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BUILDING-RELATED RISK FACTORS AND WORK-RELATED LOWER RESPIRATORY SYMPTOMS IN 80 OFFICE BUILDINGS

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ABSTRACT

We assessed building-related risk factors for lower respiratory symptoms in office workers. The National Institute for Occupational Safety and Health in 1993 collected data during indoor environmental health investigations of workplaces. We used multivariate logistic regression analyses to assess relationships between lower respiratory symptoms in office workers and risk factors plausibly related to microbiologic contamination. Among 2,435 occupants in 80 office buildings, frequent, work-related multiple lower respiratory symptoms were strongly associated, in multivariate models, with two risk factors for microbiologic contamination: poor pan drainage under cooling coils and debris in outside air intake. Associations tended to be stronger among those with a history of physician-diagnosed asthma. These findings suggest that adverse lower respiratory health effects from indoor work environments, although unusual, may occur in relation to poorly designed or maintained ventilation systems, particularly among previously diagnosed asthmatics. These findings require confirmation in more representative buildings.

INDEX TERMS

Indoor air quality, ventilation systems, symptoms, respiratory health, asthma

INTRODUCTION

Documented building-related respiratory disease such as hypersensitivity pneumonitis or humidifier fever associated with microbiologic contamination of the indoor environment has been reported occasionally in indoor, nonindustrial workplaces such as office buildings (e.g., Kreiss, 1989; Hodgson *et al.*, 1987; Seuri *et al.*, 2000). In contrast, episodes of nonspecific health complaints in indoor workplaces (sometimes called sick building syndrome or nonspecific building-related symptoms), not attributable to specific recognized disease or exposures, have been commonly reported in recent decades (Mendell, 1993). Although specific causal exposures for nonspecific building-related symptoms have not yet been established, research has identified a number of person-, job-, workplace-, and building-related risk factors for these symptoms (e.g., air-conditioning systems, low ventilation rate, high temperature, dust, endotoxin) (Mendell, 1993; Gyntelberg *et al.*, 1994; Teeuw *et al.*, 1994; Bornehag *et al.*, 2001). Few of these reports have considered lower respiratory symptoms, the least common symptoms reported in indoor work environments (Mendell, 1993; Mendell *et al.*, 1996; Malkin *et al.*, 1996). Some recent studies have associated risk factors in non-industrial indoor work environments with increased work-related lower respiratory symptoms (Mendell *et al.*, 1996a; Sieber *et al.*, 1996; Ruotsalainen *et al.*, 1995).

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We explored relationships within existing data on risk factors and symptoms in office buildings. For this analysis, we hypothesized that microbiologic contamination of indoor spaces or ventilation systems in office buildings may cause or exacerbate *unrecognized building-related respiratory disease* that presents as *work-related lower respiratory symptoms*. We also hypothesized that associations between these symptom outcomes and risk factors would be stronger among doctor-diagnosed asthmatics, due to increased sensitivity among prior asthmatics and among any with new-onset asthma caused by exposures at work.

METHODS

Data Collection

Methods used in conducting the surveys (Crandall and Sieber, 1996) are briefly discussed below. Between April and July 1993, NIOSH investigators collected standardized health, building, and environmental data from a randomly chosen evaluation area within each of 105 U.S. office buildings. Buildings were selected from over 800 buildings that requested health hazard investigations from NIOSH. A self-administered questionnaire was used to assess health histories and symptoms in workers. Industrial hygienists assessed characteristics of the study buildings, including their ventilation systems and their indoor environments, using a standardized inspection form and simple measurements. Complete data collected according to the study protocol were available from 80 office buildings and 2345 workers.

Outcome and risk variables in analyses

The full analysis included twenty outcome definitions constructed from four lower respiratory symptoms – wheeze, shortness of breath, chest tightness, and cough. Definitions required symptom occurrence at least once per week in the previous four weeks and improvement away from the workplace, as in Sieber *et al.* (1996). We report here only results for the outcome definition used in previous analyses by Sieber *et al.* (1996), there called “frequent multiple lower respiratory symptoms,” but here called “at least three of four frequent, work-related (FWR) lower respiratory symptoms.”

Twenty dichotomous building-related risk factors were selected for these analyses (Table 1): those previously associated with work-related lower respiratory symptoms in partially adjusted regression models (Sieber *et al.*, 1996), hypothetically related to risk of microbiologic contamination, and having adequate data for analysis. Regression models also included dichotomous personal risk factor variables for gender, age, smoking, and asthma. A set of similar models with interaction terms assessed whether history of asthma influenced the relationships of risk factors to outcomes.

