Occupational determinants of health

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Abstract: Occupational determinants of health encompass a broad spectrum of workplace factors that wield considerable influence over an individual's holistic well-being, encompassing physical, mental, and social dimensions. This viewpoint aims to provide an expansive and nuanced examination, evaluation, and definition of these determinants, elucidating the intricate interplay between one's occupation and their health. Extensive research, including a meticulous review of qualitative and quantitative studies conducted between 2000 and 2023, has been undertaken to delineate occupational hazards prevalent across diverse professions. The findings underscore the pivotal roles played by biological and chemical hazards, alongside the intricate web of occupational and socioeconomic factors, in shaping the health landscape of workers. This comprehensive analysis not only highlights the varied dimensions of occupational health but also sheds light on the multifaceted nature of hazards, emphasizing their significant impact on the well-being of individuals within the workforce.

Keywords: Occupational, workplace, health, United States

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Introduction

Occupational determinants of health encompass a spectrum of factors and circumstances found in the workplace that wield substantial influence over an individual's overall health and wellness. These determinants can exert favorable and unfavorable impacts on a person's physical, mental, and social well-being (1). Based on an analysis to estimate the number of United States workers that are frequently exposed to infectious and disease-causing agents in the workplace, the result from the survey showed that as of 2018, of 144.7 million people employed in the United States, approximately 10% (14,425,070) and 18.4% (26,669,810) of workers were exposed to disease or infection at least once per week and once per month respectively (2). It was also noted that the majority of the exposed workers are employed in healthcare sectors and others, including protective service occupations, office and administrative support occupations, education occupations, community and social services occupations, and construction and social services occupations (2). It is important to explore comprehensively how workers are exposed to infectious and disease-causing agents in the workplace and the factors responsible for this.

Occupational hazards negatively impact workers' health; they are classified as physical, biological, chemical, ergonomic, mechanical, and psychosocial hazards (3). Other factors that impact workers' health include physical work environment, organizational, socioeconomic, occupational disparities, occupational health promotion and occupational health protection can have both favorable and unfavorable impact on workers' health (4).

Research has shown diseases and health complications associated with occupations due to exposure to the above-stated hazards at their workplace. Some of the health complications include chemical burns, skin disorders, respiratory problems, anxiety and depression, organ damage, and cancers in some extreme cases of exposure to toxic chemicals (5-7). A research study aimed at examining the impact of physical hazard exposure on the health of forestry vehicle operators engaged in wood logging operations found that 27% of the workers had been diagnosed with a range of health conditions. These conditions included osteo-musculoskeletal disorders, dermatological issues, respiratory problems, and cardiovascular diseases. Among these health issues, osteo-musculoskeletal disorders were the most prevalent. These health problems were attributed to the workers' exposure to workplace hazards, including noise, whole-body vibration, and various environmental elements (8). In another study, occupational hearing impairment was detected among twenty-two million workers, encompassing both men and women aged between 18 and 65. These individuals had been exposed to unsafe noise levels within various industries across the United States (9).

This paper aims to embark on a comprehensive exploration, assessment, and definition of the overarching occupational determinants of health. In doing so, we endeavor to dissect and illuminate the multifaceted aspects that shape an individual's health within the context of their occupation.

To achieve this objective, we will extensively review existing literature, drawing upon various disciplines such as public health, occupational science, sociology, psychology, and epidemiology. This interdisciplinary approach will enable us to identify and comprehensively analyze the diverse factors that influence health outcomes in the workplace.

Our investigation will encompass an exhaustive examination of the physical, psychosocial, and environmental factors that individuals encounter while engaged in their occupations. We will delve into the impact of workplace hazards, ergonomic considerations, and occupational exposures on health. Simultaneously, we will explore the interplay of psychosocial stressors, job satisfaction, work-life balance, and mental well-being in shaping an individual's overall health status. Furthermore, we will scrutinize the role of workplace policies, organizational culture, and access to healthcare resources in this complex equation.

By elucidating these multifaceted determinants, we aim to provide a comprehensive framework that not only identifies the factors at play but also defines their collective influence on an individual's health. Figure 1 shows the summary of occupational determinant of health.

Figure 1. Occupational determinant of health

Methods

In this viewpoint, we aimed to undertake a thorough investigation, evaluation, and clarification of the fundamental occupational factors influencing health. We conducted computer-based searches in academic databases including PubMed and ScienceDirect. To optimize search outcomes, we employed diverse combinations of keywords identified in the literature, Medical Subject Heading (MeSH) and general terms associated with various types of workplace hazards and their health implications. Some of these terms such as occupational health, workplace hazards, prevalence of occupational hazards, physical hazards, chemical hazards, biological hazards, musculoskeletal disorder, Covid-19 pandemic, occupational diseases, and socioeconomic status. The table showing the combination of the searched words can be found in table 1.

