

Respiratory Morbidity and Medical Visits Associated with Dampness and Air-conditioning in Offices and Homes

Abstract We used data from 4345 adult US residents who were part of a 2004 national random mail survey to investigate associations between dampness and air-conditioning (AC) in homes and offices, and health outcomes, sick leave due to respiratory symptoms and medical visits during the past 12 months. We identified from this group 1396 office workers employed in professional, executive, administrative, managerial or administrative support occupations. Office workers reporting home dampness had an elevated prevalence of nasal symptoms [prevalence ratio (PR) = 1.4, $P = 0.01$] and constitutional symptoms (PR = 1.3, $P = 0.01$) in the previous year. Office workers reporting workplace dampness had an elevated prevalence of sick leave attributed to respiratory symptoms (PR = 1.3, $P = 0.04$) in the previous year. Office workers with home AC were more likely to have visited a medical specialist in the previous year (PR = 1.3, $P = 0.02$). We did not find any statistically significant associations between workplace AC and any of the health outcomes. We estimated an annual cost of US\$1.4 billion for excess respiratory-related sick leave among office workers with workplace dampness. Our study strengthens the evidence of a relationship between dampness and health effects, and highlights the resulting economic impact.

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Practical Implications

This study adds to the literature on respiratory morbidity associated with home and office exposures to mold and dampness. Public health response to lessen these exposures will improve the health and well-being of residents and workers as well as diminish the economic burden of lost work time and medical costs.

Introduction

In the US there has been a shift of workers from industrial occupations to office-, service-, and sales-related occupations. In addition, there has been a growing concern over the health effects associated with indoor air quality. During 2005, 56% (217/386) of the requests received by the US National Institute for Occupational Safety and Health for workplace health hazard investigations pertained to indoor air quality concerns (internal analysis). The Institute of Medicine of the US National Academies has found sufficient evidence to conclude that there is an association between mold or dampness in indoor environments and upper respiratory tract symptoms, wheeze, cough, and asthma symptoms in sensitized asthmatic persons, and

hypersensitivity pneumonitis in susceptible persons – and limited or suggestive evidence for an association between dampness in indoor environments and lower respiratory illness in otherwise healthy children and the development of asthma (Institute of Medicine (IOM), 2004). Air-conditioning (AC) is thought to improve air quality by lowering ambient outdoor allergens, but reports of adverse health associations of AC are long-standing (Graudenz et al., 2005; Lee et al., 2006; Mendell and Smith, 1990; Seppänen and Fisk, 2002; Solomon et al., 1980; Teculescu et al., 1998). Additionally, Preziosi et al. (2004) found otolaryngologist visits and sick leave to be significantly positively associated with the presence of workplace AC.

The major aims of the study were to determine whether Previosi's findings in France could be

corroborated by a research study in the US and to estimate the prevalence of dampness and AC problems in workplaces in the US. In our study we used data from a nationally representative mail panel survey to determine whether respiratory morbidity, healthcare utilization, and sick leave attributed to respiratory symptoms among office workers were associated with visible mold, moldy/musty odor, or water damage (dampness) or AC in homes and offices.

Methods

Participants

Porter Novelli, a public relations firm, administers an annual HealthStyles mail panel survey which generated the 2004 data described below. Individuals willing to participate were identified by mail solicitation. From a pool of 600,000 individuals who completed a four-page recruitment survey, stratified random sampling based on region, household income, population density, age, and household size was used to select 10,000 adult (aged ≥ 18 years) potential respondents for a consumer survey and subsequent HealthStyles survey. HealthStyles data were additionally post-stratified and weighted so that the sample distribution of age, race, sex, household size, and household income matched that of the general population according to the US census. Weighting for the entire HealthStyles dataset adjusted for over- or under-representation of the above demographic variables. The consumer survey was mailed out in May to June 2004, with a 62% (6207/10,000) participation rate. The 2004 HealthStyles survey, which was mailed out during July to August 2004 to respondents of the first survey, had a 70% (4345/6175) participation rate. Nominal gift rewards were provided to participants. A full description of the HealthStyles survey is published elsewhere (Maibach et al., 1996).

