWs, and translation of the questionnaire was not imperative. The hard-copy version was the preferred mode of questionnaire administration.

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References

1. Vecchio D, Sasco AJ, Cann CI. Occupational risk in health care and research. *Am J Ind Med* 2003;**43**:369-97.
2. Bureau of Labor Statistics. Table II. Numbers of nonfatal occupational injuries and illnesses by industry and case types, 2017; 2018. Available from *www.bls.gov/web/osh/summ2_00.htm* (Acessed July 30, 2019).
3. Safe Work Australia. Australian Work Health and Safety Strategy 2012–2022. 2012. Available from *www.safeworkaustralia.gov.au/about-us/australian-work-health-and-safety-strategy-2012-2022* (Acessed July 30, 2019).
4. World Health Organization. The world health report 2006 - working together for health. Geneva: World Health Organization; 2006. Available from *www.who.int/whr/2006/en/* (Acessed July 26, 2019).
5. McDiarmid MA. Hazards of the health care sector: Looking beyond infectious disease. *Ann Glob Health* 2014;**80**:315-9.
6. Coggon D, Harris EC, Poole J, Palmer KT. Mortality of workers exposed to ethylene oxide: extended follow up of a British cohort. *Occup Environ Med* 2004;**61**:358-62.
7. Ratner PA, Spinelli JJ, Beking K, *et al*. Cancer incidence and adverse pregnancy outcome in registered nurses potentially exposed to antineoplastic drugs. *BMC Nurs* 2010;**9**:15.
8. Vaughan TL, Stewart PA, Teschke K, *et al*. Occupational exposure to formaldehyde and wood dust and nasopharyngeal carcinoma. *Occup Environ Med* 2000;**57**:376-84.
9. Arif AA, Delclos GL. Association between cleaning-related chemicals and work-related asthma and asthma symptoms among healthcare professionals. *Occup Environ Med* 2012;**69**:35-40.
10. Trapé M, Schenck P, Warren A. Latex gloves use and symptoms in health care workers 1 year after implementation of a policy restricting the use of powdered gloves. *Am J Infect Control* 2000;**28**:352-8.
11. Fuente A, McPherson B. Organic solvents and hearing loss: The challenge for audiology. *Int J Audiol* 2006;**45**:367-81.
12. National Institute of Occupational Health and Safety. State of the Sector: Healthcare and Social Assistance. NIOSH; 2009. Available from *www.cdc.gov/niosh/docs/2009-139/pdfs/2009-139.pdf* (Accessed July 19, 2019).
13. Tipayamongkholgul M, Luksamijarulkul P, Mawn B, *et al*. Occupational Hazards in the Thai Healthcare Sector. *New Solut* 2016;**26**:83-102.
14. Amarasekera M, Rathnamalala N, Samaraweera S, Jinadasa M. Prevalence of latex allergy among healthcare workers. *Int J Occup Med Environ Health* 2010;**23**:391-6.
15. Brower PS, Attfield MD. Reliability of reported occupational history information for US coal miners, 1969–1977. *Am J Epidemiol* 1998;**148**:920-6.

16. Nieuwenhuijsen M. Design of exposure questionnaires for epidemiological studies. *Occup Environ Med* 2005;**62**:272-80.
17. Steege AL, Boiano JM, Sweeney MH. NIOSH health and safety practices survey of healthcare workers: training and awareness of employer safety procedures. *Am J Ind Med* 2014;**57**:640-52.
18. Fritschi L. OccIDEAS–occupational exposure assessment in community-based studies. *Occup Med* 2019;**69**:156-7.
19. Thinley S, Tshering P, Wangmo K, *et al*. Health systems in transition : the Kingdom of Bhutan health system review, 2017. Regional Office for South-East Asia: WHO. **2017**.
20. McHugh ML. Interrater reliability: the kappa statistic. *Biochem Medica* 2012;**22**:276-82.
21. Meadows KA. So you want to do research? 5: Questionnaire design. *Br J Community Nurs* 2003;**8**:562-70.
22. Teschke K. Exposure surrogates: job-exposure matrices, self-reports, and expert evaluations. In: Nieuwenhuijsen MJ, ed. *Exposure assessment in occupational and environmental epidemiology*. Oxford Scholarship Online, **2003**:119-32.
23. Ikin JF, Fritschi L, Sim MR. Reproducibility of survey results from a study of occupation-related respiratory health in the aluminum industry. *Appl Occup Environ Hyg* 2002;**17**:774-82.
24. Touvier M, Méjean C, Kesse-Guyot E, *et al*. Comparison between web-based and paper versions of a self-administered anthropometric questionnaire. *Eur J Epidemiol* 2010;**25**:287-96.
25. Le TT, Tran TT, Ho HT, *et al*. Prevalence of food allergy in Vietnam: comparison of web-based with traditional paper-based survey. *World Allergy Organ J* 2018;**11**:16.
26. Mutepfa MM, Tapera R. Traditional Survey and Questionnaire Platforms. In: Pranee L, ed. *Handbook of Research Methods in Health Social Sciences*. Springer Singapore, **2019**:541-58.
27. Giovannetti E, Sigloch S. An Internet periphery study: Network centrality and clustering for mobile access in Bhutan. *Telecomm Policy* 2015;**39**:608-22.
28. McColl E, Jacoby A, Thomas L, *et al*. Design and use of questionnaires: a review of best practice applicable to surveys of health service staff and patients. *Health Technol Assess* 2001;**5**:1-256.
29. Beaton DE, Bombardier C, Guillemin F, Ferraz MB. Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine* 2000;**25**:3186-91.
30. Perneger TV, Courvoisier DS, Hudelson PM, Gayet-Ageron A. Sample size for pre-tests of questionnaires. *Qual Life Res* 2015;**24**:147-51.