Preliminary models

We used multivariate logistic regression models to estimate adjusted odds ratios (ORs), a measure of strength of association for which ORs >1.0 imply increased risk. To decrease the large number of inter-correlated independent risk variables, we first screened each in a regression model with only personal covariates for gender, age, smoking, and asthma status. We included in further analyses only the risk variables with p-values <0.20 in screening models. We then created preliminary models for four subgroups of risk variables: potential sources of microbiological contaminants less than 25 feet from the outside air intake; problems with particle filtration in the heating, ventilation, and air-conditioning (HVAC) system; dirt in the HVAC system; and moisture in the HVAC system (see Table 1). Three variables - no scheduled HVAC inspection, water damage in the workspace, and indoor

surface dusting daily -- were considered by themselves without inclusion in a subgroup. Each subgroup model also included personal covariates for gender, age, smoking, and asthma status. From each subgroup, variables for which $p > 0.20$ were eliminated sequentially. A final model was created containing the selected risk factor variables from the reduced subgroup models, the ungrouped risk factor variables, and gender, age, smoking, and asthma variables. This full model was reduced by elimination of terms for which $p > 0.10$.

We added interaction variables for (building risk factor * asthma history) to selected partially adjusted models and to final reduced models.

RESULTS

Among models constructed with terms for interaction between asthma history and building risk factors, only the partially adjusted models containing single risk factors converged. Most ORs among asthmatics were higher than among non-asthmatics (Figure 1), although p-values exceeded 0.05 for all the interaction terms.

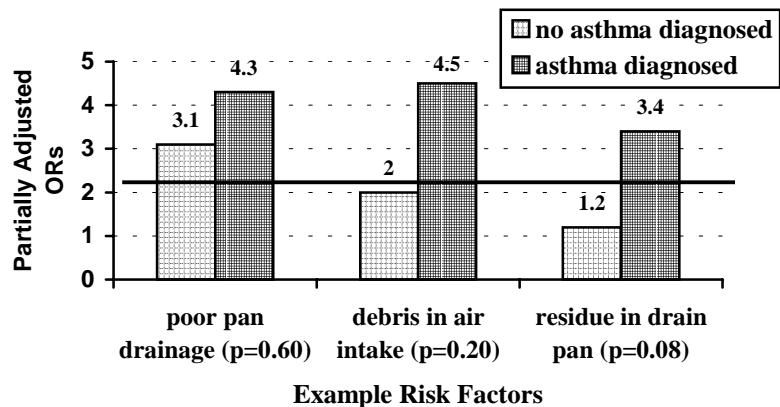
For single environmental risk factors included in partially adjusted models, lower confidence limits for 10 of the 20 factors exceeded 1.0, and for the two potentially protective factors upper confidence limits equaled 1.0. Table 2 shows estimates for variables in the final

Table 1. Building-related risk factors assessed in initial multivariate models

Outdoor Air Intake Near Contaminant Sources:	Air Filter Problem
Standing water ^a	Filter not secure in place ^a
Exhaust vents ^a	Dirty filters ^a
Sanitary vents ^a	Limited or no access for changing or inspection ^a
Trash dumpster	Poor filter fit in frames
Dirt in HVAC	Moisture in HVAC
Dusty air handling housing	Moist sound liner
Dirty sound liner	Poor or no drainage from pans ^a
Debris inside air intake ^a	No scheduled HVAC inspection ^a
Coils dirty	Workspace Moisture Incursion
Residue/dirt in drain pans	Water damage in workspace ^a
Dirty duct work	Workspace Maintenance
Dirty duct liner	Surface dusting daily ^a

^a p-value < 0.20 for association with both outcomes – at least 3 of 4 FWR respiratory symptoms; FWR wheeze, shortness of breath, and cough – in partially adjusted models containing this subgroup of risk factors

Figure 1. History of asthma as effect modifier for risk of at least 3 of 4 FWR lower respiratory symptoms in office buildings studied by NIOSH



model, including two building-related risk factors: debris in air intake and poor pan drainage.

DISCUSSION

The multivariate-adjusted analysis found strong associations between frequent, work-related multiple lower respiratory symptoms in office workers and two building-related risk factors: poorly draining drain pans under cooling coils and debris inside outdoor air intake (Table 2). This finding extends previously reported findings by Sieber *et al.* (1996) from these same data. Sieber *et al.* reported relative risks for associations between

three kinds of respiratory health outcomes, including the one assessed here, and a number of risk factors in office buildings. Sieber *et al.* adjusted the estimates for each risk factor, however, only for age and gender, not for other personal factors or for any building-related risk factors. Analyses here adjusted simultaneously for personal factors (Table 2) and other building-related risk factors.