Table 1. Searched words combination

Database	Type of search	Search terms
Google Scholar	General terms	Occupational health, chemical hazard, physical hazard, biological hazard, w
PubMed database	Medical subject headings	Musculoskeletal disorder, physical hazard, occupational hazard, occupationa
ScienceDirect	General terms	Occupational determinant of health, work hazard, work injuries, occupation

Study selection

This viewpoint was conducted a thorough search for qualitative and quantitative studies that reported findings on hazards associated with various occupations spanning from 2000 to 2023. The inclusivity of our search extended to studies conducted both in the United States and internationally. However, to maintain language consistency, studies not published in English language were excluded. The scope of our inquiry aimed to gather comprehensive insights into occupational hazards across diverse settings and geographic

locations. The selected timeframe allowed us to capture a broad spectrum of relevant research conducted over the past two decades.

Results

When searching through Google Scholar, PubMed and ScienceDirect for articles on occupational determinant of health, 63 articles,46 articles and 49 articles were found from each database respectfully. Our initial search identified a total of 158 articles and identified five records from websites and organizations. After all the duplicate articles and articles that were not eligible were removed, we were left with 103 articles for screening. During the screening of the articles, 26 articles were excluded against titles and abstracts, 27 articles were excluded because we were unable to obtain the full text for our review and seven were excluded because they were not published in English.

Table 2. Occupational health hazards, sources, health risks and preventive measures

Occupational hazards	**Sources**	**Health risks**	**Preventive measure**
Physical hazard	Machinery and Equipment Electrical Sources Noise and Vibration Falling Objects Confined Spaces Extreme temperatures Radiation Sources Wet floors	Bruises Electric shock Burns Acute radiation syndrome Hearing loss Stress and fatigue Musculoskeletal disorders	Use of personal protective equipment Training on handling Proper of tools and equipment. Proper ventilation
Biological hazard	Bloodborne pathogens Parasite Bacterial Virus Organic dust and bioaerosols	Infectious diseases such as influenza, tuberculosis, hepatitis, and blood-borne diseases Respiratory problem Skin Infections Gastrointestinal Issues	Use of personal protective equipment Vaccination Infection Control Practices Training Routine Cleaning and Disinfection Personal Hygiene
Chemical hazard	Toxic chemicals Irritants and corrosives Carcinogens flammable and combustible chemicals Mutagenic substances	Respiratory problems Organ damage Skin burns Anthrax Aches Ulcers in the hand and nose Irritation of windpipes Cancer Genetic mutations	Use of personal protective equipment Training and Education Proper labeling of chemicals Spill Response Kits Regular Inspections Proper Storage of chemicals
Organizational factors	Workload and Work Pressure Job Insecurity Workplace Violence and Bullying Inadequate Training and Development Discrimination and Harassment Poor Social Support	Stress Anxiety Depression Hypertension Psychological Disorders Decreased Productivity Increased Risk of Accidents	Leadership and Management Training Employee Involvement Workload Management Support Programs Promote a Positive Work Environment

In this viewpoint, a total of 48 studies were used to explore how physical hazards, biological hazards, chemical hazards, socioeconomic factors and occupational health promotion and protection at different workplaces and how they affect the health of the workers. Table 2 shows the summary of occupational hazards, sources, health risks and preventive measures. Of the 48 articles, 10 studies of occupational determinant of health

are summarized in table 3.

Table 3. Summary of studies for occupational determinants of health

Author	Date	Sample s
Alexopoulos, E. C., Stathi, I. C., & Charizani, F.	2004	430 dentis
Baer, R., Turnberg, W., Yu, D., & Wohrle, R.	2010	1
Baker, M. G., Peckham, T. K., & Seixas, N. S.	2020	144.7 milli
Gibb, H. J., Lees, P. S., Pinsky, P. F., & Rooney, B. C.	2000	2,357 work
Girard, S. A., Picard, M., Davis, A. C., Simard, M., Larocque, R., Leroux, T., & Turcotte, F.	2009	52,982 ma
Hu, R., Huang, X., Huang, J., Li, Y., Zhang, C., Yin, Y., ... & Cui, F.	2015	246 farme
Meyer, A., Sandler, D. P., Beane Freeman, L. E., Hofmann, J. N., & Parks, C. G.	2017	52,394 pri
Oakman, J., Ketels, M., & Clays, E.	2021	331 partic
Parks, C. G., Walitt, B. T., Pettinger, M., Chen, J. C., De Roos, A. J., Hunt, J., ... & Howard, B. V.	2011	76,861 pos
Pettersson, H., Olsson, D., & Järvholm, B.	2020	194,501 w

Discussion

In this review, we aim to explore the physical, psychosocial, and environmental hazards individuals are exposed to during their engagement in various occupations. Occupational determinants of health encompass a variety of factors inherent in the work environment and employment conditions, exerting a substantial impact on an individual's overall well-being and health outcomes. These determinants include a diverse set of elements associated with one's occupation, workplace, and employment circumstances. Occupational determinants are closely linked to the broader standardized social determinants of health framework, providing a comprehensive understanding of health disparities and outcomes. One's occupational nature significantly shapes socioeconomic status, a pivotal element of social determinants of health, covering aspects such as income, education, and social standing. The critical determinants within the work environment, encompassing exposure to hazards and job security, emerge as essential factors in the occupational realm that intersect with social determinants of health. The hazards individuals are exposed to at different workplaces are discussed below.

