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## Women and occupational lung disease: sex differences and gender influences on research and disease outcomes

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The investigation of the modifying effects of sex and gender is a welcome advance in occupational lung disease research. Gender is a variable that commonly is controlled for in an analysis; however, it is rare to find a separate examination into the role that gender plays on disease outcome [1]. In studies of occupational environments that are dominated by men, often there is no distinction by gender or women are excluded from the analysis [2,3]. Greenberg and Dement [1] reported that as recently as 1992, 38% fewer occupational health articles were listed on MedLine that addressed the effects of occupational exposures on the lung health of women compared with men. Because of this tendency to control for gender rather than examine it, we have a limited understanding of how sex and gender interact with occupational exposures to produce lung disease.

This article examines the issues that surround gender and occupational lung disease and specifically

focuses on how the occupational environment affects women's respiratory health. The study of occupational lung disease in women involves much more than determining if women have an increased or decreased susceptibility to various toxins and particles compared with men. It involves applying a "gendered-based lens" to all aspects of the research process to ensure an accurate representation of the risks to respiratory health that are associated with occupation. Therefore, our discussion begins with an overview of how gender issues may impact the study of occupational lung disease. We examine how research methodology, including classification of occupation, measurement of exposure, and identification of disease cases, can be impacted by gender. We conclude by reviewing the literature on the current state of knowledge regarding women and several common occupational lung diseases: asbestosis, silicosis, lung cancer, and occupational asthma, as well as predisease respiratory signs and symptoms that relate to occupational exposure.

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P. Camp is supported by a Canadian Institute of Health Research Fellowship and a Canadian Physiotherapy Cardio-respiratory Society (Canadian Lung Association) Fellowship.

S.M. Kennedy is supported in part by the British Columbia Lung Association and the Michael Smith Foundation for Health Research.

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### Sex, gender, and research methodology in occupational lung disease

Understanding the differences between male and female workers requires an appreciation of the distinction between sex and gender. Generally, "sex" refers to the primary and secondary sex characteristics,

including anatomy and physiology, that distinguish male and female organisms from each other [4]. “Gender” is considered to be the result of the environmental, individual, societal, or cultural influences that allows an individual to identify themselves as either male or female. Therefore, gender is relational and its influences differ depending on the person, the place, or the time (eg, era)

There is evidence that there are sex differences in lung anatomy and physiology that may influence the development of lung disease. Over a lifetime, the female lung tends to be smaller than the male lung in individuals of the same height. On average, vital capacity and total lung capacity are greater in adult males, yet female lungs have higher forced expiratory flow rates and forced expiratory volume in 1 second:forced vital capacity (FEV<sub>1</sub>:FVC) ratios, even after standardizing for differences in body size [5]. Despite this evidence, we continue to have little understanding as to how physical and physiologic sex differences might impact overall susceptibility to occupational disease. In addition, any measurement of occupational disease susceptibility must include accurate exposure measurement, yet we have little understanding regarding the influence gender may have on the exposure to, and measurement of, various occupational toxins and agents. Research that investigates women’s health and occupational lung disease must consider possible sex differences in susceptibility to various exposures and development of occupational lung disease (ie, there may be differential rates of absorption of toxins in men or women). There also are likely to be gender influences on the occupational environment that will impact the investigation process.

*Gender differences in occupation: same title, different job*

Sex segregation in the workforce is commonplace but varies throughout the world. In Canada and the United States, men continue to hold most positions in the primary and secondary industries, such as logging, fishing, and manufacturing, whereas women hold most of the jobs in the service industries, including health care, retail, and clerical sectors [6,7]. Although it may be assumed that this segregation in the workplace clusters men in “high-risk” jobs such as mining and smelting, in actuality, women are exposed routinely to hazardous materials on the job, even in those industries that are considered to be “safe.” Stellman [8] reported that women commonly are exposed to a large number of carcinogenic substances in the workplace. She identified 46 different

carcinogens that were used commonly in industries that employed a minimum of 25,000 women in the United States in 1992, including the service and the health care industries. Many other hazardous chemicals and agents have been found in other occupational environments where a large proportion of women are employed (Table 1). The workplace environment

