Air Quality and Ergonomics in the Office: Survey Results and Methodologic Issues

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A survey of office workers at four sites was conducted by Columbia University School of Public Health during 1981 and 1982 to explore the relationships between office working conditions and employee health. Walk through surveys of each site were conducted by the research team with joint labor-management sponsorship. A total of 2074 non-managerial office workers filled out a 30-minute self-administered questionnaire at their respective workplaces. Multiple item scales were tested and constructed to measure indoor air quality and ergonomic factors. Significant differences in ergonomic conditions and air quality between the sites were observed. These differences corresponded with researcher observations prior to the surveys. Significant associations between the reported air quality and respiratory symptoms and between ergonomic factors and musculoskeletal symptoms were found. Specificity of the relationship between reports about the environment and health symptoms was demonstrated. The implications of this approach for industrial hygiene investigations of non-industrial environments are discussed.

Introduction

Many industrial hygiene analyses of the office environment, even when initiated as a result of health complaints among the working population, fail to detect conditions with which the complaints can be firmly associated.⁽¹⁻³⁾ The dilemma that faces the industrial hygienist in such a situation is to analyze an environment which is usually characterized by comparatively low levels of several chemical substances not in excess of ACGIH recommended levels for occupational health hazards. Although the industrial hygienist may obtain "negative" results, employees may still be dissatisfied and/or continue to exhibit non-specific symptoms such as upper respiratory tract irritation, headaches and various musculoskeletal aches and pains. The non-specific nature of the complaints adds to the industrial hygienist's dilemma since such symptoms are not readily linked to particular agents.

This paper presents partial results from a survey of more than 2000 office workers employed at four sites, and working in six different buildings in the United States and Canada. The full study represents an attempt to delineate relevant physical and psychosocial risk factors in the office, and to relate these conditions to self-reported states of physical and mental health. We focus on two aspects of the physical environment which have been the subject of numerous complaints among office workers: air quality and the biomechanical factors of the job and work stations. Worker self-reports of these two conditions are analyzed in relation to upper respiratory tract and musculoskeletal symptoms

This paper also examines the place of survey questionnaires in meeting the need for developing procedures which the industrial hygienist may use to analyze conditions in the

modern office in order to help determine whether there are indeed statistically meaningful patterns of non-specific health complaints, and, if such patterns exist, whether they can be related to physical factors in the office.

Methods

A cross-sectional survey of 2074 non-managerial office workers employed at four different establishments in six separate buildings in the United States and Canada was undertaken to study physical and psychosocial working conditions in the modern office and to relate these conditions to participants' reports of mental and physical health and well-being. Study participants represented a wide range of clerical and technical occupations within the public employment sector.

Sites

The investigators had previous working relationships with the national Unions representing the employees at each of the sites. Based on these previous relationships, initial contact was made with the local Union representing the employees and management cooperation was then obtained. Selection for inclusion in the study required that there be sufficient numbers of employees in similar jobs and working environments to provide subgroups large enough for statistically meaningful analyses.

Three of the buildings were modern, "sealed" buildings (i.e. windows could not be opened) with open plan layouts (Site H1, Site L, and Site B). One of the sites was an older

TABLE I
Description of Study Sites

Site	Description	N
Office H		
Building 1	Open plan office in a large, modern 'sealed' building.	442
Building 2	Open plan office in an older 'sealed' building.	99
Office C		
Building 1	Conventional office in a converted warehouse.	141
Building 2	Conventional office in a modern 'sealed' building.	50
Office B	Large open plan office in a 'sealed' building.	610
Office L	Large open plan office in a 'sealed' building.	488
Total		1830

building, which had recently been converted to an open plan layout (Site H2). The fifth building was a converted warehouse (Site C1) and the sixth was a small modern building with a "traditional" (Site C2) layout. An open plan is defined as an office where individual workstations are differentiated by movable partitions or other space separators. It is distinguished here from the traditional office with permanent walls and doors and the office "pool" arrangement with no space partitioning.