Measures

The recruitment survey included questions on age, gender, race/ethnicity, education, household income, geographic location, occupation, and occupational status. The HealthStyles survey included numerous questions pertaining to attitudes on health issues, personal health (including obesity), health behavior (including flu vaccination and the number of medical visits to primary care doctors and specialists during the previous year), and sources of health information. We added to the HealthStyles survey questions on lifetime smoking status; four specific environmental conditions present during the previous year (any visible mold, moldy/musty odor, or water damage in the home; any visible mold, moldy/musty odor, or water damage in the workplace; AC in the home; AC in the workplace);

number of episodes of colds or flu, bronchitis, and sinus infections during the previous year; symptoms (presence of weekly upper respiratory symptoms and presence of monthly lower respiratory symptoms and whether these symptoms worsened, remained the same, or improved away from work; and two or more of episodes of muscle aches, fever, chills, or disabling fatigue) in the previous year; medical conditions (seasonal allergies and asthma) during the previous year; sick leave attributed to upper (nasal) or lower respiratory symptoms during the previous year; and number of medical visits to otolaryngologists, pulmonologists, and allergists during the previous year.

Statistical and economic analysis

We studied two subgroups: all participants, to examine the effects of home exposures; and office workers, to study the effects of home and office exposures. We defined office workers as participants currently employed in professional, executive, administrative, managerial, or administrative support occupations. Prevalence ratio modeling was carried out using Cox proportional hazards models with robust variance estimates. We tested associations between environmental variables (home dampness, workplace dampness, home AC, and workplace AC) and nine health outcome variables, controlling for up to 10 covariates, specifically, age, gender, smoking status, race, education, household income, geographic region, seasonal allergies, whether a flu shot had been received in the previous year, and the presence of obesity. We converted health outcomes with numerical responses to dichotomous categorical variables as follows: for colds or flu we used < 2 versus ≥ 2 episodes, for sinus infections we used < 4 versus ≥ 4 episodes, for bronchitis we used < 2 versus ≥ 2 episodes, for work days lost attributed to respiratory symptoms we used one or more days versus none, and for medical visits we used one or more visits versus none. We used a two-step process in our models: covariates were selected using backward elimination regression with the significance level for a covariate to stay in the model set at $P \leq 0.10$; then environmental variables were added to the model. Models included single environmental variables or all relevant environmental variables (multiple environmental variable models). For office workers, we present results for both models in the tables, and describe the results for multiple environmental variable models in the text. For all participants, we only present results for multiple environmental variable models. Models investigating work-related symptoms and sick leave among all participants excluded participants who were not working. Phi coefficients were used to investigate the correlation among all four categorical environmental variables (Conover, 1999).

We used weights to estimate the percentage of the US population with home dampness and AC. These weighted prevalences were used for economic calculations for the US population. Because weights were not available for the subset of participants who were office workers, we used unweighted prevalences of environmental conditions in economic calculations pertaining to office workers. None of our statistical analyses required the use of the weight function. A *P*-value of 0.05 was used to establish statistical significance and $0.05 < P \leq 0.10$ to establish marginal statistical significance. All analyses were done using SAS software version 9.1 (SAS Institute Inc., Cary, NC, USA).

Population attributable risk (PAR) is an estimate of the fraction of the population with the health outcome that can be attributed to a particular risk factor or exposure. We calculated PAR for a given exposure according to the following formula: $PAR = PF(RR - 1) / [PF(RR - 1) + 1]$, where PF is the fraction of the population with the health outcome and RR is the relative risk (Kahn and Sempos, 1989). We used prevalence ratios to estimate RR. This approach has been used by other researchers (Soriano et al., 1999). The excess number of specific health outcomes due to a given exposure (EO) was estimated by multiplying PAR by the fraction of the US population exposed. Annual yearly economic burdens for a specific health outcome due to a specific exposure were calculated by multiplying EO by the individual cost of the health outcome incident. As prevalence ratios used were for one or more work days lost attributed to respiratory symptoms, one or more visits to a primary care doctor, and one or more visits to a pulmonologist, annual yearly economic burdens are an underestimation of true economic burdens. Adult US population numbers were obtained from estimates published by the US Census Bureau (2005). We estimated the cost of a medical visit with a pulmonologist as \$150 and the cost of a medical visit with a primary care physician as \$80. Estimated numbers of US office workers and US adult workers and the estimated cost of one work day of productivity lost were derived from US Bureau of Labor Statistics (US BLS) (2006a,b,c).

