Respiratory Illness in Nonsmokers Chronically Exposed to Tobacco Smoke in the Work Place

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We evaluated CO levels as an index of cigarette smoke in the work place and analyzed diary entries on respiratory symptoms, eye irritation, chest colds and lost days from work due to respiratory illness in 40 passive smokers (nonsmokers chronically exposed to tobacco smoke in the work place) and 40 control subjects (nonsmokers not exposed to tobacco smoke in the work place) matched for age and gender. Passive smokers experienced greater CO levels during the workday. Also they reported significantly more cough, greater phlegm production, more shortness of breath, greater eye irritation, more chest colds and more days lost from work due to chest colds than control subjects. Nonsmoking workers and their employers are likely to incur significant financial loss because of missed workdays due to illnesses resulting from exposure to second-hand tobacco smoke. (Chest 1991; 100:39-43)

There is concern regarding the health consequences of men and women exposed to tobacco smoke in the work place. The involuntary inhalation of tobacco smoke is termed "passive smoking." Smoke exposure is produced from the burning cigarette and from that exhaled by the smoker.

During active smoking the level of tobacco smoke collecting in the lungs is high compared to that found in the lungs of passive smokers. Various respiratory irritants in tobacco smoke are thought to be part of the reason that active smokers experience more chest colds, eye irritation and respiratory illness than nonsmokers. The present study asks the question: does exposure to tobacco smoke in the work place, as measured by CO levels, produce respiratory and eye symptomatology, and cause respiratory illness and chest colds in passive smokers? The authors found no adult studies that investigated the effects of environmental tobacco smoke exposure on the prevalence and symptoms of respiratory illness. The concentration of inhalable particulate matter in work areas where smoking is permitted has been recorded to be 1.5 to 25 times higher than in nonsmoking areas. Since any amount of smoke exposure will result in elevated levels of suspended, respirable, particulate matter, and the cumulative effect of exposure will vary among individuals, the purpose of this study was to determine if tobacco smoke exposure in the work place put coworkers at greater risk of developing respiratory symptoms, eye irritation and chest colds than nonexposed co-workers.

Methods

Subjects

To examine the effects of passive smoking, we used the health scores and clinical data of participants who had been physiologically evaluated during a course, "Physical Fitness Profile," sponsored by the Department of Physical Education, University of California at San Diego between 1979 and 1985. The subjects selected for this study were part of a separate, three-year study that required each participant to maintain a diary of daily activities. Only subjects who faithfully completed the diary were considered for this study. The majority of subjects resided and worked in the coastal section of San Diego County, an area low in air pollution. Exposure to environmental pollution, smoking habits and physical characteristics were assessed from a self-administered questionnaire completed during the fitness course.

From an original 378 candidates who completed the course, 188 were disqualified from participation as either a passive smoker or nonsmoker in this study because they indicated on the questionnaire they: (1) were currently a smoker of any material; (2) had been a previous smoker of any material; (3) had lived in a home where smoking was permitted; (4) were exposed to dust or toxic fumes in their occupation; (5) had lived in a smoggy or industrial area for more than one year; (6) had been employed in areas associated with industrial pollution; (7) had been working in an enclosed area where smoking was permitted for less than 12 months (12 months was the minimal exposure time to qualify as a passive smoker); (8) had a history of pulmonary or cardiac disease, persistent cough, recent asthma, respiratory illnesses or bronchial disturbances; (9) would not be able to maintain a diary for nine months; or (10) would not be available to participate in the work place evaluation. (It was explained that the work place study entailed completing a respiratory questionnaire, an eye irritation index and having their immediate work place analyzed for CO. All diary information was gathered from September to the end of May in order to bypass the vacation months when subjects might be absent from the work place. Entry data included physical injuries, illness and lost days from work resulting from injuries or illness. Diaries were collected on the first and third Fridays of each month and data were coded and entered into a database and returned to the subject on the next collection date.)

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The remaining 190 candidates were subdivided into two cadres, "nonsmoker" (81 men and 45 women) and "passive smoker" (43 men and 41 women). Passive smokers met the same criteria of nonsmokers, but were currently exposed to tobacco smoke at work and had been for at least one year. The nonsmokers said they were neither currently exposed nor had they been exposed in the past.

