Background: The increase in work-related respiratory complaints in artificially ventilated buildings have multiple causes, and intervention studies are a valuable approach to understanding possible mechanisms.

Study objectives: To analyze the effects of an intervention in a ventilation system with > 20 years of continuous use, and with a high rate of building-related respiratory complaints.

Design: An epidemiologic study was done among individuals working in places with ventilation machinery and ducts with > 20 years of use, before and after intervention. Analysis of symptoms and logistic regression were performed to check the associations between air-conditioning intervention and reported symptoms.

Results: The air-conditioning intervention showed a protective effect on building-related worsening of respiratory symptoms (odds ratio, 0.132; 95% confidence interval, 0.030 to 0.575), naso-ocular symptoms (odds ratio, 0.231; 95% confidence interval, 0.058 to 0.915), and persistent cough (odds ratio, 0.071; 95% confidence interval, 0.014 to 0.356).

Conclusion: Intervention in high-risk occupational locations can be effective in improving perceived indoor air quality.

Key words: air conditioning; air pollution; indoor; intervention studies; occupational health

Abbreviations: IAQ = indoor air quality; HVAC = heating, ventilation, and air conditioning

An increasing number of complains and health effects related to time spent in artificially ventilated buildings have been reported during the last 30 years. Mucosa-related complaints such as nasal congestion, pharyngeal pruritus, persistent cough, wheezing, dry throat, and increased number of viral and bacterial infections are frequently reported in these populations. Considering that no single causative agent is commonly reported in cross-sectional or prospective studies, the role of protective and improvement measures is still a matter of debate. We have previously reported an association between upper airway symptoms and places with heating, ventilation, and air conditioning (HVAC) systems with > 20 years of continuous use, but no improvement measures were mentioned. After the evalu-
tion, the HVAC system with the highest rate of health complaints was renovated and the same population returned to the studied place. After reoccupation, the population was reassessed to evaluate the modifications in the perceived indoor air quality (IAQ).

**Materials and Methods**

The studied office is located on the 35th floor of a building located in the downtown area of São Paulo. It has artificial illumination during daytime and is fully carpeted. The equipment used by the studied group consisted of individual video displays, one photocopy machine, five laser printers, five fax machines, and a self-service coffee machine. All of this equipment was replaced after renovation, except for the addition of another laser printer.

The epidemiologic survey was based on a self-administered questionnaire regarding atopy, smoking status, respiratory symptoms, diagnosis of previous asthma or rhinitis, and work relation of the respiratory symptoms. The questionnaire was a combination of two previously standardized questionnaires validated for Portuguese language: the American Thoracic Society Division of Lung Diseases 78 questionnaire,4 and the International Study of Asthma and Allergies in Childhood questionnaire.5 The questions about asthma symptoms were as follows: Did you have wheezing or whistling in your chest in the last 12 months when you did not have a flu? Have you ever had attacks of shortness of breath with wheezing? The core questions about nasal symptoms were as follows: In the past 6 months, have you had a problem with sneezing, or a runny or a blocked nose when you did not have a flu? In the past 6 months, has this nose problem been accompanied by itchy-watery eyes? The question about sinus symptoms was as follows: In the last 12 months, did you have sinusitis (purulent nasal discharge accompanied by sinus pain and fever)? The question about upper respiratory infection was as follows: How many flu-like episodes did you have in the last 12 months. The question about persistent cough was as follows: Do you have daily coughs for > 3 weeks every year? The question about where the symptoms were perceived was as follows: Where were the above symptoms more frequently evoked? The questionnaire was applied before and after the renovation of the air-conditioning system to the population of 23 subjects working in the studied place, and the occupational medical advice was to use antihistamines on an as-needed basis. Questions concerning sinusal and naso-ocular symptoms were considered as related to upper airways, whereas questions about wheezing and breathlessness were considered as related to the lower airways.

The renovation of the HVAC system (Hitachi; Tokyo, Japan) [self-type, 10 tons of refrigeration] consisted of exchanging the ventilation ducts, and cleaning and maintenance of the ventilation machinery. There was an internal rearrangement of the office desks and exchange of the carpets and coverings as well. The renovations were done simultaneously, and the office was reoccupied 3 months after the work was initiated. Reassessment of the symptoms was done in September of 2002 (spring in Brazil), 14 months after the initial survey, which was done in July of 2001 (winter in Brazil).

The control group was the population working in the same company, with the same office design, similar jobs, and with the same HVAC system but with < 2 years of continuous use, interrogated on the initial study. The population-reported symptoms before and after the air-conditioning renovation were compared using McNemar tests and after intervention and control using \( \chi^2 \) tests. Univariate and multiple logistic regressions were used to analyze the effect of the air-conditioning renovation on naso-ocular, chest wheezing, sinus symptoms, persistent cough, and building-related worsening of self-stated symptoms. The symptoms were the outcome variables, and the control variables were gender, age, accumulated work time, smoking habits, passive smoking, history of familiar atopy, previous medical diagnosis of asthma and rhinitis, and the ventilation system groups. The Hosmer and Lemeshow tests were used to evaluate the goodness of fit of the model.