Physical hazards

Physical hazards in the workplace pose risks and dangers to employees due to their physical properties or characteristics, potentially resulting in injuries, health issues, or even death. Despite the serious consequences associated with physical hazards, they are sometimes considered to be of lesser concern when compared to chemical hazards (3). Physical hazards in occupational settings can occur in various forms and circumstances, which can vary depending on the specific workplace environment. Some of these forms include mechanical, electrical, thermal, radiation, noise, and vibration hazards (3). Mechanical hazards involve using equipment and machinery containing moving components capable of shearing, cutting, or crushing, potentially causing harm to individuals operating them. These hazards can lead to a range of injuries, including bruises, cuts, puncture wounds, fractures, head and eye injuries, as well as back and spinal injuries, among others (10). Physical hazards related to electricity can be caused by faulty electrical equipment, exposed wire or bad or damaged wiring system causing electric shock, burns, electrocution, internal injuries, or death (11). Thermal and radiation hazards are caused by extreme cold or hot temperatures and ionizing or non-ionizing radiation exposure (12). Thermal hazards can lead to health issues such as heat exhaustion, heat stroke, frostbite, hypothermia, and burns, whereas radiation hazards can cause conditions in cancer, acute radiation syndrome, radiation burns, cataracts and radiation sickness (12). Noise hazard occurs as a result of exposure to excessive noise in a work environment over a prolonged period of time, it could be from industrial machinery, construction activities, power tools, or firearms among others (13). Exposure to prolonged noise at workplace could cause stress and fatigue, sleep disturbance, hearing loss, cardiovascular effect such as high blood pressure and heart disease etc. (13). Vibration hazard occurs due to workers' exposure to continuous

vibration over a long period of time. The vibration can be from different sources such as equipment, vehicles, tools or machinery (14). Vibration can occur as whole-body vibration, where the entire body is in contact with the vibration surface like vehicle seat usually in construction, transportation and agriculture or hand-arm vibration, where the vibration only affects the arm when using vibrating hand tools (14). The health effects associated with whole-body and hand-arm vibration are musculoskeletal disorders, circulatory problems, neurological problems, Raynaud's phenomenon, neurological problems, fatigue and reduced work performance (8,14). Extensive research has revealed the consequences of workers' exposure to physical hazards in various occupational settings and the resulting adverse effects on their well-being.

In a study to explore the role of occupational physical activity, physical demand, and psychosocial work-related factors on low back pain and neck-shoulder pain amongst workers with physically demanding professions, data was collected from 331 participants comprising of 142 males and 189 females between the age of 20 and 65 within the service and manufacturing sector in the Flemish Employees' Physical Activity using a modified Nordic questionnaire on low back pain and neck-shoulder pain. Using objective measures to evaluate physical activity, two accelerometers were positioned on the middle of the back and right thigh and worn continuously for 3-4 days. Using subjective measures, participants were requested to maintain a diary documenting their daily activities. Psychosocial work factors, such as job demands, job control, and social support, were assessed using constructs from job content questionnaire. Musculoskeletal pain information concerning the lower back and neck-shoulder regions was collected through a modified version of the Standardized Nordic questionnaire, which is used to assess musculoskeletal symptoms. This study showed that about 25% of the participants reported low back pain for more than 30 days during the last year, 30% reported neck-shoulder pain and 17% reported a combination of low back and neck-shoulder pain. Objective measures showed that 37% of workers with physically demanding jobs were standing most of the time, followed by 30.4% sitting and 14.5% performing moderate-to-vigorous physical activity. No correlation was found between objective measures and the occurrence of low back and neck-shoulder pain. However, self-reported measures offered valuable insights into potential workplace hazards, including physical demands and job control, which can inform the development of future strategies to prevent the onset of low back pain and neck-shoulder pain (15).