Table 1  
Common hazards in women-dominant occupations that result in lung disease or lung irritation

Type of work	Common hazards
Household	Cleaning substances — drain and oven cleaners, bleach, aerosol sprays, waxes Pesticides
Clerical	Poor air quality and ventilation Toxic substances in photocopy toner, correction fluids, printers
Hospital	Sterilizing chemicals (e.g. glutaraldehyde), anesthetic gases Antineoplastic drugs Infectious agents — tuberculosis, SARS
Retail sales education	Poor ventilation Viral infections
Art	Paints, solder Clays, glazes, pottery dusts Welding and firing fumes
Health care laboratory	Toxic chemicals
Textile, apparel, furnishings manufacturing (including sewing and stitching)	Fabric treatment, dyes, cleaning solvents Cotton dust Synthetic fibers
Electrical and electronic technicians	Solvents Solder fumes Poor ventilation
Meat wrapping	Plastic wrap burning fumes
Hair and beauty salons	Hair sprays and dyes, aerosol sprays, other cosmetic preparations
Laundry and dry cleaning	Fumes from soaps, bleaches, acids Dry cleaning solvents

*Abbreviation:* SARS, severe acute respiratory syndrome.  
*Adapted from* Logan P, Davis L, Marbury M, et al. Environmental and occupational health. In: The Boston Women’s Health Book Collective Staff, editors. The new our bodies, ourselves. New York: Simon & Schuster; 1992. p. 105–30; with permission.

continues to change for women, as there has been a shift toward more women being employed in traditionally “male” occupations and vice versa.

Although it is recognized that men and women are exposed to different occupational hazards because of their segregation in the workforce, less attention has been paid to differing exposures between men and women who have the same job title. Segregation of task by gender can occur in the workplace which results in differing exposures between men and women with the same job title [9]. For example, Messing and colleagues [10] reported that male cleaners who worked in the railway industry often were assigned different tasks than female cleaners. Female cleaners consistently were assigned to toilet-cleaning tasks, whereas male cleaners were responsible for floor mopping. The women worked in closer proximity to the cleaning fumes compared to men, resulting in different levels of exposure. In a different study, Messing et al [11] reported that male and female gardeners who were employed by city hall in a Quebec municipality were assigned different tasks, either because of personal choice or the lack of appropriate-sized equipment for women. In a recent study of university employees, women reported more physical and malaise symptoms than their male counterparts in the same job [12]. There were no gender differences after controlling for occupation grade,

perceived working conditions, and orientation to gender roles. The investigators concluded that differential exposure, rather than differential vulnerability, influenced the gender differences in health. These studies show that job classification alone often is a poor proxy for exposure. A woman may be assigned to different tasks with different exposures compared with men, or her work environment may differ from other workers in different industries that have the same job title. For example, a woman whose job is classified as “secretary” may be employed in a sawmill and be exposed to levels of wood dust or wood antigens that are sufficiently high to elicit a lung response.

*Gender differences in exposure, exposure measurement, and resulting pathology*

Exposure assessment is an important component of occupational lung disease research. The measurement of occupational exposures is integral to the understanding of how exposures impact health and the development of appropriate preventative guidelines [13]. The goal of exposure measurement is to “define and quantify an individual’s dose of a specific agent” [13]; specifically, the biologically effective dose that is capable of causing disease. One rarely can measure the actual biologically effective dose; instead, an estimate of the effective dose is