The sites were characterized by varying levels of previous complaints about the environment and of organizationally structured union health and safety activities. In three sites Union initiated investigations and filing of formal grievances with management about the environment had already occurred (Sites C, L, B). At Site H the Union was well-organized and active and strong channels for labor management interaction existed. However, general environmental conditions of the site had not been a major Union emphasis.

Complaints about the air quality and overall maintenance of the facilities were most widespread at Site C1. At site L, a government-run social service organization housed in a sealed building, employees expressed numerous complaints about the air quality and had initiated industrial hygiene investigations of the worksite. At Site B, a health insurance organization, there were some complaints about the air quality and also many non-specific complaints from computer operators, particularly about musculoskeletal problems and about the noise masking system in the building. The number of participants and a description of each site is summarized in Table I.

At Site H, a representative sub-sample of 15% of the employees was surveyed, since the workforce was greater than 6000 people. Employees representing each major job category and workstation type were selected from the organ-

ization's two buildings, H1 and H2. In the three remaining sites, all employees were invited to participate.

The surveys were carried out on-site during work hours by the research team, with labor and management sponsorship. Prior to the actual survey, an educational brochure was distributed and meetings with supervisors and union representatives took place as part of the strategy to maximize participation in the study. The survey questionnaire was then given to the designated employees. They were permitted by management to fill out the questionnaires at their desks during working hours.

Questionnaire Construction

The survey questionnaire was self-administered and consisted of groups of items on:

1. physical characteristics of the office
2. job characteristics
3. employee reports of psychological and physical health and opinions and feelings about work
4. basic demographic information

Items pertaining to job characteristics and health were derived from several previous studies.⁽⁴⁻⁶⁾ Questions on specific environmental characteristics were developed on the basis of walk-through surveys and interviews with workers and management which were conducted by the research team. Items on health largely consisted of questions from other published surveys and validated items were used to the greatest extent feasible.^(7,8)

In order to improve the analytical precision of the questionnaire, a standard method for analysis of social science data which combines several related questions into a single measure, or scale, was used since it is well established that multiple item measures are more reliable than single items.⁽⁹⁾ For example, questions which related to the air quality, such as temperature, ventilation, odor and airborne contaminants, were mathematically combined into an "air quality stressors" scale. Similarly, several questions related to the ergonomic conditions in the environment, such as comfort and convenience of furniture and equipment, were combined into an "ergonomic stressors" scale. The response scale for items pertaining to air quality was as follows: (1) "very rarely or never"; (2) "occasionally"; (3) "almost constantly." The response scale for items pertaining to "ergonomic stressors" was: (1) "not at all"; (2) "a slight amount"; (3) "a moderate amount"; and (4) "a lot".

The reliability of the scales was calculated using Cronbach's alpha as a measure of average inter-item correlation. Only scales achieving moderate to high internal consistency reliability ($\alpha > 0.67$) and consisting of logically related items were used in the analysis. The "air quality" scale achieved an overall reliability coefficient of 0.82. The "ergonomic stressors" scale had an overall reliability coefficient of 0.78. The individual items contained in these scales, the source of the items, and their reliabilities are presented in Table II.

TABLE II
Measures of Environmental Stressors and Health Symptoms

Measure and Items	Source	Response Scale ^A	Coefficient Alpha
AIR QUALITY STRESSORS			
How often does your job expose you to the following conditions?			0.82
Too little air movement	(5)	A	
Uncomfortable temperature	(5)	A	
Stuffy air	(5)	A	
Unpleasant odor	(5)	A	
Dust, smoke fumes	(5)	A	
ERGONOMIC STRESSORS			
Does your job require you to work in uncomfortable positions or use awkward motions?	(6)	B	0.78
To what extent does your workstation have the following conditions?			
Enough surface to lay out your work		B	
Convenient furniture arrangement		B	
Comfortable chair		B	
Comfortable desk height		B	
RESPIRATORY SYMPTOMS			
During the past 6 months how often did you experience the following symptoms?			
Nose or throat irritation	(8)	C	
Colds or sore throats	(8)	C	
Persistent cough	(8)	C	
MUSCULOSKELETAL SYMPTOMS			
During the past 6 months how often did you experience the following symptoms?			
Cramps in hands, fingers or wrists	(8)	C	
Painful or stiff arms or wrists	(8)	C	
Painful or stiff neck or shoulders	(8)	C	
Back pain	(8)	C	

^ARESPONSE SCALES:

- A 1 = Very rarely or never; 2 = Occasionally; 3 = Almost constantly.
 B 1 = Not at all; 2 = A slight amount; 3 = A moderate amount; 4 = A lot.
 C 1 = Almost never; 1 = Sometimes; 3 = Often; 4 = Almost all the time.

