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BIG AIR QUALITY COMPLAINERS - ARE THEIR OFFICE ENVIRONMENTS DIFFERENT FROM WORKERS WITH NO COMPLAINTS?

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INTRODUCTION

Numerous complaints about air quality among workers in mechanically ventilated office buildings has created an interest in identifying the possible causes of these complaints, and interventions to remedy the problem [1-3]. There is systematic evidence that complaints about the office environment are associated with work-related illness and sickness absence [4-6]. What is surprising is that no association has been demonstrated between the worker's perception of the air quality in their work environment and actual measurements of these environmental conditions [7]. It was our hypothesis that the absence of association may be due to a number of methodological problems: inadequate sampling of the prevailing conditions in the workplace, and statistical methods used to summarize these conditions. The purpose of this study was to evaluate this possibility.

Study Questions

1. Is there a difference in the indoor air quality of workers with major air quality complaints[a] and in comparison to those with no air quality complaints?
2. Are workers' ratings of the usual office temperature, humidity, air circulation associated with objective ratings of the same phenomenon?
3. Do workers with major air quality complaints experience more frequent and numerous work-related symptoms?
4. What are the worker and office environment characteristics that are significantly associated with the odds of a worker being a major air quality complainer?

METHODS

A cross-sectional observational study design was used to answer the four research questions. A convenience sample of 10 mechanically ventilated buildings were selected for study. The 4 buildings studied in 1990 were privately owned office buildings, and the 6 buildings studied in 1991 were publicly owned, university buildings. The study population consisted of all workers with a fixed office location who worked in the building at least 2 days a week. Those on maternity leave were excluded. A census of all eligible workers in the building (when total occupancy was ≤ 500), or on a random selection of floors (when total occupancy ≥ 500) was used to construct the study sample.

A self-administered, standardized questionnaire was used to collect data on the worker's perceptions of the usual air quality in their office environment. Workers rated three aspects of indoor air quality: temperature, humidity and air circulation. Each aspect was rated on an ordinal scale with a central anchor point of 0 used to depict ideal and 4 ordinal scale points on either side of zero to depict deviations from ideal (e.g.. too hot, too cold). Workers with major air quality complaints were defined as those who rated all three aspects (temperature, humidity, and air circulation) on the extreme categories of the scale (a rating of 3 or 4 for every air quality item). The comparison group; workers with no air quality complaints, were defined as workers who rated all three aspects

[a] Complaints are used in this paper to refer to the poor ratings of usual office air

as being ideal or close to ideal (a rating of 0 or 1). The questionnaire was administered the week prior to 6 consecutive weeks of repeated environmental measurements in 1990, and in the month prior to 8 months of environmental measurements in 1991.

The same questionnaire was also used to collect information on socio-demographic characteristics (age, gender), health status (atopic history, smoking status, medication use, contact lens use), work characteristics (job type, computer use, tobacco smoke exposure, job control, job stress), and experience with cardinal symptoms of sick building syndrome at work (headache, nasal irritation/stuffiness, dry/sore throat, cough, fatigue, poor concentration, eye irritation). Atopic history was defined as reporting any one of the following health problems (asthma, eczema, hay fever, allergies, sinus problems). Job control and job stress were measured using the 7 point ordinal scale developed by Burge et.al. [8]. Occupation was coded using the Statistics Canada classification system, and collapsed into four main categories: management, professional, clerical, and other. Frequent, numerous work-related symptoms was defined as having at least four of the seven symptoms probed, with each occurring only at work, and at least once a week. Asymptomatic was defined as having none of the seven symptoms probed on the questionnaire.