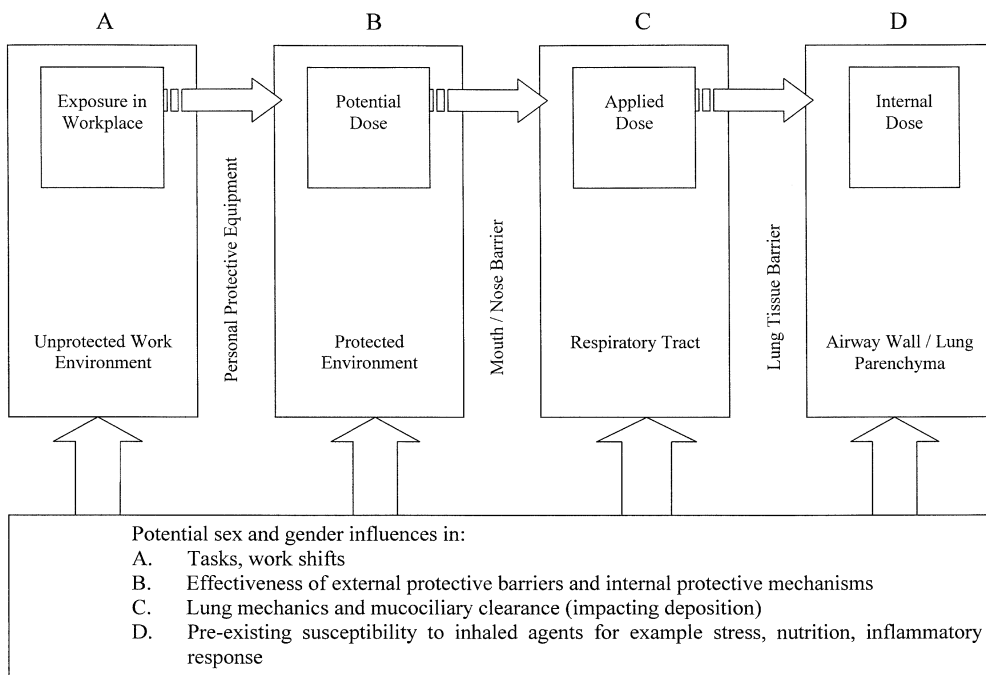


Fig. 1. Potential sex and gender influences.

calculated based on the amount of agent that is present in the work environment and the amount of time that a worker is exposed.

Although men and women may have the same job title and perform identical tasks, they may have different occupational exposures and differing resultant body burdens of environmental toxins. The model presented in Fig. 1 illustrates the pathway that a toxin can take from the environment to the lung and how sex and gender may impact the process at several steps.

Toxins that are implicated in lung disease are present in the unprotected work environment. The dose of toxin from the work environment is variable and dependent on many factors, several of which are impacted by gender differences in the workplace. There may be gender differences in the actual tasks assigned. This may result in different exposures to toxic substances despite similar job descriptions. Finally, differences in the size, surface area, and design of equipment and machinery may have an impact on exposure levels, particularly if the breathing zone is in close proximity to the sources of exposure. The impact of sex differences in ergonomics was demonstrated in musculoskeletal injury research [14–16] but its importance in the development of occupational lung disease is not known.

To prevent toxins and other occupational hazards from being inhaled by the worker, personal protective equipment or other barriers often are required for use in the workplace. Nevertheless, gender can impact how much of the toxin passes the protective equipment barrier and enters the protected environment. Personal protective equipment, such as gloves or respirators, may not be designed to fit a woman's body; this may result in an increased exposure. Greenberg and Dement [1] identified this problem as a potential confounder in occupational health research and noted that although it was recognized as a problem as early

as 1942 [17], little research has been done to determine the impact of improperly-fitting protective equipment on women's occupational health. A Korean study of three commonly-used respirators found decreased fit factors (indicating less protection) among women compared with men, even after taking differences in facial dimensions into account [18]. In addition, the education on, and use of, protective equipment or other safety training may be impacted by gender. Women are more likely to be employed on a part-time or temporary basis [19,20], which may result in fewer opportunities for adequate training in personal protective practices. It also may be more physically demanding for women to wear protective equipment compared with men. Murphy et al [21] reported that compared with men, women experienced a greater increase in percent of  $VO_{2max}$  and rating of perceived exertion while wearing chemical protective clothing (compared with wearing regular clothing) and engaging in continuous activity. This greater increase in energy cost while wearing protective clothing may provide a disincentive to women, especially if it affects a woman's capacity to perform in a male-dominated work environment.