In another study, a retrospective study of 52,982 male workers between the ages of 16 and 64 years who had experienced prolonged exposure to occupational noise over a period of 5 years was done using hearing status and noise exposure from the registry held by the Quebec National Institute of Public Health to investigate any relationship between noise exposure levels in the workplace, degree of hearing loss, and the relative risk of accident. After accounting for age, a regression analysis was conducted to examine the relationship between hearing threshold level measurements, noise exposures, and the incidence of accidents. From this study, it was shown that the proportion of workers with mild-to-severe hearing loss is higher among the workers exposed to the higher noise level of [?]90 dBA, indicating that the likelihood of high-frequency hearing impairment rises with increasing levels of noise exposure, in line with what is anticipated in cases of noise-induced hearing loss. Additionally, from this study it was indicated that occupational noise exposure has a detrimental impact on workplace safety. It substantially elevates the likelihood of both single and multiple accidents, adding to the well-documented consequences of noise exposure on hearing (16).

Another study was conducted to examine the possible association between occupational exposure to noise, working and living in cold conditions, and the risk of mortality in myocardial infarction and stroke among workers in the Swedish construction industry who participated in health examinations between 1971 and 1993. As method, 194,501 workers answered a questionnaire regarding their working conditions and their health status. A job exposure matrix was created to categorize 21 different work groups in a cohort based on their noise exposure levels. The noise exposure data was derived from a survey of working conditions conducted by industrial hygienists in the mid-1970s. Noise categories were assigned to each working group on a scale of 1 to 5, with levels 1 to 3 representing acceptable noise exposure (45-75 dB(A), level 4 indicating exposure in the range of 76-85 dB(A), and level 5 signifying exposure above 85 dB(A). For analysis purposes, these noise categories were grouped into low ([?]75 dB(A)), moderate (76-85 dB(A)), and high (>85 dB(A)) levels. The study highlights a correlation between working in environments with hazardous noise levels

and residing and working in cold conditions, leading to an elevated risk of mortality in cases of myocardial infarction evidenced by increased myocardial infarction and stroke mortality with both moderate (76–85 dB) and high noise exposure (> 85 dB). There was a significant increase in myocardial infarction in the coldest region. Noise exposure and climate region interacted to increase the risk of myocardial infarction, with the highest risks observed in individuals exposed to high noise levels while living and working in cold climates. The greatest relative risk of myocardial infarction occurred in the coldest region among those with the highest noise exposure however, this interaction did not affect stroke mortality (17).

The relations between physical, psychosocial and individual characteristics and different endpoints of prevalence of musculoskeletal disorder complaints of low back, neck, shoulders and hand or wrist was investigated in dentists. Musculoskeletal disorders encompass various medical conditions affecting the musculoskeletal system, including both soft tissues (muscles, tendons, ligaments) and hard tissues (bones). These disorders can lead to issues such as pain, inflammation, and reduced mobility. Soft tissue problems may involve inflammation or tears, while hard tissue conditions include fractures, arthritis, or osteoporosis. Overall, musculoskeletal disorders emphasize the interconnectedness of both soft and hard body tissues in maintaining musculoskeletal health. A survey involving 430 dentists in Thessaloniki, Greece, with an 88% response rate, collected data on physical and psychosocial workload, need for recovery, perceived general health, and musculoskeletal complaints in the past year. Logistic regression analysis was used to estimate odds ratios for various risk factors related to these complaints, including chronic issues lasting at least one month, complaints leading to sickness absence, and the seeking of medical care. As result, the physical load among the dentists seems to put them at risk for occurrence of musculoskeletal disorders with the result from the questionnaire showing that from the total of 430 participants, 62% of all subjects reported at least one musculoskeletal complaint, 35% reported at least two musculoskeletal complaints, 15% reported at least three musculoskeletal complaints and 6% reported spells of all four complaints in the past 12 months. Subjects with back pain more often reported neck pain (41%) and hand/wrist pain (38%) than those without back pain (13% and 16%, respectively). Neck and hand/wrist pain was strongly associated since 50% of subjects with neck pain also experienced hand/wrist pain in the past 12 months. Dentists' physical workload appears to increase their risk of musculoskeletal disorders. Severe and multiple complaints are linked to their general health perception, while high perceived exertion and social factors are connected to sickness absence. Chronic symptoms play a role in seeking medical care. Preventing hand/wrist complaints may benefit from ergonomic interventions. When studying the impact of work-related risk factors on musculoskeletal health, it's important to consider psychosocial and personal characteristics (18).

Biological hazards

Biological hazards are health risks associated with exposure to biological agents or pathogens, substances or processes such as bacteria, viruses, fungi, toxins and biological materials in the workplace that can cause acute or chronic health conditions. The presence of biological hazards in the workplace represents a substantial risk to the well-being and safety of employees, raising valid concerns about the potential transmission of these dangers to fellow workers (19). For instance, individuals in healthcare, laboratory and research roles, as well as those in the food industry, may encounter elevated exposure risks of biological hazards (20). Other occupations and industries affected by biological hazards include agriculture and farming, construction, veterinarians and animal handlers, and wastewater and sewage treatment personnel (19). Healthcare workers are faced with potential exposure to bloodborne pathogens such as HIV, hepatitis B, and hepatitis C when they come into contact with contaminated bodily fluids. In laboratory environments, there is inherent proximity to biological agents (20,21).