The questionnaire was pretested with workers in two small offices to ascertain the understandability of the questions and the ease of answering the survey.

Data were coded, keypunched and entered onto a VAX 11/780 computer. Range and logic checks were performed in order to correct for keypunching errors and inconsistencies. A random subset of questionnaires was also verified for keypunching accuracy. The analyses were conducted using SPSS-X, statistical analysis software. Univariate methods of analysis — frequencies, crosstabulations, correlations and one way analysis of variance — were used in the analyses.⁽¹⁰⁾

Results

Questionnaires were distributed to 2412 employees and 2074 filled them out at the 6 buildings where the study was conducted. Response rates ranged from 79% to 89% at each of the sites, with an overall response rate of 86%. Results are reported here for 1830 employees (1334 females and 496 males) who worked full-time and had achieved at least 6 months tenure with the employer at the time the survey was conducted.

TABLE III
Prevalence of Physical Health Symptoms

Symptom	Frequency							
	Never		Some-times		Often		Always	
	N	%	N	%	N	%	N	%
Nose and throat irritation	406	23	712	41	473	27	146	8
Colds and sore throats	486	28	913	53	298	17	41	2
Persistent cough	1089	64	428	25	153	9	41	2
Hand and finger cramps	1111	64	468	27	136	8	19	1
Arm and wrist pain	1211	70	381	22	122	7	15	1
Neck and shoulder pain	659	38	659	38	334	19	87	5
Back pain	710	41	654	38	300	17	73	4

The mean age for female respondents was 34; for males, the mean age was 40. The majority of respondents were white (86% of females and 81% males). Participants represented the following occupational groups: clerical (n=587); typists (n=144); VDT operators (n=293); clerical supervisors (n=249); professional and technical (n=394); and social workers (n=163).

Self-reports of respiratory and musculoskeletal symptoms are summarized in Table III. Thirty-five percent of the respondents reported having nose or throat irritation either "often" or "almost all the time." Twenty percent reported having colds or sore throats and 11% reported having a persistent cough either "often" or "almost all the time". The prevalence of specific musculoskeletal problems was as follows: almost 21% reported having neck and shoulder pain; 22% reported back pain; 9% reported hand, finger and wrist cramps and 8% reported having arm and wrist pain either "often" or "almost all the time".

The observed levels of ergonomic stressors and musculoskeletal symptoms are summarized in Figure 1. The mean value for all participants (grand mean) is given by the solid horizontal line in each graph. Non-overlapping error bars indicate statistically significant differences between the

means. The lowest mean values on the "ergonomic stressors" scale were found at Site H, Building 2. At Site H, Building 1, the mean level for each of the musculoskeletal symptoms measured was significantly below the grand mean. At Site H, Building 2, the mean level of musculoskeletal symptoms was significantly below the grand mean for three out of four symptoms measured. Employees at Site B were found to have the highest mean score for ergonomic stressors and the highest mean scores for the questions relating to muscular "aches and pains."

Respondent reports of air quality stressors and respiratory symptoms at each site and for all participants are shown in Figure 2. Overall, respondents in the two buildings at Site H reported both the lowest levels of air quality stressors and the lowest levels of respiratory symptoms, each significantly lower than the grand mean. The highest mean score for the air quality stressors scale, significantly higher than the mean, was reported in Building 1 at Site C — the converted warehouse. The mean levels of respiratory complaints reported by participants at this site ranked second highest in comparison with the other buildings. The highest level of respiratory complaints was found in Site B. Respondents from this site reported the second highest mean score for air quality stressors.