Results

Prevalence

Of the 4094 survey participants who indicated their employment status, 2565 (63%) were currently employed. Among employed participants, 54% worked in professional, executive, administrative, managerial, or administrative support occupations, 24% in industry, 12% in services, 8% in sales, and 2% in agriculture. Participants were mostly female, white, and had never smoked (Table 1). More than one-third of office workers reported having two or more colds or flu, or

Table 1 Demographics, health conditions, and health practices of all subjects and office workers

Covariates	All subjects (<i>n</i> = 4345)	Office workers (<i>n</i> = 1396)
Age (%)		
18–24 years	3.1	2.5
25–34 years	14.8	15.8
35–44 years	26.1	30.8
45–54 years	25.0	32.7
55–64 years	14.1	13.3
≥65 years	16.9	5.0
Female (%)	56.7	62.8
Smoking status (%)		
Current smokers	22.9	13.5
Former smokers	22.1	19.5
Never smokers	55.0	67.1
Race or ethnic group (%)		
White	69.8	71.6
Black	12.2	10.8
Hispanic	11.6	9.4
Asian, native American	6.5	8.2
Educational level (%)		
3 years of college or less	69.7	46.8
College degree	18.1	28.6
Post-graduate degree	12.1	24.7
Household income (%)		
<\$60 000 per year	63.1	41.8
≥\$60 000 per year	36.9	58.2
Geographic region (%)		
New England	4.9	4.8
Middle Atlantic	14.7	14.3
East North Central	16.4	16.6
West North Central	6.5	6.4
South Atlantic	18.7	18.8
East South Central	6.6	7.4
West South Central	11.6	11.7
Mountain	7.3	7.1
Pacific	13.7	12.9
Seasonal allergies during the previous year (%)	35.9	38.0
Flu shot received during the previous 12 months (%)	43.0	42.5
Obesity (BMI greater than 30) during the previous year (%)	16.8	16.4

constitutional symptoms (two or more episodes of muscle aches, fever, chills, or disabling fatigue) in the previous year (Table 2). Work-related nasal symptoms were present in 7% of office workers, and work-related lower respiratory symptoms were present in 3%. More than 25% of office workers reported having taken one or more days of sick leave in the previous year because of respiratory symptoms; and approximately 12% had seen an otolaryngologist, 10% had seen an allergist, and 5% had seen a pulmonologist in the previous year (Table 3).

Among all participants, weighted frequencies were 26% for home dampness and 79% for home AC. (These values were similar to the unweighted frequencies of 27% and 78%, respectively.) Among office workers, unweighted frequencies were 29% for home dampness, 23% for workplace dampness, 80% for home AC, and 89% for workplace AC. Phi coefficients

Table 2 Prevalences (%) of health outcomes in the last 12 months

Health outcome	All subjects ^a (n = 4345)	Office workers (n = 1396)
Colds or flu: two or more episodes of colds or flu	40.4	37.8
Sinus infections: four or more episodes	9.4	7.0
Bronchitis: two or more episodes	8.1	6.3
Nasal symptoms: stuffy, itchy, or runny nose most weeks	34.8	31.0
Work-related nasal symptoms: stuffy, itchy, or runny nose most weeks that is worse at work	6.6	7.1
Lower respiratory symptoms: coughing, wheezing, chest tightness, or shortness of breath most months	21.3	13.8
Work-related lower respiratory symptoms: coughing, wheezing, chest tightness, or shortness of breath most months that is worse at work	3.4	3.1
Constitutional symptoms: two or more episodes of muscle aches (excluding muscle soreness due to physical activities), fever, chills, or disabling fatigue	44.6	37.4
Asthma	10.5	8.2

^aFor work-related symptoms only subjects who worked were included.