Scientists and laboratory staff frequently handle microorganisms, cultures, and samples that may harbor infectious diseases, resulting in the potential risk of biological hazards. Biological hazards within the food industry are linked to product contamination during processing, if not effectively controlled, pathogens such as Escherichia coli and salmonella can give rise to foodborne illnesses, causing significant health concerns (22). In the agricultural and waste management sectors, employees are primarily subjected to organic dust and bioaerosols. Bioaerosols are defined as suspended airborne particles consisting of biological matter, which

may include bacterial cells, cellular remnants such as endotoxins, fungal spores, fungal hyphae, viruses, and the metabolic by-products of microorganisms. Additionally, pollen grains and other forms of biological materials can also become airborne as bioaerosols (23).

Occupational biological hazards can be transmitted to workers through various means. These include direct contact with contaminated surfaces, equipment, or co-workers who may carry infectious agents. Additionally, there is the risk of airborne transmission of respiratory pathogens, such as tuberculosis or COVID-19, through the inhalation of infectious droplets. Inadequate ventilation and close proximity to infected individuals can exacerbate this risk (20,21). Fomite transmission involves inanimate objects carrying biological hazards and can occur through shared equipment, doorknobs, or breakroom utensils. Foodborne transmission is a concern when biological hazards contaminate food products or when proper food hygiene practices are not followed (21). Furthermore, bloodborne pathogens can be transmitted through accidental needlestick injuries or contact with contaminated blood. Certain procedures, like suctioning, can lead to the generation of respiratory droplets containing infectious agents, facilitating droplet spread (20). (24) reported a female patient, aged 40, was diagnosed with tuberculosis in the middle ear on the right side. She had been employed as a nurse at the Department of Pulmonology, Clinical Hospital Rijeka in Rijeka, Croatia, for a duration of 17 years. The infection was attributed to Mycobacterium tuberculosis, acquired during her assistance in bronchoscopy, and was officially recognized as an occupational disease. An outbreak of pertussis was also documented, with transmission occurring among healthcare workers in an oncology department of a hospital, potentially originating from a patient identified as the probable source (25).

In Washington State, a veterinarian specializing in small animals contracted leptospirosis following an incident at work. Roughly 10 days before the onset of the illness, he handled a seemingly healthy pet rat to check for fleas, which urinated on his ungloved hands. Despite washing his hands after the examination, the veterinarian had abrasions on his hands from gardening (26). Ensuring the prevention of biological hazards in the workplace is essential for safeguarding the health and well-being of employees, thereby lowering the chances of illness and potential long-term health impacts.

In the workplace, it is imperative to ensure the safeguarding of employees from biological hazards. Protective measures should be implemented to preclude the possibility of exposure to biological agents and hazards. Where complete prevention may not be feasible, steps should be taken to minimize the risk of exposure to an acceptable level. Control measures encompass systems and actions to minimize exposure risks to biological agents and hazards including engineering controls, management controls and personal protective equipment (19,27). Engineering controls involves the use of mechanical or physical systems to mitigate the risk of exposure to occupational biological hazards. engineering controls for biological hazards include ventilation systems, biological safety cabinets, airborne infection isolation room, decontamination, handwashing and sterilization equipment, and physical barriers such as shields and screens (19). Management controls aimed at mitigating biological hazards in the workplace encompass administrative and organizational strategies with the primary goal of diminishing risks and safeguarding employee safety. These strategies are intended to formulate clear policies, protocols, and guidelines to ensure the effective management of biological hazards. Examples of management controls include risk assessment, written policies and procedures, training, standard operating procedures, emergency response plan, access control to areas where biological hazards are present, and supervision (19).

Personal protective equipment consists of a range of specialized gear and wear that workers utilize to protect themselves from potential hazards. Personal protective equipment include mask, gowns, eye protection, appropriate footwear, hearing protector and gloves (27). Collectively, these measures serve to reduce the likelihood of employees being exposed to biological hazards in the workplace and contribute to establishing a safer environment for them.