After a toxic substance passes through the protective equipment into the protected environment, it has access to the upper airway by way of the nose and mouth. The crude mass of a toxin in this applied dose may be lower on average in women as a result of the lesser volume of air exchanged (2900 L versus 3600 L over an 8-hour period for a reference woman and man, respectively) [22]. Aerosol deposition, however, may be enhanced on average in women because of higher airway flow rates [23]. It also is possible that sex differences in clearance mechanisms may exist and result in differing levels of applied dose; however, these do not seem to have been well explored. Table 2 identifies sex differences in the pulmonary

Table 2  
Structural differences in adult male and female lungs

Respiratory outcome	Sex differences	Implication in occupational lung disease
Overall lung size	Male greater than female	Volume of agent inhaled per breath
Vital capacity		
Total lung capacity		
Airways in relation to lung size	Female greater than male	Deposition of agent in the lung
Expiratory flow rates		
FEV <sub>1</sub> /FVC ratio		

Data from Becklake MR, Kauffmann F. Gender differences in airway behaviour over the human life span. Thorax 1999;54: 1119–38.

system that could impact how much of the applied dose is absorbed into the body.

After the toxin passes into the lungs and becomes the internal dose, numerous gender and sex-related factors can impact how much is absorbed into the body, how the dose is metabolized, or how the toxin activates the various inflammatory and other physiologic responses. Differences in pre-existing lung conditions, current or past smoking behavior, nutritional status, stress level, sex hormone actions, and various metabolic processes can be affected by sex and gender differences and ultimately can determine if the toxin is a biologically effective dose and will result in lung disease.

#### *Gender differences in case identification*

The determination of a causal relationship between exposure and disease requires the accurate classification of individuals who have the disease in question. Again, gender differences in diagnostic patterns can introduce bias into a study if not accounted for. This was demonstrated in nonoccupational lung disease by Dodge and colleagues [24]. They found that although the reporting of symptoms was similar between older male and female subjects, the diagnosis of asthma and chronic bronchitis was more frequent in women, whereas emphysema was diagnosed more often for the men. If men and women who have occupational lung disease are identified based on compensation claims, gender differences in claim success could bias the results. This was shown by Lippel [25] for chronic stress claims; in a sample of 185 compensation applications, women who applied for chronic stress claims were significantly less likely to have their claim accepted by a review board than men. In contrast, a Canadian study showed that the relative proportion of men and women was consistent across the three claim categories of “confirmed occupational asthma,” “nonoccupational asthma,” or “no asthma” [26]; this suggested no gender difference in claim success.

Identification of cases also can be hampered by incomplete record-keeping. Davies et al [27] reported that in the mining industry of South Africa, labor registries of female workers are rarely kept. Worldwide in the agriculture industry, men tend to be farmers of cash crops and are considered “employed,” whereas in many countries women are the farmers of subsistence crops [28] but are not considered in employment registries. The extent of women’s participation in agricultural activities often is underestimated. For instance, McCoy and colleagues [29] found that approximately one half of more than 1600

rural women from farm households who were surveyed in Kentucky or Texas described themselves as homemakers, yet they were involved regularly in work with farm animals (40%) and driving farm tractors (30%).

In summary, the study of occupational lung disease in women has been hampered by incomplete surveillance, inadequate measures of exposure dose, and poor understanding of the risks that are associated with the tasks that are assigned to women workers. The evidence that exists must be evaluated with these weaknesses in mind. We now turn to the review of the scientific literature on the impact of occupational lung disease on women workers, with a specific emphasis on the diseases that have caused considerable mortality and morbidity among women workers worldwide. In the next section we outline the current knowledge of the impact of silicosis, asbestosis, occupational lung cancer, occupational asthma, and other respiratory signs and symptoms in women workers in North America and abroad. Excluded from this section is a discussion of byssinosis, a disease that has affected a large number of women workers in cotton production worldwide because this was reviewed recently elsewhere [30].