To select subjects for this study, a stratified sampling technique was used.* First, passive smokers and nonsmokers were stratified into one-year age groups by gender. Next, within each gender an age was randomly selected, and from that age group a passive smoker and a nonsmoker were randomly selected. Twenty-five passive smokers were matched with 25 nonsmokers from each gender group. A total of 100 subjects were used. During the nine-month period, five men (three passive smokers and two nonsmokers) and five women (two passive smokers and three nonsmokers) dropped out of the study because of illness, injury or relocation or because they did not complete the diary. These data and data from their respective matched pair were eliminated from the database. Data from 80 subjects were used in the final analysis.

The men ranged in age from 38 to 65 years. Passive smokers averaged 52.6 years (SD = 7.6) and nonsmokers, 52.6 years (SD = 7.8). The women ranged in age from 38 to 62 years. Passive smokers averaged 50.2 years (SD = 5.8) and nonsmokers, 50.3 years (SD = 6.0). All subjects were Caucasian. Eighty percent of both men and women were currently married. Locations of work and residence according to zip codes were analyzed for population distribution. Subjects were evenly distributed and no zip code area was overrepresented. All subjects were employed and held full-time positions.

Carbon Monoxide Levels at the Work Site

Carbon monoxide, a component of tobacco smoke, was not intended to be identified as a specific incite agent, but was used to identify the presence and level of tobacco smoke in the workplace.** Carbon monoxide is an accurate tobacco smoke marker when no other sources of CO are present and when the ambient levels of CO are subtracted from the measured level.13,14

To obtain objective measures of tobacco smoke concentrations and dimensions of the working areas, a single trained technician visited the work site on three occasions. During a visit, the technician (1) measured the dimensions of the work space, (2) counted the co-workers within a 60-foot radius of the subject’s primary work area, (3) recorded the number of individuals frequenting the area during an entire 8-h workday and noted those who smoked, and (4) on three different occasions (separated by at least 30 days) placed a recording CO analyzer on the subject’s desk. The CO levels were recorded continuously for 24 h. Results from the three days were then averaged. The CO analyzer (Ecozyler, Energetics Science, Elmsford, NY) was calibrated in the laboratory and at the work site and found to have plus or minus 2 percent reproducibility and a plus or minus 2 percent accuracy at a level between 0 to 50 ppm.

Of the 80 working areas tested for CO concentrations, none was located within 1 mile of a freeway, all were located on well-traveled city streets and 71 were air-conditioned. No attempt was made to determine direction of the circulation of refrigerated air or the exact air exchange. Buildings codes required a minimum of five to six complete air exchanges per hour.

Independent Measures Recorded at the Work Site

Each subject responded to a respiratory questionnaire of the American Thoracic Society (ATS-DLD-78-A) administered by a trained technician during one of the three visits to each work place.15 (A revised questionnaire can be obtained from the British Medical Council, 20 Park Crescent, London W1 4AL, England.) The respiratory symptoms include:

- Chronic cough: customary cough occurring most days for three consecutive months or more during the year.
- Chronic phlegm: customary phlegm occurring most days consecutive months or more during the year.
- Breathlessness: troubled by breathlessness or shortness of breath when hurrying on the level or walking up a slight hill.
- Chest colds and chest illnesses: chest colds and chest illnesses occurring in the past three years, causing a lost day on the job: indoors, at home or in bed.
- Number of days missed from work due to chest cold or chest illness: occurring during a nine-month period, the number of days lost from the job due to chest colds and chest illnesses.
- Eye irritation: occurring routinely within the normal working area.

Days missed from work due to colds or chest illness were determined from diary records. Employee medical records were received from nine subjects (five passive smokers and four nonsmokers). A comparison of medical records with diary entries showed days missed from work due to colds or chest illness were not significantly different.

The eye irritation index was calculated from the subject’s rating of eye irritation or discomfort experienced in the work place. The following scale was modified from Weber:16

0 = No eye irritation and/or discomfort.
1 = Barely noticeable eye irritation and/or discomfort.
2 = Mild eye irritation and/or discomfort.
3 = Significant eye irritation and/or discomfort.
4 = Strong eye irritation and/or discomfort.
5 = Very strong eye irritation and/or discomfort.
6 = Almost unbearable eye irritation and or discomfort.