The onset of the COVID-19 pandemic, resulting from infection with the novel coronavirus SARS-CoV-2, marked by various symptoms including fever, cough, breathing issues, and fatigue, has spurred a global prioritization of managing biological risks in occupational environments (28,29). This underscored the urgent requirement for the development of comprehensive standards and guidelines to effectively tackle these

challenges. Considering this situation, companies had to consider their respective national governments' health contingency plans as well as the recommendations of the World Health Organization (WHO) and the International Labor Organization (ILO) (29,30). This approach was crucial for achieving a necessary balance between reopening operations and the imperative of maintaining low infection rates. The achievement of this balance heavily depended on workers' awareness and the implementation of measures to safeguard their health. Occupational safety and health (OSH) practitioners hold a crucial position in strategizing for the maintenance of secure work environments and in offering guidance and technical support to companies, workers, and their representatives on matters concerning the intricate connection between health and work. Their efforts are primarily concentrated in two key domains, including the recognition and evaluation of occupational hazards (stemming from work-related activities) and the evaluation of individuals' health conditions in the workplace (28).

The emergence of the coronavirus era highlighted the necessity of safeguarding at-risk workers from occupational hazards, particularly those posed by biological factors. Assessing biological risks entails gathering personal data from employees, understanding their health vulnerabilities, and considering their biological condition to accurately evaluate evolving risks (28). This information is vital for devising essential preventive measures and implementing protective protocols. These events have raised awareness and led to changes in workplace safety practices to minimize the risk of virus transmission and protect employees at different levels. Some of these changes include the adoption of remote work arrangements to reduce the number of employees physically present at workplaces, maintaining of a safe distance between employees, wearing of masks to prevent the spread of respiratory droplets, frequent handwashing, sanitizing and good personal hygiene practices, screening and temperature checks to identify potential case, increased cleaning and disinfection, improved ventilation, and workplace safety training (31,32).

Chemical hazards

Chemical hazards in the workplace are a prevalent worry across multiple industries, presenting dangers to employees' well-being and the work environment's overall stability. These hazards include contact with various chemical compounds, such as harmful substances, combustible elements, corrosive materials, etc. Over 30 million employees within the United States are subject to unsafe chemicals in their workplace (33). The 2021 data addendum reveals that in 2019, exposure to specific chemicals resulted in the loss of approximately two million lives and 53 million disability-adjusted life-years. Nearly 50% of the deaths linked to chemical exposures that year were primarily caused by lead exposure, leading to cardiovascular diseases (34). Employees can be exposed to chemicals at the workplace through inhalation, eye contact, skin contact, ingestion, and injection (35). Exposure to chemicals at work can have several effects on health, ranging from skin burns, anthrax, aches, ulcers in the hand and nose, irritation of windpipes, and cancer (36).

Hazardous workplace chemicals vary based on the work environment. These pose significant health risks, highlighting the need to understand the different types and potential consequences. These chemical hazards are categorized as toxic, corrosive, irritant, carcinogenic, flammable, and mutagenic (36). Toxic chemicals are commonly present in chemical manufacturing, agriculture, and mining industries, where substances like solvents and pesticides are utilized (37,38). Exposure to these toxins can lead to both acute and chronic health issues, such as respiratory problems, organ damage, and even cancer. Irritants and corrosives, on the other hand, encompass chemicals like strong acids, cleaning agents, and alkalis, which find application in industries like manufacturing, cleaning, and metalworking (36). Carcinogens are used in many industries like healthcare, construction, and laboratories. Some of these carcinogens include asbestos, formaldehyde, and certain solvents. Prolonged exposure to carcinogenic substances poses a serious threat to workers' health as it can lead to the development of cancer (39). In industries such as chemical plants, oil refineries, and automotive repair shops, the use of flammable and combustible chemicals like gasoline, aerosols, and propane increases the risk of exposure, potentially resulting in burns, asphyxiation, or even fatalities (40).

Mutagenic substances encountered in workplaces can cause DNA changes and genetic mutations in exposed individuals, significantly elevating the risk of enduring health issues, including a variety of cancers. Exposure to these mutagenic substances in the workplace can have long-lasting and profound health consequences, with

the substances encompassing a wide array of chemicals, ranging from specific solvents and heavy metals to pharmaceuticals and even ionizing radiation, such as X-rays and gamma rays (40,41).

Several studies have been conducted to determine the effect of chemical exposure on individuals in the workplace. In research conducted by Herman Gibb and fellow researchers, the objective was to assess the lung cancer risk associated with exposure to both trivalent and hexavalent chromium among individuals employed in chromium production facilities. They examined a cohort comprising 2,357 workers who were initially hired between 1950 and 1974 at a chromate production plant, and the vital status of these workers was tracked until December 31, 1992. From examining the cohort, a progressive relationship between cumulative hexavalent exposure and the incidence of lung cancer was indicated (39). According to Van Rooy et al (42), the development of bronchiolitis obliterans syndrome among chemical process operators was attributed to their exposure to diacetyl during its manufacturing for food flavorings (42). Armando Meyer and his team conducted a study examining the correlation between the risk of rheumatoid arthritis and the utilization of pesticides among male pesticide applicators enrolled between 1993 and 1997. The study found that heightened occurrences of rheumatoid arthritis were linked to exposure to various pesticides, including fonofos, carbaryl, and imuran ethyl (38). In a similar study, Parks et al (43) observed an elevated risk of rheumatoid arthritis and the associated condition, systemic lupus erythematosus, in women who self-reported using insecticides during the Women's Health Initiative Observational Study. This risk was more pronounced in women with a farming background. In a sample of the US population as part of the National Health and Nutrition Examination Survey, increased serum levels of organochlorine insecticides were linked to self-reported cases of arthritis, including rheumatoid arthritis (43).