¹ Reported by means
 I 95% Confidence Interval
 — Grand Mean

Figure 1 — Ergonomic stressors and musculoskeletal symptoms by site.

¹ Reported by means
 I 95% Confidence Interval
 — Grand Mean

Figure 2 — Air quality stressors and respiratory symptoms by site.

Further analysis of the relationship between musculoskeletal symptoms and ergonomic stressors was carried out by dividing the ergonomic stressors scale into two groups (high and low) using a median scale split. These responses were then crosstabulated with reports of musculoskeletal symptoms. Results are shown in Figure 3. Among survey respondents who reported having frequent hand and finger cramps (i.e. "almost all the time"), 84% scored in the upper half of the ergonomic stressors scale (high stressors), while 16% scored in the lower half of the ergonomic stressors scale. Among those reporting frequent arm and wrist pain, the prevalences were 80% and 20%; for neck and shoulder pain the prevalences were 77% and 23%, and for back pain the prevalences were 74% and 26%, respectively.

Similarly, the air quality stressors scale was divided into two groups (high and low) using a median split. Responses were then crosstabulated with reports of respiratory symptoms. Results are shown in Figure 4. Among people reporting respiratory symptoms (nose and throat irritation, colds and sore throats, or persistent cough) "almost all the time", 84% scored in the upper half of the air quality stressors scale (high air quality stressors) while 16% scored in the lower half of the air quality stressors scale (low air quality stressors).

Differences in reported frequency of upper respiratory tract and musculoskeletal symptoms as a function of the

level of the relevant stressors (high vs. low) were statistically significant ($p < 0.0001$) using a chi-square test.

The relationship between respiratory symptoms and ergonomic stressors was also examined as one test of the specificity of reported health complaints. Using the median scale splits described previously, respondents were grouped into the following three categories: (1) low air quality stressors and low ergonomic stressors; (2) high air quality stressors and low ergonomic stressors; and (3) low air quality stressors and high ergonomic stressors. Respiratory symptoms were crosstabulated by each of the groups. The results are presented in Figure 5. Among people who reported respiratory symptoms either "never" or "sometimes", the greatest percentage also reported having low ergonomic and low air quality stressors; the second highest percentage was among people who reported high ergonomic stressors and low air quality stressors; and the lowest were those who reported low ergonomic and high air quality stressors. These results were statistically significant ($p < 0.05$) using a chi-square test, and in the direction expected.

Discussion

The results presented here indicate that patterns of health complaints were consistently associated with relevant stressors in office workplaces. Both the distribution of means for

Figure 3 — Distribution of musculoskeletal symptoms in relation to ergonomic stressors.

AIR QUALITY STRESSORS¹

Figure 4 — Distribution of respiratory symptoms in relation to air quality stressors.

RESPIRATORY SYMPTOMS¹

Figure 5 — Specificity of respiratory symptoms.

Methodological Issues

Several questions are raised by these analyses. One concerns the direction of causality. Were respondents with health

symptoms more likely to report environmental stressors or did stressors in the environment lead to the health symptoms? The cross-sectional nature of the study does not permit drawing conclusions about causality. However, some support for the second interpretation — that environmental stressors led to health symptoms — is provided by independent observations of the research team. Respondent reports about air quality were consistent with the investigators' prior observations about the buildings. The lowest mean levels of air quality stressors were reported at Site H, the only site in which the study was initiated by the researchers, rather than as a result of specific complaints or union actions by the workers. Anecdotal reports and researcher observations suggested that air quality problems were greatest at Site C. Responses to the air quality scale appear consistent with these observations.

The reports of ergonomic stressors are equally consistent with prior knowledge of conditions in the buildings. In both buildings at Site C, a lower percentage of respondents than at the other sites reported that the furniture and equipment were comfortable and conveniently arranged. Prior to the questionnaire survey, the research team had observed that Site C contained the least attractive, modern and well-designed furniture, arranged in a haphazard fashion. The other sites had recently undergone conversion to open plan layouts and hence the furnishings were newer and in better repair than at Site C.