Data Analysis

Because participants were matched for gender and age, analyses primarily involved performance of paired t tests in order to compare

<table>
<thead>
<tr>
<th>Time</th>
<th>Passive Smokers (n = 40)</th>
<th>Nonsmokers (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Range</td>
</tr>
<tr>
<td>7:00 AM</td>
<td>5.9 ± 1.1</td>
<td>4.1-7.9</td>
</tr>
<tr>
<td>10:00 AM</td>
<td>11.1 ± 5.2</td>
<td>4.1-24.4</td>
</tr>
<tr>
<td>12:30 PM</td>
<td>9.8 ± 4.9</td>
<td>4.2-20.1</td>
</tr>
<tr>
<td>1:20 PM</td>
<td>15.2 ± 5.4</td>
<td>5.9-25.8</td>
</tr>
<tr>
<td>(peak CO)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4:00 PM</td>
<td>10.8 ± 6.1</td>
<td>4.1-20.7</td>
</tr>
<tr>
<td>7:00 PM</td>
<td>6.7 ± 1.3</td>
<td>4.1-8.9</td>
</tr>
<tr>
<td>Midnight</td>
<td>6.3 ± 1.2</td>
<td>4.1-8.5</td>
</tr>
</tbody>
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*Based on matched pair t test (df = 39).
passive smokers to nonsmokers. In cases involving dichotomized outcome variables, McNemar's chi square test for matched pairs was performed. Preliminary analyses that included gender as a factor revealed this to be nonsignificant. Only analyses based on the sample as a whole are presented.

RESULTS

Work Space and Carbon Monoxide Levels

All subjects worked in an enclosed area. Nine nonsmokers and eight passive smokers worked in private offices. The mean size of the work area for passive smokers was 90±26 square feet and for nonsmokers, 94.5±26 square feet. The difference is not significant. The number of co-workers within a 60-foot radius of passive smokers averaged 11.4±6.8 people, of which 3.8±1.3 were tobacco smokers. For nonsmokers, the number of co-workers was 11.7±6.3, of which none was a smoker. To determine whether passive smokers were exposed to more tobacco smoke than nonsmokers, CO concentrations were recorded continuously for 24-h in all work areas. As seen in Table 1, there were no significant differences in CO concentration at 7:00 A.M., but during the rest of the workday, CO levels were significantly higher in passive smoker areas than in the nonsmoking areas.

Lost Days from Work and Eye Irritation

Illness and work attendance were determined from each nine-month diary. These data were analyzed for the number of lost days from work due to chest colds and chest illnesses and then extrapolated to represent a 12-month period. The results indicated that passive smokers missed twice as many workdays due to chest illness during an average 12-month period than did nonsmokers, M = 1.94 vs 0.74, p<0.01. Rated eye irritation was likewise significantly greater for the passive smokers than for the nonsmokers, M = 3.47 vs 1.22, whether analyzed by paired t test or Wilcoxon's test for matched samples, p<0.001.

Respiratory Symptoms

Passive smokers reported more respiratory symptoms than nonsmokers. Specifically, passive smokers were significantly (p<0.001) more likely than nonsmokers to report chronic cough symptoms, chronic phlegm symptoms, shortness of breath and chest illnesses (Table 2).

DISCUSSION

Several methods were used to minimize bias in this study. First, CO levels were measured to assess whether the self-reported passive smokers actually experienced more smoke at the work place than nonsmokers. Measures on the paired subjects were gathered on the same day or on consecutive days to eliminate diurnal or seasonal variations.

Second, candidates who were ex-smokers, who had ever lived in a home where smoking was permitted or who had health, environmental or occupational conditions that could affect pulmonary function adversely were not included in the study.

Third, all tests and evaluations were administered identically to all subjects by the same technician. The technician did not disclose the study hypothesis. Even though the technician carefully avoided discussing tobacco smoke, it is possible, because of strong community feelings about tobacco smoke exposure, that some subjects may have differentially reported symptoms of eye irritation and respiratory symptoms. However, subjects were not selected based on their prior complaints about tobacco smoke exposure, and their recorded lost days from work cannot be attributed to bias against any perceived smoke exposure.

Fourth, many studies use diary entries collected for a single day or up to 90 days or more. In this study, the subjects faithfully recorded their information for a full nine months, thus minimizing sampling error.