Long-term pesticide exposure was linked to increased abnormalities in nerve conduction, particularly in sensory nerves. This extended exposure also broadly impacted various health indicators based on blood tests. It resulted in reduced amplitudes of the tibial nerve's compound muscle action potential. Short-term exposure had immediate health effects, including changes in complete blood count, hepatic and renal functions, and alterations in nerve conduction velocities and amplitudes (44).

The exposure to chemical hazards originating from coal combustion emissions and diesel engine exhaust was determined to be correlated with urinary mutagenicity, which in turn was associated with an increased risk and development of cancer at multiple locations in the body (40). Therefore, reducing employees' exposure to chemical hazards within their workplace is crucial. Emerging chemical hazards in various industries arise from new chemical compounds, processes, and evolving risk awareness. They can result from innovative chemicals, processes, or the discovery of previously unrecognized risks in existing substances. It is crucially important to adopt a forward-looking strategy to anticipate potential risks posed by chemicals to the health and safety of workers within an ever-evolving work landscape.

With the constant changes in work, an imminent requirement exists to proactively identify potential hazards that may not yet be known or expected. Early detection and alerts can significantly mitigate the likelihood of severe consequences in terms of negative health impacts and broader socio-economic ramifications. Some of the emerging chemicals include nanomaterials, per- and polyfluoroalkyl substances (PFAS), and metal-organic frameworks (MOFs). In recent years, there has been a growing interest in the use of nanotechnology. Nanotechnology involves manipulating matter at scales below 100 nm, resulting in nanoparticles with high surface area-to-volume ratios that enhance reactivity and affect chemical reaction rates (45). Nanomaterials, owing to their unique and beneficial characteristics encompassing chemical reactivity (due to their small size), ductility, flexibility, optical properties, biocompatibility, tunability, enhanced strength, and improved magnetic attributes, offer versatile applications across an array of industries. These applications span diverse fields, including electronics, medicine, energy, aerospace, food production, textiles, cosmetics, and construction (46). PFAS, or per- and polyfluoroalkyl substances, represent a group of artificially produced chemicals. Typically, they contain a carbon chain with most carbon sites saturated by fluorine atoms, along with at least one functional group, like carboxylic acid, sulfonic acid, or amine.

It is important to note that the carbon backbone may not be exclusively carbon; for instance, ether-type PFAS include oxygen atoms in their structure (47). Due to their high production costs, PFAS are typically

employed in scenarios where alternative substances are unable to meet the necessary performance standards, or where PFAS can function effectively in much smaller quantities compared to non-fluorinated chemicals while delivering the same level of performance. For instance, they are utilized in applications that operate across broad temperature ranges and in situations that demand exceptionally stable and non-reactive materials (48). PFAS have gained widespread usage across more than 200 application areas, ranging from industrial-mining operations to food production and fire-fighting foams. The key driving force behind the extensive adoption of PFAS lies in the remarkable properties associated with the carbon-fluorine (C-F) bond, which imparts exceptional chemical and thermal stability and the unique ability to repel oil and water (48). MOFs are ordered crystalline materials characterized by structured networks. These frameworks are composed of single metal ions or clusters linked together by multidentate organic groups (49). Their distinct characteristics, such as their expansive surface area, adjustable porosity, and varied chemical compositions, render them applicable across various fields (49). These fields include gas storage and purification, catalysis, drug delivery, energy storage, electronics, coating and films, photocatalysis, and hydrogen storage (49, 50).

Organizational factors

Organizational factors concerning occupational hazards encompass components within an organization's structure, policies, and practices that either amplify or alleviate the risks and threats encountered by employees in the workplace. These factors wield substantial influence over the health and safety of workers. Organizational factors in the workplace wield considerable influence on employee well-being across various dimensions. From a physical standpoint, conditions such as subpar ergonomics, inadequate safety measures, and excessive workloads can contribute to injuries and musculoskeletal disorders (51).

On a mental level, challenges such as overwhelming job demands, job insecurity, and insufficient social support may precipitate stress, anxiety, and depression (52). Psychosocially, the existence of a negative organizational culture, instances of workplace bullying, and discriminatory practices can collectively foster a hostile environment, further impacting mental health (53). The emergence of these health complications emphasizes the intricate interplay among physical, mental, and psychosocial factors within the workplace. Ultimately, it is imperative to address these organizational factors to cultivate a healthier work environment and enhance the overall well-being of employees.