Table 3 Sick leave and healthcare visits in the previous year

Health outcome	All subjects ^a (n = 4345)	Office workers (n = 1396)
Number of workdays lost due to upper or lower respiratory symptoms		
One or more days (%)	27.5	28.7
Mean number of days	1.92	1.93
Number of visits to a primary care physician (family practitioner, internist, OB/GYN)		
One or more visits (%)	88.5	89.7
Mean number of visits	3.30	2.74
Number of visits to an otolaryngologist		
One or more visits (%)	13.8	11.6
Mean number of visits	0.53	0.52
Number of visits to an allergist		
One or more visits (%)	11.2	10.4
Mean number of visits	0.54	0.44
Number of visits to a pulmonologist		
One or more visits (%)	7.7	4.8
Mean number of visits	0.29	0.14
Number of visits to any specialist physician		
One or more visits (%)	43.6	41.9
Mean number of visits	1.45	1.37

^aFor workdays lost because of upper or lower respiratory symptoms, only subjects who worked were included.

Table 4 Prevalence ratios and 95% confidence intervals for multiple environmental variable models for respiratory infections in the previous year among all participants

Respiratory infection	Environmental variable	PR	95% CI	Selected covariates ^a
Colds	Home dampness	1.10**	1.01–1.20	Age, income, seasonal allergies, flu shot, obesity
	Home AC	1.00	0.90–1.10	
Sinus infections	Home dampness	1.27*	0.98–1.65	Smoking, education, income, geographic region, seasonal allergies
	Home AC	0.93	0.67–1.29	
Bronchitis	Home dampness	1.11	0.84–1.46	Gender, smoking, income, seasonal allergies, flu shot, obesity
	Home AC	0.71**	0.53–0.95	

Models include health outcome, selected covariates, and home dampness and home AC variables.

PR, prevalence ratio; CI, confidence interval; AC, air-conditioning.

^aIncluded in model if $P \leq 0.10$.

* $P \leq 0.10$, ** $P \leq 0.05$.

See Table 1 for description of covariates.

ranged in absolute value from 0.003 to 0.23, demonstrating low or no correlations among the four environmental variables.

Dampness

For all participants, statistically significant positive associations were found between home dampness and the prevalence of two or more episodes of colds or flu, nasal symptoms, work-related nasal symptoms, lower respiratory symptoms, work-related lower respiratory symptoms, two or more episodes of constitutional symptoms, and one or more days sick leave attributed to respiratory symptoms during the previous 12 months (Tables 4–6). Among office workers, statistically significant positive associations were found between home dampness and nasal symptoms and two or more episodes of constitutional symptoms; and between work dampness and one or more days sick leave attributed to respiratory symptoms in the previous year (Tables 7–9).

Air-conditioning

For all participants, the presence of home AC was associated with an increased prevalence of having visited a primary care doctor and pulmonologist in the previous year; and a decreased prevalence of two or more episodes of bronchitis in the previous year (Tables 4–6). Home AC was also significantly associated with an increased prevalence of having visited a medical specialist in the previous year among office workers (Table 9). We did not find any statistically significant associations between workplace AC and any of the tested health outcomes, including sick leave and medical visits.

Economic burden

Estimated annual additional US economic costs for four health outcomes associated with indoor environmental conditions were as follows: respiratory-related

Table 5 Prevalence ratios and 95% confidence intervals for multiple environmental variable models for respiratory symptoms in the previous year among all participants

Health outcome	Environmental variable	PR	95% CI	Selected covariates ^a
Nasal symptoms	Home dampness	1.31*	1.20–1.43	Smoking, race, education, income, seasonal allergies, obesity
	Home AC	1.01	0.91–1.13	
Work-related nasal symptoms	Home dampness	1.79*	1.29–2.47	Gender, education, geographic region, seasonal allergies
	Home AC	1.05	0.69–1.58	
Lower respiratory symptoms	Home dampness	1.38*	1.20–1.58	Gender, smoking, race, education, income, seasonal allergies, flu shot, obesity
	Home AC	1.06	0.90–1.24	
Work-related lower respiratory symptoms	Home dampness	2.13*	1.36–3.35	Smoking, income, seasonal allergies, flu shot
	Home AC	1.04	0.62–1.74	
Constitutional symptoms	Home dampness	1.30*	1.20–1.40	Smoking, education, income, seasonal allergies, obesity
	Home AC	1.05	0.96–1.16	
Asthma	Home mold	1.14	0.94–1.39	Gender, race, income, geographic region, seasonal allergies, flu shot, obesity
	Home AC	0.98	0.77–1.24	

Models include health outcome, selected covariates, and home dampness and home AC variables.