Four environmental conditions were measured: temperature, relative humidity, C02, and air velocity. Measurements were taken twice a day, in the morning and afternoon, at 8-10 worksites per study floor. Environmental measurement sites were defined by ventilation system, perimeter/interior location, and direction of exterior walls. Each location, contingent on worker density contained 1-6 worksites/offices. Workers were assigned the values measured for their work location in the analysis. In each work location, repeated measurements were taken of the environmental conditions. In the 4 buildings studied in 1990, measurements were carried out each Wednesday or Thursday over 6 consecutive weeks. In the 6 buildings studied in 1991, measurements were taken 6 times over an 8 month period, providing estimates of the environmental conditions prevailing in the office space for three seasons of the year (winter, spring and fall). Repeated measurements of the environment were summarized to provide an estimate of the usual conditions in the worker's office environment. We used five statistical indices to summarize environmental conditions; temperature, relative humidity, ppm of C02, and air velocity. They included: 1) the mean value observed in repeated measurements of the same worksite, 2) the average deviation of the measured value from the optimal value (or range) for that season according to ASHRAE guidelines [9], 3) the average range observed between the morning and afternoon values in the same worksite, 4) the average value when above the optimal value (or range), and 5) the average value when below the optimal value (or range).

To test the hypothesis that temperature, humidity, air velocity, and/or C02 were different in the office environments of major air quality complainers and non-complainers, we used independent t-tests, adjusting the type 1 error for multiple comparisons. Logistic regression was then used to identify the subset of environmental parameters which were most strongly and significantly associated with the odds of being a major air quality complainer. To evaluate the relationship between rating of indoor air quality and objective measurement of the same parameters in the workers' office areas, we used multiple regression analysis, and adjusted the type 1 error for multiple comparisons. Spearman and Pearson product moment correlations were used to explore the association between the three environmental ratings and the four objective measurements of indoor air quality. Chi-square analysis was used to test the hypothesis that there would be a greater proportion of workers with major air quality complaints who would have frequent and numerous work-related symptoms than workers with no complaints. Finally the independent and joint contribution of worker demographics, health status, work characteristics, and environmental measurements to the odds of being a major air quality complainer were explored using logistic regression.

RESULTS

In 1990, 84% of eligible workers participated, and in 1991, 78% of eligible workers participated in the study resulting in a total study population of 2650 workers. Among these workers, 9.3% (n=247) had major complaints about the usual indoor air quality in their offices and 18.8% (n=499) had no complaints. Workers with major air quality complaints experienced the same mean temperature and daily range of temperature at their worksite as workers with no complaints (Table 1). However in repeated samples we found that they were exposed to greater variability in temperature. There were larger deviations in temperature from seasonally adjusted optimal temperature values (above and below) in the offices of workers with major complaints than those with no complaints. Relative humidity was significantly lower in the offices of major complainers, and when humidity deviated from the optimal seasonal range, values for major complainers were significantly lower than those with no complaints. Air velocity was also significantly lower in the office spaces of workers with major complaints, however daily range in air velocity and deviations from optimum were similar in the two groups. Mean carbon dioxide values were lower in the offices of workers with major air quality complaints, the daily range was smaller, as were deviations above 1000 ppm of C02. Using the ASHRAE formula for converting C02 to cubic feet per person (cfmpp) of ventilation[9], both groups of workers received ventilation well above the minimum standard of 20 cfmpp, and the workers with major complaints received, on average, better ventilation (a higher proportion of outdoor air) than non-complainers. Using logistic regression analysis, we found that absolute deviation from optimal temperature, and mean relative humidity were the two factors which were most strongly associated with the odds of major air quality complaints (log likelihood ratio=633.9, p=.0000).

Table 1. The office environments of workers with major air quality complaints in comparison to workers with no air quality complaints.

Environmental Measure	Major Air Quality Complaints (n=247)	No Air Quality Complaints (n=499)	P-Value
	Mean (sd)	Mean (sd)	
Temperature (°C)			
Mean Temperature	22.55 (0.92)	22.54 (0.68)	0.892
AM-PM Range	0.57 (0.35)	0.54 (0.46)	0.294
Absolute Deviation from Optimum	1.09 (0.69)	0.86 (0.56)	0.000
Degrees Over Optimum	+ 0.93 (0.69)	+ 0.63 (0.59)	0.000
Degrees Below Optimum	-1.39 (1.79)	-0.94 (0.76)	0.000
Humidity (%)			
Mean Humidity	32.21 (6.47)	37.15 (6.03)	0.000
AM-PM Range	3.64 (2.00)	4.06 (2.46)	0.019
Deviation Optimum	-1.22 (1.09)	-0.49 (1.48)	0.000
%Over Optimum	3.26 (2.16)	5.19 (3.72)	0.000
%Under Optimum	-4.20 (1.88)	-4.14 (2.20)	0.731
Air Velocity (m/sec)			
Mean Air Velocity	0.089 (.02)	0.099 (.04)	0.000
AM-PM Range	0.03 (.01)	0.06 (.39)	0.166
Deviation from Optimum	-0.02 (.01)	-0.01 (.04)	0.001
m/sec Over Optimum	-	0.39 (.60)	-
m/sec Under Optimum	-0.03 (.00)	-0.03 (.01)	0.801
Carbon Dioxide (ppm)			
Mean CO2	614 (113)	668 (110)	0.000
AM-PM Range	71 (60)	111 (84)	0.000
Over 1000 ppm	29 (20)	45 (40)	0.005