Finally, both genders were tested, all subjects were randomly selected from cadres and passive smokers were age- and gender-matched to nonsmokers. Because of financial constraints, the number of subjects was limited to 100.

Carbon monoxide measures were used because they are inexpensive and are a valid measure of tobacco smoke concentration. Future studies should include measures of either carboxyhemoglobin, cotinine or thiocyanate in blood, saliva or urine.

In our study, CO levels in the work place of nonsmokers were higher than expected, indicating contamination of the refiltered air carried from other parts of the building. Because ventilation systems are designed to recirculate air, not to filter out particulate matter, they are often responsible for bringing polluted air from smoking areas into designated "smoke-free" areas.

Mean CO levels at the beginning of the workday are not significantly different. By mid-morning coffee break, however, passive smokers experience twice the level of CO exposure compared with nonsmokers. The
CO level falls shortly after 12:00 noon when many leave the work area, then peaks immediately after lunch hour and remains high into the evening hours. Where smoking is permitted, ventilation is not sufficient to sustain CO concentrations below 9 ppm, which Holbrook defines as the "upper limits" of CO for enclosed areas with adequate ventilation.14

Prior research has shown that light smokers (smokers of one to ten cigarettes per day) experience 1.7 times more wheezing, 1.5 times greater sputum production and 3.9 times more cough than nonsmokers.15,16 In our study, 70 percent of the passive smokers complain of chronic coughing, occurring about three times more often than in nonsmokers. Almost 70 percent of passive smokers experience chronic phlegm symptoms and they produce phlegm nearly 3½ times more often than nonsmokers. Passive smokers also complain of shortness of breath 4½ times more often than nonsmokers. These results agree with other studies that looked at the symptomatic responses of headache, nasal irritation and cough to chronic passive cigarette smoke exposure in healthy subjects.17,18

Eye irritation is the most common symptom experienced by passive smokers.12 According to a report by the US Department of Health and Services,20 60 minutes of exposure at low levels of tobacco smoke (as measured by CO concentration) between 3 and 10 ppm, produces significant eye irritation. In our study, 82.5 percent of exposed subjects report significant eye irritation. Smoke exposure levels averaging 5.7 ppm of CO are subjectively described as producing "significant eye discomfort." Levels between 9.0 and 28.2 ppm incite subjective ratings of "strong discomfort" to "almost unbearable."

Active smokers miss between three and six days of work per year because of respiratory illness caused by smoking.16,21 We found that passive smokers lose an average of 1.20 days more per year from chest colds than nonsmokers. To determine the minimal financial impact of lost work time, the number of missed days is divided by 245 (approximate number of work days per year), and that percentage is multiplied by the annual salary.22 In our study, women averaged 1.12 sick days per year (annual salary, $32,000) and men averaged 1.28 lost days (annual salary, $50,000). Estimated financial loss above that of nonexposed workers with identical salaries is $146 per year for women and $261 for men.

No studies have investigated the direct and indirect costs of the health consequences of passive smoking. Since passive smokers choose not to smoke, the medical disabilities and cost of illness from passive smoking does not fall upon the shoulders of the smoker, but is diverted directly to nonsmokers and their employers. The out-of-pocket loss is reflected ultimately in higher premium costs for private and government health agencies.

In working areas where smoking is permitted, passive smokers often are exposed to tobacco smoke concentrations similar to those found in active smokers. Calculations according to the "ventilation standards" of the American Society of Heating, Refrigerating and Air-conditioning Engineers indicate that during an 8-h work shift, passive smokers inhale the equivalent smoke found in two to three cigarettes.21 The Surgeon General reports that active smoking is the leading contributory factor in respiratory disease mortality, that indoor air polluted with tobacco smoke poses a significant threat to the health of nonsmokers, and there is no safe level of tobacco smoke consumption.4,23

We conclude that chronic exposure to tobacco smoke in the workplace produces significant eye irritation and increases respiratory symptoms and the incidence of chest colds. With additional illness, employees lose more days from work. Both workers and employers share significant financial loss when absenteeism occurs from tobacco smoke-induced chest illnesses and chest colds.

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Booth Memorial Medical Center, Department of Radiation Oncology (Flushing, NY) will sponsor this conference at Booth Memorial Medical Center, September 12-13. For information, contact Dr. D. Nori, 56-45 Main Street, Flushing, NY 11355 (718:670-1500).

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