PR, prevalence ratio; CI, confidence interval; AC, air-conditioning.

^aIncluded in model if $P \leq 0.10$.

* $P \leq 0.05$, other values are > 0.10 .

See Table 1 for description of covariates.

Table 6 Prevalence ratios and 95% confidence intervals for multiple environmental variable models for sick leave and medical visits in the previous year among all participants

Health outcome	Environmental variable	PR	95% CI	Selected covariates ^a
Any workdays lost because of respiratory symptoms	Home dampness	1.34**	1.09–1.64	Age, gender, smoking, education, seasonal allergies, flu shot, obesity
	Home AC	0.94	0.75–1.18	
Visited a primary care physician	Home dampness	1.02	0.99–1.04	Gender, flu shot
	Home AC	1.06**	1.03–1.10	
Visited an otolaryngologist	Home dampness	1.06	0.87–1.28	Age, race, flu shot, obesity
	Home AC	1.00	0.81–1.23	
Visited an allergist	Home dampness	0.92	0.69–1.22	Smoking, race, seasonal allergies
	Home AC	1.27	0.91–1.77	
Visited a pulmonologist	Home dampness	1.06	0.80–1.40	Age, smoking, race, income, seasonal allergies, flu shot
	Home AC	1.58**	1.12–2.24	
Visited any specialty physician	Home dampness	1.07	0.98–1.17	Age, smoking, education, income, geographic region, flu shot, obesity
	Home AC	1.10*	0.98–1.23	

Models include health outcome, selected covariates, and home dampness and home AC variables.

PR, prevalence ratio; CI, confidence interval; AC, air-conditioning.

^aIncluded in model if $P \leq 0.10$.

* $P \leq 0.10$, ** $P \leq 0.05$.

See Table 1 for description of covariates.

sick leave among US workers associated with home dampness, \$3.2 billion; respiratory-related sick leave among US office workers associated with office dampness, \$1.4 billion; primary care visits among US adults associated with home AC, \$2.6 billion; and pulmonology visits among US adults associated with home AC, \$3.1 billion.

Discussion

Dampness

Home mold or water damage in the previous year was commonly reported by our study participants. An international study also found a large percentage of homes with water damage (12%), water on the basement floor (2%), and mold (22%) during the previous year (Zock et al., 2002). When asked about

current conditions in the 2003 US Census survey, 11% of the US population reported having homes with external water leaks, and 8% reported having homes with internal water leaks (US Census Bureau, 2004). We identified statistically significant positive associations between self-reported environmental dampness (both in the home and office) and a wide variety of health effects (infections, symptoms, and sick leave).

Our finding of associations between home dampness and colds or flu should be interpreted with caution, because misclassification of respiratory symptoms as respiratory infections by both participants and physicians is possible. Other studies have found associations between mold in the home and colds in the previous year (Kilpenläinen et al., 2001; Pirhonen et al., 1996). Mucosal inflammation and immunosuppression are biologically feasible explanations for an increased risk

Table 7 Prevalence ratios and 95% confidence intervals for respiratory infections in the previous year among office workers

Respiratory infection	Environmental variable	Single environmental variable model ^a		Multiple environmental variable model ^b		Selected covariates ^c
		PR	95% CI	PR	95% CI	
Colds or flu	Home dampness	1.21*	1.04–1.40	1.13	0.91–1.41	Age, seasonal allergies, obesity
	Work dampness	1.13	0.95–1.35	1.13	0.92–1.38	
	Home AC	1.03	0.86–1.23	1.05	0.82–1.34	
	Work AC	1.04	0.77–1.42	1.02	0.69–1.50	
Sinus infections	Home dampness	1.17	0.70–1.96	0.92	0.37–2.31	Education, geographic region, seasonal allergies
	Work dampness	0.94	0.49–1.81	0.91	0.42–1.99	
	Home AC	1.36	0.57–3.24	1.69	0.23–12.30	
	Work AC	0.79	0.20–3.13	0.77	0.14–4.34	
Bronchitis	Home dampness	1.00	0.58–1.74	0.95	0.36–2.46	Smoking, flu shot
	Work dampness	0.53	0.22–1.28	0.53	0.18–1.55	
	Home AC	0.72	0.41–1.25	0.74	0.32–1.69	
	Work AC	0.50	0.21–1.21	0.61	0.19–1.90	

PR, prevalence ratio; CI, confidence interval; AC, air-conditioning.