### **The burden of work on women: occupational lung diseases and the female worker**

#### *Silicosis*

Silicosis is caused by the inhalation of crystalline silica particles, usually in the form of alpha quartz dust. Crystalline silica is abundant in many types of stone, such as sandstone, granite, or shale [31] or can be converted from noncrystalline silica in several manufacturing processes. Exposure to heavy amounts of dust over a long time period is necessary to develop chronic silicosis. The clinical symptoms of dyspnea, cough, and sputum production often are not present until the disease is advanced. In the absence of regular screening, it is likely that silicosis is underdiagnosed. Historically, excessive silica exposure was considered to be confined to certain industries, namely metal and coal mining and foundries [32] that traditionally hired a high proportion of male employees. United States’ regulations regarding the permissible levels of silica exposures were based upon research done in the 1920s and 1930s on male workers in the Vermont granite industry. Silica also is present in high levels in the ceramic industry, which employs large numbers of female workers.

Forastiere et al [33] measured the incidence of silicosis and changes in lung function in a cohort of 642 female ceramic workers in Italy. There was a significant risk of silicosis in this occupational group, with an odds ratio (OR) of 17.8 in women who had more than 20 years of exposure and 57.9 in women who had been employed before 1970, when more stringent exposure criteria were introduced. They concluded that an association between duration of exposure and silicosis was similar between the women in their study and a similar population of men in another study; however, the men demonstrated more severe disease with fewer years of exposure. This was attributed to the greater proportion of men who worked in the sanitary crockery industry (manufacturing sinks and toilets), which generates higher levels of dusts.

The findings of this study were in contrast to those reported in a Swedish study by Gerhardsson and Ahlmark [34] in 1985, which compared men and women in the pottery industry. Women had a shorter prediagnosis exposure period and were more likely to advance to the more severe forms of the disease. They also compared female workers from the pottery industry with male workers in the quartz processing industry, who were considered to have a high risk for silica exposure. Female workers had a higher rate of progression of disease, despite working in an environment that had supposed lower rates of exposure. This study generated data from an occupational disease registry without individual contact with the workers. It is not clear how the tasks that the men and women performed differed, and whether this resulted in different levels of dust exposure. It is possible that women may have been more involved with the finishing aspect of the pottery work, which generates large amounts of dry dust, whereas men may have been more likely to work with the damp product.

Recent research has identified inorganic agricultural dust as a potential source of silica exposure. Studies that have shown silicosis in agricultural populations often do not include [35] or report [36] data that describe the effects on women.

Other studies have examined silicosis risk, stratified by gender, and found conflicting results. Zitting et al [37] reported an increased risk of pneumoconiosis in women compared with men (relative risk 3.8 versus 2.2, respectively) in a population-based sample in Finland. Rastogi et al [38] and Gielec et al [39] found no significant gender differences in the prevalence of pneumoconiosis in cross-sectional studies of agate workers and ceramic plate manufacturers, respectively. Because of these conflicting reports, it is

not possible to theorize that either men or women are more susceptible to the effects of silica dust; however, it is apparent that the risk is present for both sexes, with a strong dose-response relationship.

### *Asbestosis*

Asbestos refers to a group of fibrous minerals; the most common ones that are involved in occupational exposures are chrysotile, a white asbestos that is mined heavily in Canada, and amosite. Exposure to asbestos tends to result in two main outcomes: asbestosis and lung cancer. Asbestosis is an interstitial fibrotic disease that results directly from the inhalation of asbestos fibers [40]. Asbestosis usually occurs after exposures over many years to high levels of dust, with a latency period of 20 years or more. Workers who have asbestosis also are at higher risk for developing lung cancer, especially if they smoke [41]. In addition, asbestos is associated with a rare form of pleural cancer, malignant mesothelioma.