The two building-related factors included in the final models – “poor pan drainage” and “debris inside air intake” – indicate conditions that would allow growth of microbiological organisms and dissemination of their products – allergens, irritants, or toxins -- through the ventilation system. Because of correlations between the 20 risk factors (discussed in Sieber *et al.* (1996)), replication of these analyses in larger data sets is necessary to better characterize the environmental risks.

The tendency towards increased susceptibility to microbiologic risk factors (of which subjects were not aware) among previously diagnosed asthmatics (Figure 1) is noteworthy. For instance, for “residue in drain pan,” the ORs of 3.4 among asthmatics vs. 1.2 among non-asthmatics for the outcome “at least three or four FWR lower respiratory symptoms” represents a much greater increase in risk among asthmatics ($p=0.08$ for this difference). Although differences were less dramatic (Figure 1) for the two risk factors included in the final multivariate models, reassessment of this finding in larger populations is essential.

Limitations of study

The office buildings included in this analysis, all buildings for which health hazard investigations had been requested from NIOSH, may differ from other buildings. Findings

Table 2. Odds ratios (OR) and 95% confidence intervals (CI) for building risk factors from final multivariate models

Independent Variable	At least 3 of 4 FWR symptoms		FWR wheeze, shortness of breath, and cough	
	OR	(95% CI)	OR	(95% CI)
<i>Dirt in HVAC variables:</i>				
Debris inside air intake	2.0	(1.0-3.9)	3.6	(1.4-9.4)
<i>Moisture in HVAC variables:</i>				
Poor pan drainage	2.6	(1.3-5.2)	2.8	(1.1-7.4)
<i>Personal variables:</i>				
female gender	3.0	(1.4-6.6)	3.2	(1.0-9.8)
age over 40 years	2.3	(1.2-4.5)	2.2	(0.8-5.9)
ever smoked	1.2	(0.6-2.1)	1.8	(0.7-4.2)
dr.-diagnosed asthma	8.0	(4.4-14)	6.9	(3.0-16)

thus should not be extrapolated to the general population of office buildings unless replicated in more general studies. These “complaint” buildings nevertheless represent an important set of buildings requiring resolution of environmentally related health complaints. Occupants’ concerns about effects of their indoor environments may have exaggerated estimates of symptom prevalence in these buildings. However, these concerns could not create apparent associations of symptoms with risk factors of which respondents were unaware, such as conditions within the ventilation systems.

CONCLUSIONS AND IMPLICATIONS

Although work-related lower respiratory symptoms reported in industrial or agricultural settings are considered potential indicators of work-related disease, such symptoms in non-industrial indoor environments are generally accorded little clinical significance because of the presumed lack of causal exposures. Yet multiple reports have described serious respiratory disease, caused by building or HVAC-related moisture and mold in workplaces (Kreiss, 1989; Woodard *et al.*, 1988; Seuri *et al.*, 2000; Hoffman *et al.*, 1993; Thörn, 1996; Jarvis and Morey, 2001).

The findings here, although requiring replication, suggest that building-related respiratory health effects may occur without recognition among a subset of indoor workers with moisture- or contaminant-related exposures. A history of asthma may confer heightened susceptibility to these exposures, or asthma *caused* by exposures in the building may be chronically exacerbated by continuing exposure. Even if the proportions of buildings and of workers with such exposures were small, the absolute numbers, among the almost 70 million US workers in indoor environments, would be of public health significance.

Replication of the findings reported here would provide an initial method for identifying indoor workers at increased risk for work-related respiratory health effects. Investigators of health complaints in buildings often assess and describe only the most commonly reported symptoms such as headache, fatigue, or eye irritation, excluding the rarer lower respiratory symptoms. Yet this exclusion, as suggested in the findings here, may hide an important biologic response in a key susceptible subpopulation. The symptoms studied here may represent unrecognized sub-clinical manifestations of known building-related disease such as asthma or hypersensitivity pneumonitis (Kreiss, 1989).

Our findings show that moisture- and contaminant-related risks in indoor work environments are associated with work-related respiratory health effects among the workers. History of asthma may confer increased susceptibility to, or indicate initial sensitization by, microbiologic exposures associated with risk factors such as poor pan drainage and debris in air intake. Future research, possibly focused within susceptible subgroups, on occupants with multiple lower respiratory symptoms exacerbated within buildings may help identify more specific risks for building-related respiratory disease.

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