Socioeconomic factors

Socioeconomic factors in the workplace encompass the social and economic conditions shaping the work environment, employment opportunities, and overall well-being of individuals. These factors, including social status, economic position, and resource access, impact various aspects of work life. Considerations such as income level, education, job security, and social support networks play a major role, significantly influencing the type of work individuals engage in and their occupational health outcomes (54).

These socioeconomic factors exert a profound impact on health determinants within the occupational context, influencing access to resources and opportunities. In the sphere of occupational health, these factors shape the nature of work, the quality of employment conditions, and overall well-being (55). Individuals of higher socioeconomic status often find themselves in less hazardous occupations with superior working conditions, while those with lower socioeconomic status may face precarious employment arrangements and increased exposure to occupational risks. This socioeconomic gradient extends to healthcare access, with higher-status individuals benefiting from better preventive care and potentially improved health outcomes (55).

Recognizing and addressing these socioeconomic factors is crucial for fostering health equity and implementing interventions to enhance the overall well-being of the workforce. By acknowledging disparities rooted in socioeconomic factors, initiatives can be tailored to bridge gaps and promote a more inclusive and health-conscious work environment, integral for cultivating a workplace prioritizing the health and prosperity of all its members.

Occupational health promotion and protection

Occupational health promotion involves taking proactive steps in the workplace to improve the overall well-

being of employees. This includes creating a positive work environment, promoting healthy behaviors, and preventing health issues before they occur (56). When addressing occupational hazards, health promotion activities may consist of implementing wellness programs, initiatives to manage stress, interventions to improve ergonomics, and educational campaigns to inform employees about potential workplace risks. The objective is to empower workers to make healthier choices and establish a work environment that fosters both their physical and mental health (56).

Occupational health protection on the other hand entails implementing preventive measures and safeguards to reduce or eliminate risks associated with workplace hazards (57). This involves following safety protocols, using personal protective equipment (PPE), adhering to occupational health and safety standards, and identifying and controlling potential hazards. The goal of occupational health protection is to guarantee the physical safety of workers, prevent accidents and injuries, and shield against the harmful effects of occupational exposures. It encompasses the establishment of a secure and hazard-free work environment through activities such as risk assessment, hazard control, and the enforcement of safety regulations (57).

Integrating occupational health determinants with standardized social determinants of health

The review extensively discusses the myriad occupational hazards – physical, biological, chemical, and organizational – and their profound impact on workers' health. These hazards, ranging from exposure to harmful substances to psychosocial stressors, significantly affect the health and well-being of individuals across various occupations.

Comparing these findings with the standard social determinants of health (SDOH), it's evident that occupational determinants of health are intricately intertwined with these broader social factors. For instance, socioeconomic status, a key element of SDOH, is directly influenced by one's occupation, which in turn affects access to resources, healthcare, and overall quality of life. Job security, workplace conditions, and exposure to occupational hazards contribute significantly to health disparities.

However, the CDC's SDOH framework, which includes economic stability, education access and quality, healthcare access and quality, neighborhood and built environment, and social and community context, notably omits specific mention of occupational factors. This exclusion is significant because the nature of one's occupation can profoundly impact overall health, both through direct exposure to hazards and indirectly through socio-economic pathways.

For example, individuals in lower socioeconomic positions often engage in more hazardous jobs due to limited options, leading to increased health risks. This demonstrates a clear intersection between occupational and social determinants of health. Moreover, workplace environments, job security, and conditions significantly influence mental health, stress levels, and overall well-being, further tying occupational factors to broader SDOH.

Conclusions

In conclusion, delving into the occupational determinants of health highlights the complex and multifaceted interconnection between work and well-being. This review's comprehensive exploration of various occupational hazards – from physical to psychosocial and environmental – unequivocally demonstrates their profound impact on individual health outcomes. These findings align with and extend the existing framework of social determinants of health.

The results of this study compellingly justify the inclusion of occupational factors in the standardized list of SDOH. They reveal that occupational determinants, often overlooked, are as influential as other recognized social determinants like economic stability and education access. In many instances, the nature of one's occupation directly influences socio-economic status, access to healthcare, and living conditions, thereby intersecting with, and exacerbating other SDOH.

As workers navigate a dynamic work environment marked by diverse occupations and evolving demands, it becomes increasingly evident that the well-being of the workforce is intrinsically linked to broader social

health determinants. This viewpoint contributes to the ongoing discourse on occupational health, urging a re-evaluation of traditional SDOH frameworks to encompass occupational factors. Ultimately, recognizing the role of occupational determinants in public health is not only an ethical imperative but also a strategic investment in enhancing the overall health and productivity of the population.

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