Women in Canada and the United States have not been exposed to asbestos as heavily as men, primarily because women traditionally have not been employed in asbestos mining in North America, although they are employed frequently as miners in other parts of the world [27]. Women still are at risk, by being exposed to fibers in the work clothes of their spouses who are employed in the asbestos industry [42,43] and by their employment in asbestos-related non-mining occupations. In Canada and the United States, women are employed in other aspects of the asbestos industry, such as in asbestos textile plants and asbestos cement manufacturing factories. Their employment in these jobs may be of shorter duration, which could affect the ability to accurately measure their disease risk.

Wignall and Fox [44] provided an example of how employment of short duration in the asbestos industry could lead to increased mortality for women. They studied 500 women who were employed in the manufacturing of gas masks during World War II. There was a significantly higher risk of death due to lung cancer and mesothelioma in women who had been exposed to asbestos for as little as 1 to 5 years and an increased risk in women who had been exposed for less than 1 year.

In countries that have few regulations regarding asbestos exposure limits, the burden of disease can be high. Davies et al [27] measured the prevalence of asbestos-related disease in 770 black women in the northern province of South Africa; 99% had worked in the amosite asbestos mine industry. The mines had closed 20 years earlier but the women had never been

investigated for asbestos-related disease, such as asbestosis. Seventy-four percent of the women had begun working in the mines before they were 24 years old; the majority (60%) had worked in the mines for 10 years or less. Mining companies did not keep labor records on women and vital statistics are poorly kept; it was not possible to confirm the completeness of their sample or to measure the survivor effect. Nevertheless, 97% of the women had a clinical diagnosis of asbestosis that was based on history of occupational exposure, clinical findings, and radiographic evidence. Women and young children were employed in the high-exposure work of manually removing rock from “cobs” of asbestos fiber with hammers, a practice that was only outlawed in 1973.

Wang et al [45] examined pulmonary function and radiographic asbestosis in 142 men (smokers and nonsmokers) and 127 women (all nonsmokers) who were employed in an asbestos textile and shingles manufacturing plant in China. They compared these individuals with 176 male and 98 female controls. Radiographic asbestosis was seen in 35.2% of the men and 16.5% of the women and reduced lung volumes were associated with asbestos exposure in both sexes. Exposure duration (mean 22 years in men; 18 years in women) was associated with decreased lung function in male workers but not in female workers. Their data suggested that radiographic parenchymal abnormalities were more closely associated with reduced lung function in women compared with men and pleural abnormalities were more strongly associated with reduced lung function in men. Because few women had pleural abnormalities, this finding could not be explored in sufficient detail. Because the only method of estimating exposure in this study was to use duration of employment, it is possible that the gender differences could be attributed to differences in exposure intensity.

#### *Occupational lung cancer*

Although the literature on occupational lung cancer in women is growing, a clear pattern of the risk of this disease in female workers remains elusive. In many countries, more men die from lung cancer due to all causes each year; more recently, there has been an increase in the incidence and mortality of lung cancer in women who live in developed countries [46,47]. Examining the incidence of lung cancer that is due to occupational risk factors often is hampered by the confounding, and often, synergistic, impact of concurrent cigarette smoking in workers.

Jahn et al [48] conducted a case-control study in Germany that examined occupational risk factors for

lung cancer in women. Women showed an increased risk of lung cancer in occupations that traditionally are associated with men (eg, chemical and oil industries) but also showed an increased risk of lung cancer for female-dominated industries (eg, cleaning services, hairdressing, and food and beverage service). Lung cancer due to exposure to dry cleaning fluids were investigated by Brownson et al [49] who found a significant risk for lung cancer (OR 2.9; confidence interval 1.5–5.4) although an earlier study by Katz and Jowett [50] did not demonstrate this risk. Workers who are exposed to environmental tobacco smoke also have elevated risks for respiratory cancers. For instance, Dimich-Ward et al [51] found elevated proportionate mortality ratios for lung cancer among bartenders, waiters, and waitresses. A California study of occupational mortality in women found that waitresses have high risks for lung cancer (standardized mortality ratio: 368) [52]. A standardized incidence ratio of 2.3 for lung cancer was observed in study of a large cohort of waitresses in Norway [53]. Smoking is an important confounder; however, a review by Siegel [54] found that when personal smoking habits and other confounders were controlled for, there was a 50% excess of lung cancer on average (range 10%–90%) among restaurant workers.