Legend: (sd): standard deviation

Using the ratings from all 2650 worker, we examined the relationship between ratings of the usual air quality conditions of the office environment and measured values of these parameters in the worksite. We found that air circulation was rated as being terrible (a rating of 4) by the highest proportion of workers (23%), followed by humidity (17%), and temperature (8%). Correlations among questionnaire ratings of temperature, humidity and air circulation were moderate ranging from r=0.39 for temperature and humidity ratings to r=.53 for humidity and air circulation ratings. There was a systematic linear relationship between workers' ratings of temperature and absolute deviations of office temperature from optimum values (p<.001). The poorest ratings of temperature were associated with the largest average deviations from optimum values. Those rating the office temperature conditions as terrible experienced office temperatures which were, on average, 1.14 C above or below the optimum. Worker ratings were less specific for office humidity. Poorer ratings of temperature, humidity, and air circulation were all linearly related to lower mean humidity (p<.001). Workers do not seem to be able to differentiate these components of air quality, and may label problems with humidity as air circulation or temperature problems. Ratings of 'terrible' for temperature, humidity, and air circulation were associated with mean office humidity of 31.8%, 33%, and 32.9% respectively. In comparison those who rated temperature, humidity or air circulation as ideal experienced an average relative humidity between 35.8% to 36.8% (about a 3% difference). Similarily, there was a linear trend for mean air velocity to be lower as ratings for temperature, air circulation, and humidity deviated from the ideal. Although the model with all three ratings was significantly associated with mean air velocity (p<.01), no one rating scale proved to be a significant independent predictor. There was a systematic trend for poorer ratings of temperature and humidity to be associated with lower C02 values (p<.0001), with no relationship being demonstrated between air circulation ratings and C02. We believe this unexpected result is probably explained by the substantial correlation between mean C02 and mean relative humidity (r=.82). As C02 diminished (proportion of outdoor air increases), so did relative humidity. We suspect that this association arose because most of the environmental measurements were collected during the drier seasons of the year (winter, late fall, and early spring). Since variability in the relative humidity of indoor air is the strongly associated with the humidity of outdoor air, workers who experienced a higher proportions of outdoor air during the these drier seasons may also have been exposed to lower relative humidity.

The differences between major air quality complainers and non-complainers with respect to work-related symptoms, socio-demographic and work characteristics are summarized in Table 2.

Table 2. The personal and work characteristics with major air quality complaints in comparison to workers with no air quality complaints.

	Major Air Quality Complaints	No Air Quality Complaints	P-Value
Personal Demographics			
Mean Age	38.4 yrs	39.5 yrs	.238
Percent Female***	70.5%	27.0%***	.000
Health Status			
% with Atopic History	45.5%	18.4%	.000
% Using Prescribed Medications	18.7%	12.1%	.036
% Wearing Contact Lenses	13.4%	11.9%	.625
% Smokers**	21.4%	11.6%	.001
Sick Building Symptoms			
% no symptoms ***	3.6%	20.8%	.000
%numerous-frequent work-related symptoms ***	12.2%	0.4%	.000
Work Characteristics			
Job Type: clerical	24.6	10.5	.000
professional	50.7	78.9	
management	21.7	5.3	
other	2.9	5.3	
% Exposed to Smoke at Worksite	18.7	4.4	.0001
Mean Job Control Score (1=no job, 7=total job control)	3.1	2.3	.0001
Mean Number of Computer Hours/Day	3.1	2.3	.0001
Job Stress (1=very stressful, 7= not stressful)	3.5	3.9	.005