At Site B, where the highest levels of ergonomic stressors and the highest levels of musculoskeletal complaints were reported, a large number of the employees worked as VDT operators, and sat in stationary positions for long periods of time during the workday. Union activities had already been centered around these health and safety conditions. Recent studies have found that VDT operators may experience higher levels of musculoskeletal complaints than clerical workers who do not use such equipment.⁽¹¹⁾ These relationships will be explored in forthcoming papers.

Another methodological issue is that of individual sensitivity: Are those who report the highest levels of symptoms the most 'sensitive' by virtue of preexisting health problems? To the extent that the prevalence of health symptoms reflects pre-employment conditions or sensitivities, we would not expect to find differences between sites, since our sample consists of a relatively homogeneous population of office workers. It is not likely that the workers with nose and throat complaints self-selected themselves by choosing to work in those offices with the poorest indoor air quality.

A related issue is the potential for multicausality of the observed symptoms. Many of the physical and mental health symptoms experienced by the non-industrial workforce may result not only from conditions in the physical environment, but from simultaneous stresses associated with job design, task assignment and organizational dynamics. In order to adequately address this issue, more detailed analysis on the impact of occupation, job characteristics and tasks is required. Such analyses will not detract from the results presented here but rather will broaden our understanding of the etiology of the observed health symptoms.

Another important question relates to using a symptom survey questionnaire of workers in assessing the workplace environment and health status. Any self-reported survey of workers will entail many subjective opinions and will also be, in part, reflective of the personality, health status and work history of the respondent, as well as of his or her training, education and expectations. Objective assessments of the office ventilation systems and ergonomic features of workstations would be required to validate worker reports presented here. However, with respect to symptom data, it is often difficult to obtain more "objective" data. The commonly used sources of data used to 'validate' self reports — e.g. physicians' diagnoses, medical records and attendance rosters — are in themselves based on 'subjectively reported symptoms', since patient reports are frequently the physician's major source of information in making diagnoses. Furthermore, the chronic conditions reported here do not readily lend themselves to biochemical tests and other "objective" clinical measures.

Despite these drawbacks, the concordance between the results obtained from the worker questionnaires and prior knowledge of the research team, as well as the statistical reliability of the scales given in Table II, lead us to propose that: (1) the relationships observed here are meaningful and deserving of serious follow-up attention; and (2) well-designed symptom surveys of workers, particularly when combined with observational walk-through surveys of working environments, can be used by the industrial hygienist as one tool in his or her armamentarium of methods for analyzing the potential health risks in office environments, particularly in situations where air sampling or other more concentrational approaches do not yield definitive results.

The survey instruments used by the industrial hygienist should be carefully constructed by a researcher knowledgeable in survey techniques. Among the considerations in survey questionnaire design is the need to include several questions which deal with various aspects of the same problem, such as the indoor air quality scale shown in Table II. As in physical science, where replicate runs are carried out and statistically combined (usually averaged) to increase the precision of the measurement, one greatly increases the precision of survey responses by "measuring" an effect with several different questions about that effect and combining these responses into a scale. Such a series of questions can only be combined into a scale when they meet both theoretical and empirical criteria, establishing logical and statistical intercorrelation of items.

Conclusions

The work-related etiology of many health problems is often obscured by the difficulty in assessing exposures. One solution to the dilemma of analyzing the combination of low contaminant levels and non-specificity of health complaints has been to dismiss the complaints as unfounded or to attribute them to purely psychological causes as in the example of "mass psychogenic hysteria."^(12,13) The present study indicates that symptoms, which at first glance may appear to be non-specific, express a consistent pattern when

examined in relation to specific environmental conditions. A consistent relationship between respiratory complaints and discomfort with the air quality and between musculoskeletal complaints and ergonomic factors was observed. The finding of unique distributions of environmental conditions and physical health symptoms in each of the sites surveyed, and the consistency of these reports with the researchers' observations strengthen the validity of this approach to the evaluation of risk factors in office settings. In addition, it underscores the need for industrial hygienists to widen the armamentarium of tools to deal with non-industrial workplaces that are not amenable to traditional methods.

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