Brown et al [55] investigated mortality patterns among male and female chrysotile asbestos textile workers. Their study involved 1247 white men, 1229 white women, and 546 black men who were employed in various sectors of a South Carolina textile factory. They found higher standardized-mortality ratios (SMRs) for white men compared with white women or black men for every disease analyzed, including all cancers and respiratory disease. Gender differences in follow-up explained much of the apparent difference in mortality. Although only 1.5% of the white men had an unknown vital status at the end of the study period, 22.8% of the white women were in this category. When the analysis corrected for the missing data, the SMRs for all causes of death and for lung cancer in white women increased from a statistically significant deficit to a statistically significant increased risk associated with asbestos exposure. The investigators reported that women had work histories of short duration and the lack of accurate follow-up likely underestimated the SMRs compared with men.

Whether women have an increased susceptibility to lung cancer is unknown. Susceptibility to cancer varies depending on the carcinogen involved. With hundreds of probable or possible carcinogens linked to lung cancer, identifying unique susceptibilities by gender is problematic. Nevertheless, researchers have



identified that differences may exist between men and women in the type of lung cancer that is diagnosed. A European study reported that among women who have lung cancer, adenocarcinoma has the highest incidence, whereas among men who have lung cancer, squamous cell and adenocarcinoma are distributed equally [56]. A United States study concluded that in most histologic subgroups of lung cancer, the risk ratios for both sexes are converging [57]. It is unknown whether these diagnostic differences are related to different exposures or to different physiologic responses to the same exposure.

### *Occupational asthma*

Occupational asthma (OA) is defined as “a disease characterized by variable airflow limitation or airway hyperresponsiveness due to causes and conditions attributable to a particular occupational environment and not to stimuli encountered outside the workplace” [58]. The American Thoracic Society distinguishes two types of OA; immunologic, which has a latency period and is caused by agents that may have a demonstrated immunologic mechanism, and nonimmunologic (also known as irritant-induced asthma or reactive airways dysfunction syndrome) which may occur after only a single exposure to irritants at high concentrations [59].

The prevalence of OA varies by country—ranging from as low as 3 cases/million in some areas of the United States [60] to 187 cases/million in Finland [61]. This wide range is likely due to differences in reporting practices. Nevertheless, it was suggested that OA is the most prevalent occupational respiratory disease in most developed countries [62]. Gender differences in OA were reported but it is difficult to identify a clear pattern of susceptibility to disease and expression of disease by gender. Gender differences in nonoccupational asthma [63] and bronchial hyperresponsiveness [64–66] were reported; it may not be possible to sort out those aspects of asthma that are related uniquely to occupational exposures and moderated by gender. In some countries, the prevalence of OA is higher in men [67,68], but in others, the rates seem to be similar [69,70]. In the United Kingdom, surveillance data suggested higher rates in men than women; however, when the occupation was taken into consideration the rates were similar in both sexes [71]. Higher rates in men may be attributed to a larger proportion of men being employed in high-risk occupations; nevertheless, women are exposed to many OA-inducing agents and may show different manifestations of disease.