** p<.001, ***: p<.0001

A greater proportion of workers with major air quality complaints experienced frequent and numerous work-related symptoms (12%) relative to non complainers (0.4%), and a much smaller proportion reported that they had none of the cardinal symptoms of sick building syndrome (4% versus 21%). Major air quality complainers were also more likely to be female, have an atopic history, smoke, and be employed in management or clerical positions. A greater proportion of major air quality complainers were exposed to smoke at their worksite, reported less control over their work, and worked longer hours per day at a computer. Using logistic regression to examine the independent and joint association of environmental conditions and sociodemographic and work conditions, we found that mean humidity at the worksite, sex, atopic history, and job control were the four factors which were significantly associated with the odds of being a major air quality complainer. These factors each contribute significantly to the model but they are not completely independent. Although there is no significant difference between males and females in rated job control or office humidity, 11% more women than men reported an atopic history, and those reporting an atopic history were in office spaces with lower relative humidity (33% relative humidity versus 37%: p=.0001), and worked in jobs where they believed they had poorer job control (3.5 versus 4: p=.01)

DISCUSSION

The main purpose of this study was to determine whether the indoor air quality (temperature, relative humidity, air velocity, C02) of workers with major air quality complaints differed in a significant way from workers with no air quality complaints. By using repeated measurements of the workers office environment to provide a more precise estimate of office conditions, we demonstrated that significant differences did exist, particularly in temperature and humidity. Workers with major air quality complaints experienced lower relative humidity, more variable office temperatures, and slightly lower air velocity than workers with no complaints. As estimated by C02, workers with major air quality complaints also received a greater proportion of outdoor air. On the basis of the strong association between C02 and relative humidity, and the time of year when the samples were taken, we believe these results were attributable to the exposure to lower humidity as the proportion of outdoor air delivered to the worksite increased.

We evaluated the association between ratings of air quality and repeated office measurements of indoor air to determine if workers ratings were associated with indoor conditions. We found that there were significant linear associations between workers' ratings and temperature, humidity, air velocity, and C02 at the worksite. Although workers ratings were systematically associated with greater deviations from optimal temperature, humidity, and air velocity conditions, ratings were not very specific. For example, ratings of poor air circulation were not associated with air velocity or mean C02 but were associated with lower humidity. There are four practical implications suggested by these findings. A single measurement of a worker's office environment is too imprecise to draw any conclusions about the usual conditions in their office space. Secondly measurements of indoor air quality need to be summarized to reflect not only the average value, but also the variability in conditions. As was illustrated by the findings for temperature in this study, mean values alone masked the exposure of major air quality complainers to significant, and randomly distributed, variability in office temperature conditions. Thirdly, workers' perceptions that there is an indoor air quality problem in their office space is probably a valid indicator of sub optimal conditions. However, specific complaints about temperature, humidity, and/or air circulation may not be very accurate indicators of the exact nature of the problem. "Terrible air circulation", a common complaint made by office workers may mean a problem with temperature, humidity or air velocity. Finally, inadequate humidification of outdoor air in the winter months in colder climates may lead to more frequent air quality complaints, even when average humidity is within norms for the seasonally adjusted comfort range. A balance needs to be struck between adequate dilution of indoor contaminants by increasing ventilation, and maintenance of adequate indoor humidity.

We found that workers with major air quality complaints were also more likely to have frequent and numerous work-related symptoms. These findings have been systematically reported in other studies 7,10. Our findings simply serve to confirm that the expected relationship between complaints and work-related symptom reporting existed in this study sample.

The factors which were associated with air quality complaints in this study are also the same factors which have been associated with the occurrence of work-related symptoms 10,11,12. We identified that sex, atopic history, job control, and office humidity were the most important factors for increasing the odds of air quality complaints. These findings suggest that worker susceptibility, coupled with work conditions, and office environment act in a multiplicative way to increase the odds of air quality complaints and work-related symptoms. We cannot explain the finding that workers with atopic history perceived that they had less control over their jobs, or the observation that atopic workers experienced lower office humidity. A cross-sectional study is poorly suited to understanding the direction of these relationships. Although the results we observed may be spurious, it would be worth exploring the potential nature of these relationships in subsequent research.

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