^aModel includes health outcome, selected covariates, and one environmental variable.

^bModel includes health outcome, selected covariates, and all four environmental variables.

^cIncluded in model if $P \leq 0.10$.

* $P \leq 0.05$, other values are > 0.10 .

See Table 1 for descriptions of covariates.

Table 8 Prevalence ratios and 95% confidence intervals for respiratory symptoms and disease in the previous year among office workers

Health outcome	Environmental variable	Single environmental variable model ^a		Multiple environmental variable model ^b		Selected covariates ^c
		PR	95% CI	PR	95% CI	
Nasal symptoms	Home dampness	1.38**	1.18–1.62	1.39**	1.09–1.77	Race, education, seasonal allergies, obesity
	Work dampness	1.00	0.81–1.24	0.91	0.71–1.17	
	Home AC	0.97	0.80–1.18	1.05	0.79–1.38	
	Work AC	0.90	0.65–1.24	0.88	0.59–1.32	
Work-related nasal symptoms	Home dampness	1.50*	0.97–2.32	1.35	0.73–2.52	Education, geographic region, seasonal allergies, flu shot
	Work dampness	1.84**	1.17–2.89	1.66*	0.94–2.92	
	Home AC	1.17	0.65–2.11	1.12	0.53–2.37	
	Work AC	2.00	0.47–8.56	1.65	0.36–7.50	
Lower respiratory symptoms	Home dampness	1.51**	1.13–2.02	1.10	0.66–1.84	Race, education, smoking, seasonal allergies, obesity
	Work dampness	1.48**	1.04–2.11	1.52*	0.98–2.36	
	Home AC	1.21	0.83–1.77	1.40	0.76–2.56	
	Work AC	0.84	0.45–1.59	0.68	0.32–1.48	
Work-related lower respiratory symptoms	Home dampness	1.44	0.70–2.96	1.20	0.37–3.85	Race, smoking, flu shot, obesity
	Work dampness	1.84	0.86–3.95	1.62	0.58–4.51	
	Home AC	1.88	0.72–4.88	1.59	0.39–6.53	
	Work AC	2.05	0.28–14.72	1.26	0.15–10.54	
Constitutional symptoms	Home dampness	1.36**	1.18–1.57	1.34**	1.09–1.65	Income, smoking, seasonal allergies, obesity
	Work dampness	1.16*	0.97–1.39	1.13	0.92–1.37	
	Home AC	1.01	0.84–1.21	1.13	0.88–1.45	
	Work AC	0.84	0.65–1.09	0.78	0.56–1.06	
Asthma	Home dampness	1.45**	1.01–2.08	1.12	0.68–1.86	Income, seasonal allergies, flu shot, obesity
	Work dampness	1.19	0.78–1.81	1.18	0.71–1.97	
	Home AC	0.75	0.50–1.14	0.82	0.46–1.44	
	Work AC	0.88	0.43–1.78	0.78	0.36–1.69	

PR, prevalence ratio; CI, confidence interval; AC, air-conditioning.

^aModel includes health outcome, selected covariates, and one environmental variable.

^bModel includes health outcome, selected covariates, and all four environmental variables.

^cIncluded in model if $P \leq 0.10$.

* $P \leq 0.10$, ** $P \leq 0.05$.

See Table 1 for descriptions of covariates.

of respiratory infections (Corrier, 1991; Jakab et al., 1994; Pier and McLoughlin, 1985; Smedbold et al., 2002). Associations between environmental dampness

and upper and lower respiratory symptoms have been identified in other epidemiological studies [Koskinen et al., 1999; Nörback et al., 1999; Bornehag et al.,

Table 9 Prevalence ratios and 95% confidence intervals for sick leave and medical visits in the previous year among office workers