Mendonca et al [72] evaluated occupational history, agents, exposure and symptom duration, and spirometry in 394 patients who had OA and presented to five public occupational respiratory disease clinics. Although most patients were men, women reported significantly shorter mean exposure duration (5.6 years versus 8.9 years for men,  $P = 0.0005$ ) and were more likely to report a positive atopy history (27% of women, 18.4% of men,  $P = 0.0485$ ). Men and women had similar spirometry readings. The differences in duration of exposure for men and women may be related to differences in occupations and subsequent exposure materials. Men reported significantly more exposures than women to isocyanates, metal dusts/fumes, wood dusts, and oil mists ( $P < 0.05$ ), whereas women reported significantly more exposures to cleaning products, biologic agents, and textile fibers ( $P < 0.05$ ).

Two Swedish population-based case-control studies examined occupational risk factors for asthma in men and women [73,74]. For study participants who reported exposures to flour dust, paper dust, textile dust, and engine exhaust, women consistently had greater odds of having an asthma diagnosis, although no such gender difference was seen for solvent exposure. The reason for these differences is not evident; however, gender differences in reporting exposures cannot be ruled out. In contrast, in a community-based random sample of more than 3600 adults in China, Xu and Christiani [75] reported no gender difference in the risk of asthma that was associated with dust or gas/fumes exposure.

Gender differences have been reported in studies that investigated the impact of occupational asthma on daily activities. In a survey study of 69 workers who were diagnosed with occupational asthma, women were more likely to report limitation of everyday activities as a consequence of occupational asthma and were more likely to be unemployed [76].

Assessing OA in men and women highlights the difficulties that are associated with failing to apply a gendered-based perspective to the data analysis. In many industrialized countries, OA is significantly associated with exposure to cleaning products; one report showed that 11 of 12 studies of cleaners found an excess risk of asthma [70]. Women are disproportionately employed as cleaners in many industries and are responsible for a disproportionate share of cleaning tasks in the household. Kogevinas estimated that 5% of the asthma risk in women could be attributed definitively to household exposure. This “double-shift” phenomenon, where women are exposed to cleaning products at work and at home, may not be captured adequately in the data. In addition,

asthma due to exposure at work and home may not be classified as OA; this could lead to an underdiagnosis in women.

### *Respiratory signs and symptoms*

In many cases, respiratory signs and symptoms that are due to occupational exposures likely precede a diagnosis of asthma, chronic obstructive pulmonary disease, or other lung diseases. It is suggested that more attention should be given to these “predisease” indicators. Messing [77] stated that “a requirement for diagnosed pathology may be premature when studying women’s occupational health” because we do not have a comprehensive understanding of how occupational lung disease in women manifests compared with men. Focusing purely on a specific diagnosis may ignore novel diseases or manifestations of common lung diseases that are unique to women.

Gender differences have been identified in studies of respiratory signs and symptoms in various occupational settings, including agriculture, manufacturing, and health care. Not unexpectedly, there is little evidence of a clear pattern of susceptibility. Although gender differences have been identified, they are not consistent from study to study [78–82]. In population-based studies (of lung disease in general), more consistent gender differences in symptom reporting have been seen. The analysis of 18,277 participants in a European Community Respiratory Health Survey showed that women were more likely to report nocturnal and nonproductive cough [83]. Possible explanations given include physiologic differences (females have more sensitive cough receptors), hormonal differences (female sex hormones can affect airway smooth muscle and bronchial hyperresponsiveness), and possible gender bias that are due to differences in reporting. According to the review by Becklake and Kauffmann [5] shortness of breath is reported more frequently and consistently by women in population-based studies. This may be attributed to differences in the perception of shortness of breath that are related to the interaction of environmental, sociocultural, and biologic factors.

Whether occupational exposures exacerbate these differences in symptomology requires further investigation. These studies highlight the continued need for separate analyses of the data by gender.

### **Summary**

We have attempted to describe the current state of knowledge regarding occupational lung disease in

women. A large section of this article was devoted to describing the methodologic challenges that face researchers when evaluating gender differences in occupational lung disease. The findings of the presented studies are likely limited by many of the methodologic problems that were identified earlier. To accurately identify the true risk of occupational lung disease in women workers, these findings must be replicated in future studies with special attention paid to the various aspects of occupational lung disease research that are susceptible to gender-related bias.

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