Appendix J: Comments on Paper 3 (Chapter 6) and response by the authors

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Letter to the Editor

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Comments on "Reliability and Validity of an Adapted Questionnaire Assessing Occupational Exposures to Hazardous Chemicals among Health Care Workers in Bhutan"

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Dear Editor,

We read with great interest the article recently published in *The IJOEM* by Rai, *et al*, on the reliability and validity of a questionnaire for assessing occupational exposures to hazardous chemicals among health care workers in Bhutan.[1] We really appreciate the efforts put by the authors for undertaking such a thought-provoking study that have pivotal role in occupational health of the developing countries. This paper well explained the importance of collecting valid and reliable occupational history data in estimating occupational exposures and work-related health effects. However, there are certain issues that need to be addressed.

The title of the study creates a curiosity to learn about the reliability and validity of an adapted questionnaire. As the study process, the method tapers down the study into two stages (1) adaptation of the National Institute for Occupational Safety and Health (NIOSH) questionnaire, and (2) test-retest reliability assessment that leads to the missing of the major half portion—the questionnaire validity. The process of adaptation of the questionnaire has to follow the specific recommended steps that cannot be purely expert-guided.[2] Rai, *et al*, confirm that questions on automated disinfection systems from the original NIOSH questionnaire were excluded whereas health care job module in occIDEAS were included to structure the pre-final version of the questionnaire.[1] The pre-final version of the modified questionnaire was then reviewed by the experts to assess the validity of the instrument, a method just enough for face validity. The method of rating the items or the scoring criteria for the questionnaire used by the authors was not revealed. Item rating and scale rating have been proposed to be integral components of content validity.[3] The final stage of the adaptation process should be a field test of the new questionnaire that seeks to use the pre-final version in people from the target setting that provides insight into how a person interprets the items on the questionnaire so as to measure quality in the content validity.[2] These

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aspects remained untouched in the study for validity; however, the other forms of validity are included to strengthen the validity of the adapted questionnaire, in spite of using the umbrella term "validity." This makes the validation very subjective.

The test-retest reliability is well-described with supporting statistical analysis presented. The reliability is calculated based on the questionnaire filled by the subject and completely explained in the result section, again not highlighting the validity of the questionnaire.

In the Discussion section, the authors emphasize on testing the validity and exhibit good content validity of the adapted questionnaire. The statistical analyses to reach such a conclusion, however, are not presented, which is a weak side of the study. The purpose of the study was the most needed in the occupational health domain of the developing countries and provides valuable insight, but the above-mentioned points need to be considered for justifying the title of the study.

References

1. Rai R, El-Zaemey S, Dorji N, Fritschi L. Reliability and Validity of an Adapted Questionnaire Assessing Occupational Exposures to Hazardous Chemicals among Health Care Workers in Bhutan. *Int J Occup Environ Med* 2020;**11**:128-39.
2. Beaton DE, Bombardier C, Guillemin F, Ferraz MB. Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine (Phila Pa 1976)* 2000;**25**:3186-91.
3. Bolarinwa OA. Principles and methods of validity and reliability testing of questionnaires used in social and health science researches. *Niger Postgrad Med J* 2015;**22**:195-201.

Authors' Reply

Dear Editor,

We thank the authors of this letter for expressing interest in our article,[1] and for appreciating the need for such studies to be conducted in developing countries to promote occupational health, which is a largely neglected public health issue in these countries.

The authors have raised concerns about the assessment of the validity of the questionnaire since we did not conduct statistical tests to assess content validity. We acknowledge that we assessed only face validity and this type of validity is often seen as a weak form of construct validity owing to its subjective judgement. We could have tested for content validity using statistical tests, as suggested by the authors, however, the assessment of content validity is still fundamentally a subjective process.[2] Criterion-related validity assessment was not possible since there is no gold-standard questionnaire to compare ours with.[3] Similarly, construct validity, which is the best method for testing validity,[2] could not be assessed, because we were not testing a theoretical construct or a psychosocial scale. Additionally, we were assessing whether participants undertook particular tasks, not whether they were exposed to a single chemical where it would potentially be possible to assess the validity by comparing the questionnaire to biomonitoring results of that chemical.[3]

With regards to the cross-cultural adaptation process,[4] as we discussed in the paper, the questionnaire did not need to be translated in the local language as tertiary education in Bhutan is in English. For cultural adaptation, each item of the questionnaire was assessed by the expert committee for comprehensiveness and relevance to the Bhutanese context, and for comprehensibility to the Bhutanese health care workers. In addition, the participants were asked whether they had difficulties in understanding the questionnaire and to provide reasons, if so. Only one participant had difficulty with one question and changes were made to the questionnaire accordingly, which we have described in the paper.

In conclusion, we thank the author for raising these important points which should be considered when adapting questionnaires between countries.

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References

1. Rai R, El-Zaemey S, Dorji N, Fritschi L. Reliability and validity of an adapted questionnaire assessing occupational exposures to hazardous chemicals among healthcare workers in Bhutan. *Int J Occup Environ Med* 2020;**11**:128-39.
2. Bolarinwa OA. Principles and methods of validity and reliability testing of questionnaires used in social and health science researches. *Niger Postgrad Med J N* 2015;**22**:195-201.
3. Nieuwenhuijsen MJ. Design of exposure questionnaires for epidemiological studies. *Occup Environ Med* 2005;**62**:272-80.
4. Beaton DE, Bombardier C, Guillemin F, Ferraz MB. Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine (Phila Pa 1976)* 2000;**25**:3186-91.

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