Health outcome	Environmental variable	Single environmental variable model ^a		Multiple environmental variable model ^b		Selected covariates ^c
		PR	95% CI	PR	95% CI	
Any workdays lost due to respiratory symptoms	Home dampness	1.22**	1.00–1.48	1.11	0.85–1.45	Age, gender, smoking status, education, seasonal allergies, flu shot, obesity
	Work dampness	1.30**	1.05–1.61	1.30**	1.02–1.65	
	Home AC	0.98	0.78–1.24	0.97	0.73–1.28	
	Work AC	1.23	0.83–1.82	1.14	0.73–1.78	
Visited a primary care physician	Home dampness	1.00	0.96–1.04	1.02	0.96–1.08	Gender
	Work dampness	0.99	0.95–1.04	0.98	0.93–1.04	
	Home AC	1.05*	1.00–1.10	1.05	0.99–1.12	
	Work AC	1.06	0.98–1.15	1.05	0.95–1.15	
Visited an otolaryngo-logist	Home dampness	1.33*	0.97–1.84	1.45	0.92–2.28	None
	Work dampness	1.05	0.71–1.57	1.01	0.64–1.57	
	Home AC	1.14	0.76–1.70	1.36	0.80–2.32	
	Work AC	0.92	0.48–1.75	0.93	0.41–2.13	
Visited an allergist	Home dampness	1.05	0.74–1.49	1.20	0.75–1.94	Race, seasonal allergies
	Work dampness	0.65*	0.41–1.04	0.62*	0.35–1.09	
	Home AC	1.24	0.79–1.95	1.37	0.76–2.49	
	Work AC	1.17	0.50–2.73	1.28	0.43–3.78	
Visited a pulmonologist	Home dampness	1.08	0.60–1.93	1.13	0.50–2.57	Flu shot
	Work dampness	0.75	0.34–1.63	0.69	0.29–1.66	
	Home AC	1.64	0.79–3.41	2.08	0.74–5.83	
	Work AC	0.75	0.26–2.12	0.60	0.20–1.82	
Visited any specialist physician	Home dampness	1.08	0.93–1.25	1.11	0.90–1.36	Education, flu shot
	Work dampness	1.11	0.95–1.30	1.08	0.90–1.30	
	Home AC	1.19*	0.99–1.42	1.33**	1.05–1.69	
	Work AC	1.04	0.78–1.38	1.02	0.72–1.46	

PR, prevalence ratio; CI, confidence interval; AC, air-conditioning.

^aModel includes health outcome, selected covariates, and one environmental variable.

^bModel includes health outcome, selected covariates, and all four environmental variables.

^cIncluded in model if $P \leq 0.10$.

* $P \leq 0.10$, ** $P \leq 0.05$.

See Table 1 for descriptions of covariates.

2001; Engvall et al., 2001; Kilpenläinen et al., 2001; Engvall et al., 2002; Zock et al., 2002; Gunnbjörnsdottir et al., 2003; Institute of Medicine (IOM), 2004]. Other epidemiological studies have identified significant associations between fungal concentrations in workplace chair or floor dust and work-related upper respiratory symptoms (Chao et al., 2003; Park et al., 2006).

Hypersensitivity pneumonitis is an immunologically mediated inflammatory disease of the lung that occurs as a result of inhalational exposures to organic dusts containing bacteria, fungi, animal proteins, or several specific chemicals. Symptoms of chills, fever, malaise, muscle aches, cough, headache, and dyspnea are classically present. Case reports and a literature review of hypersensitivity pneumonitis due to home and building fungal exposure have been reported in the scientific literature (Apostolakos et al., 2001; Kreiss and Hodgson, 1984; Lee et al., 2000; Thörn et al., 1996). We identified an association between home dampness and constitutional symptoms which served to raise our level of suspicion that some of the participants may have had hypersensitivity pneumonitis.

Air-conditioning

In our study, 79% of homes were air-conditioned whereas 87% were reported to be air-conditioned in the 2003 US Census survey (US Census Bureau, 2004). We identified previously unreported associations between home AC and having visited a primary care doctor, pulmonologist, or medical specialist in the previous year. Extensive epidemiologic research into the health effects of AC has identified relationships between home and workplace AC and upper respiratory symptoms, lower respiratory symptoms, eye symptoms, skin symptoms, and headache (Graudenz et al., 2005; Kodama and McGee, 1986; Mendell and Smith, 1990; Mendell et al., 1996; Teculescu et al., 1998). Possible mechanisms of action include the collection of moisture within AC systems which allows microbial organisms to proliferate (Mendell, 2004); and lower outdoor air exchange rates in buildings with AC which allow volatile or infectious contaminants to accumulate. The resulting biological agents and by-products may cause respiratory symptoms requiring visits to primary care physicians and pulmonologists. In a cross-sectional study, we could

not rule out that primary care physicians and pulmonologists may have instructed patients under their medical care to use AC in order to reduce indoor levels of aeroallergens (pollens) (Lee et al., 2006; Solomon et al., 1980) or to reduce cardiac demands caused by hot and humid environmental conditions. However, the lack of a relationship between home AC and allergist visits argues against this being the underlying cause for the association. We cannot explain the protective effect of home AC for bronchitis that was found in our study among all participants.