**Results**

The questionnaire response rate for the before and after survey was 78%, totaling 18 of the available...
population of 23 subjects (50% male, 38.9% female, and 11.1% who chose to remain anonymous). The comparison of symptoms before and after renovation showed a reduction of naso-ocular symptoms (nasal pruritus, congestion, or water discharge concomitant with itchy-watery eyes), persistent cough, and work-related worsening of the respiratory symptoms. Work-related symptoms consisted of blocked, runny, or itching noses in all subjects, and accompanied by itchy-watery eyes in 76.5% of this subset of the population. There was no significant difference between postintervention and control groups, showing a reduction of all symptoms to the basal level (Fig 1).

The logistic regression showed a protective effect of the air-conditioning renovation, in the univariated and in the multivariated model adjusted by gender, accumulated work time, and smoking habits. There was a clear association of improvement of upper airway symptoms with air-conditioning renovation, but no effect was observed on the number of reported upper airway infections (Table 1).

**DISCUSSION**

Since it was not possible to blind the participants of the study, there is a potential Hawthorne effect, due to a positive psychological impact of renovation of the air-conditioning system. However, if a positive psychological impact of the air-conditioning renovation existed, one should have expected it to have affected all types of symptoms and not only those from the upper airways.

Measuring the symptoms by a self-administered questionnaire is also a potential limitation of this study. The use of questionnaires in assessing indoor air quality is still largely used in most studies of sick-building syndrome because there is a wide range in the threshold of response in any population, and a wide spectrum of response to any given agent.\(^2\)

This study is a follow-up to a previous study,\(^6\) in which a detailed evaluation on airborne fungi, mite, animal dander, and insect allergen exposure was performed. Although the aging of the ventilation system could lead to biological contamination,\(^6\) no significant biological or allergenic significant exposure was found.\(^9\) Considering that pollen exposure in São Paulo is clinically irrelevant,\(^7\) and the allergenic level found on the carpet was clinically insignificant, the allergenic exposure in this scenario was disregarded. The atopic individuals were considered a risk group for indoor air-related complaints. This apparent controversy is quite common in epidemiologic and occupational studies.\(^8,9\) We also found that places with ventilation systems with poor control of thermic parameters are at risk for work-related symptoms. Considering that atopic individuals have a decreased capacity to warm the inspired air,\(^10\) and the potential degranulation effect on mast cells of the cold and dry air,\(^11\) this could partially explain the atopy-related complaints in the absence of significant allergen exposure.

IAQ-related problems are complex and multifactorial, involving multiple indoor pollutants, such as endotoxins, volatile organic compounds, particulate mater, and other indoor and outdoor pollutants. In spite of the fact that they could influence the perceived quality of the indoor air, the routine investigation of all these factors is considered expensive and not elucidative.\(^12\)

In the present study, the prevalence of most building-related symptoms decreased substantially after the renovation of the air conditioning, and the respiratory complaints dropped to control levels. Previously reported conservative intervention studies\(^8,13\) to improve IAQ failed to demonstrate significant improvements. Our results are in agreement with the concept that “cleanliness is next to healthiness,”\(^14\) specifically of the upper airways in this context.

IAQ is considered a major public health concern, and the efforts to produce cost-effective interventions are a current priority in occupational health.

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**Table 1—Renovation of the Ventilation System as a Related Factor for Respiratory Symptoms**

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>OR Crude</th>
<th>95% CI</th>
<th>OR Adjusted†</th>
<th>95% CI</th>
<th>H-L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building-related worsening</td>
<td>0.132</td>
<td>0.030-0.575</td>
<td>0.059</td>
<td>0.005-0.647</td>
<td>0.803</td>
</tr>
<tr>
<td>Naso-ocular symptoms</td>
<td>0.231</td>
<td>0.055-0.915</td>
<td>0.085</td>
<td>0.012-0.609</td>
<td>0.656</td>
</tr>
<tr>
<td>Wheezing</td>
<td>1.523</td>
<td>0.290-8.011</td>
<td>0.186</td>
<td>0.014-2.410</td>
<td>0.750</td>
</tr>
<tr>
<td>Persistent cough</td>
<td>0.071</td>
<td>0.014-0.356</td>
<td>0.083</td>
<td>0.016-0.438</td>
<td>0.505</td>
</tr>
<tr>
<td>Breathlessness</td>
<td>2.428</td>
<td>0.386-15.272</td>
<td>2.372</td>
<td>0.318-17.682</td>
<td>0.458</td>
</tr>
<tr>
<td>Sinusitis</td>
<td>0.400</td>
<td>0.104-1.544</td>
<td>0.294</td>
<td>0.049-1.757</td>
<td>0.995</td>
</tr>
<tr>
<td>Frequent upper airway infections</td>
<td>0.438</td>
<td>0.069-2.762</td>
<td>0.399</td>
<td>0.031-5.070</td>
<td>0.331</td>
</tr>
</tbody>
</table>

*OR = odds ratio; CI = confidence interval; H-L = Hosmer-Lemeshow.
†Adjusted by accumulated work time, smoking habits, and gender.
Controlled experiments on simulated work places and cohort studies in population samples living under artificial ventilation systems may bring further understanding of how to prevent and improve indoor air-related occupational health.

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