It is interesting that we did not find statistically significant associations between workplace AC and medical visits, whereas significant associations were found for home AC. It is possible that the different types of AC systems and a lack of maintenance of home AC compared with workplace AC systems resulted in increased microbial contamination of home systems (Mendell, 2004). Additionally, the small number of workers without workplace AC ($n = 148$) in our US study of office workers may have prevented us from identifying statistically significant associations. However, Previosi's study of French office workers, which also had small cell numbers (139 participants had workplace AC and 873 had no workplace AC), demonstrated statistically significant associations between number of visits to an otolaryngologist and sick leave despite a lower prevalence of otolaryngologist visits during the previous year (8.7% compared with our 11.6%). Differences in medical specialist usage patterns by French and US populations may have contributed to different study results.

Economic burden

We found a substantial economic burden associated with indoor air exposures. In comparison, Fisk (2002) calculated the annual cost due to allergies and asthma among US residents as a result of home dampness to be \$1–4 billion. Mendell et al. (2002) estimated a US annual cost of \$200 to 600 million because of asthma, hypersensitivity pneumonitis, and allergies associated with indoor exposures among nonindustrial indoor workers. These estimates included both direct costs (medical care) and indirect costs (lost productivity). Others have demonstrated that of the US cost of asthma and allergic rhinitis, the direct costs are about threefold greater than indirect costs (McMenamin, 1994; Smith et al., 1997). Our finding of an average of 1.9 sick days attributed to respiratory symptoms per adult worker per year compares well with an average of 2.5 restricted activity days attributed to respiratory conditions per adult (aged 18–64 years) per year based on National Health Interview Survey data (Adams et al., 1996).

Study strengths and limitations

A major strength of our study was the random mail-survey design, which has previously been shown to generate similar results to random digit dialing and other probability sampling methods (Market Facts, undated; Pollard, 2002). For example, when the HealthStyles survey was compared with the US Behavioral Risk Factor Surveillance System telephone interview survey (a national probability sample survey with a sample size of 150,000) the correlation between these two surveys for nine questions pertaining to medical conditions, health, vaccination, and smoking status was 0.99. The large number of questions included in the health survey permitted our questions to be interspersed with other questions, minimizing the risk of self-reporting bias. In addition, we were able to investigate relationships between home and workplace environmental factors and a wide range of health outcomes, while controlling for many potential confounders. This study has several limitations. There may have been nonresponse bias, because of the fairly low overall participation rate of approximately 44%. The survey weighting variable was for the entire HealthStyles dataset. However, this would not have affected multivariate analysis of the data; and because weighted and unweighted prevalences of environmental conditions among all participants were very comparable, the same may be true for office workers. The small number of participants without home and workplace AC may have made it more difficult for us to identify statistically significant relationships between home and workplace AC and health outcomes. Uncontrolled occupational exposures (e.g. dust, fumes, and chemicals) may have resulted in the unexplainable associations found between home dampness and work-related nasal symptoms and work-related lower respiratory symptoms in models involving all participants.

Conclusion

Our work demonstrates positive associations between indoor dampness and the frequency of colds and flu, upper and lower respiratory symptoms, constitutional symptoms, and sick leave because of respiratory symptoms; and between home AC and medical visits to primary care doctors, pulmonologists, and medical specialists. These findings add to the evidence of a relationship between both dampness and AC and health outcomes and should motivate a greater public health response. Given that exposure to dampness is preventable, there should be an increased effort to minimize these exposures in homes and offices. Although eliminating AC is not a practical solution, proper AC maintenance and other interventions such as the use of ultraviolet irradiation of cooling coils in offices (Menzies et al., 2003) may help prevent causative exposures.

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