



Memorandum

Date: March 27, 2001

From: Roy M. Fleming, Sc.D., Director, Research Grants Program
Office of Extramural Programs, NIOSH, D30

Subject: Final Report Submitted for Entry into NTIS for Grant 5 R03 OH003404-02.

To: William D. Bennett
Data Systems Team, Information Resources Branch, EID, NIOSH, P03/C18

The attached final report has been received from the principal investigator on the subject NIOSH grant. If this document is forwarded to the National Technical Information Service, please let us know when a document number is known so that we can inform anyone who inquires about this final report.

Any publications that are included with this report are highlighted on the list below.

Attachment

cc: Sherri Diana, EID, P03/C13 //attachment

List of Publications *None*

Title: Chronic Sinusitis and Occupational Respiratory Disease
Investigator: Susan R. Sama
Affiliation: University of Massachusetts
City & State: Lowell, MA
Telephone: (508) 394-3289
Award Number: 5 R03 OH003404-02
Start & End Date: 9/30/1996–9/29/1999
Total Project Cost: \$53,907
Program Area: NORA
Key Words:

Abstract:

The primary purpose of this investigation was to evaluate the relationship between chronic sinus symptoms and asthma in an occupational cohort. Secondary objectives were to investigate potential associations with other lower respiratory conditions or measures that also relate to obstructive processes of the lower airways. The design of the sinus question, in the form of a matrix, allowed the symptom to be classified as work-related or not. This led to a set of analyses that enabled comparisons between work-related and non-work-related sinus symptoms. Various respiratory measures outcomes were studied for this purpose including: cross-shift change in FEV1, percent predicted FEV1, FVC and PEF. Respiratory symptoms often associated with lower respiratory disease processes included measures of: bronchitis, chronic bronchitis, wheeze, cough, phlegm, shortness of breath, and chest tightness. Three upper respiratory symptoms, eye, nose and throat irritation were also evaluated in relation to chronic sinus symptoms. Because this was an occupationally exposed cohort, the relationship between chronic sinus symptoms and exposure was also evaluated using the following variables: duration of employment, machining versus non-machining, type of MWF (straight or soluble), mass aerosol concentration, operation type and part metal being machined.

Cross-sectional data present some difficulties in terms of calculating rates of disease. This problem is even further complicated in studies of working populations because of selection pressures that result in the movement of workers away from jobs or exposures that are causing them discomfort or illness (healthy worker selection). Because cross-sectional data in effect, provide a snapshot of disease processes in a population, one has to make assumptions in terms of the timing of the relationship between exposure and disease. The picture is also likely to be somewhat inaccurate because some of the cases are no longer among the population or have changed their exposure status because of their discomfort or illness. These factors were problematic in these analyses when considering the relationship between asthma and sinus symptoms. Two separate approaches were used to address these problems. The first was based on the hypothesis that asthma which developed after employment in the plant was more likely to be related to exposure and therefore sinus symptoms than pre-employment asthma. The second approach (dichotomizing asthma cases into those diagnosed within the past 10 years versus more than 10 years ago) speaks more to the purported selection of asthmatics away from exposures that exacerbate or lead to their conditions. Although most of the post-hire asthmatics are contained in this group, the categorization further restricts the

post hire asthmatics to those most recently diagnosed. This in effect should streamline the exposure-related cases and make the relationship between sinus symptoms and asthma even more visible or apparent.

There was little evidence of a relationship between all cases of physician diagnosed asthma and chronic sinus symptoms. We hypothesized that the newer onset cases were more likely to be related to sinus symptoms if exposure was largely responsible for causing irritation and creating chronic sinus symptoms. This chronic inflammation via one of the postulated mechanisms would then lead to the development and/or exacerbation of asthma. Stronger relationships were indeed observed with asthma of more recent onset. However, because the number of post hire asthmatics was small, the risk ratios were associated with wide confidence intervals.

It was hypothesized that evaluation of the work-relatedness of sinus symptoms would provide the opportunity to more accurately identify those individuals who were developing chronic sinus symptoms from irritating work exposures. If this were true, one would expect that those individuals reporting both work-related sinus symptoms and asthma of recent onset would demonstrate the strongest association between sinus symptoms and asthma. This in fact, is what we observed. Strong associations were observed between post-hire asthma as well as for asthma that began within the 10 years of the survey. This is an interesting finding because it supports several theories. The first is that the asthma-sinus relationship can be observed in an occupationally exposed cohort. The second is that it is likely that occupational exposures which result in sinus irritation may also result in the development and/or the exacerbation of asthma. These observations in addition to the exposure response relationship may suggest that workers are accurately reporting the work-relatedness of their disease.

Unfortunately, time of onset of sinus symptoms was not assessed, and so it cannot be more directly related to exposure or to the time of onset of the asthma. It would be useful to be able to examine both exposure and time of onset in an occupationally exposed cohort. These data provide enough evidence to support further investigation of this relationship.

It was hypothesized that chronic sinus symptoms would be related to cross-shift decline in FEV1, a measurement of acute airway responsiveness. However, these data provided no evidence of such a relationship. It is possible that cross-shift decline in FEV1 of at least 5% is not a sensitive enough measure of obstructive disease. Perhaps acute obstruction, which is presumed to be reversible is not as related to chronic sinus symptoms as are chronic obstructive disease processes such as asthma.

Hypotheses linking chronic sinus symptoms and various measures of PEF were also investigated. Asthmatics have more daily variation in PEF and increases in measures of amplitude in PEF have been associated with asthma. It was suspected that chronic sinus symptoms might be related to increases in measures of PEF amplitude because of their postulated associations with various measures of pulmonary obstruction. In the longitudinally collected serial PEF data, there was evidence suggestive of an association

between sinus symptoms and anchored amplitude percent mean ($(PEF_{\text{daily max}} - PEF_{\text{arising}})/PEF_{\text{daily mean}}$) Mixed models estimated that never smokers with sinus symptoms had, on average, a 3% larger anchored amplitude percent mean than did those without sinus symptoms ($p=0.19$). Increased amplitude is a measure of the liability of the airways and is often used to identify occupational asthma. Three percent is a relatively small increase in amplitude as Hendy and colleagues suggest that 15-20% amplitudes are consistent with asthma. Although in this cohort of never smokers, asthma was only associated with a 5% increase in amplitude ($p=0.04$). The mean amplitude of the asthmatics in this cohort (7 asthmatics in 46 participants) was 13% ($sd=0.15$).

There was also some evidence of an association between sinus symptoms and "nextday change" in PEF in absolute terms ($PEF_{\text{arising next day}} - PEF_{\text{pre-shift}}$) as well as in percent of pre-shift PEF ($(PEF_{\text{arising next day}} - PEF_{\text{pre-shift}})/PEF_{\text{pre-shift}}$) Mixed models estimated a 2% decline in PEF from pre-shift to arising the following morning in this cohort of never smokers ($p=0.07$). Nextday change allows for a lag in time of response by measuring decline in PEF from pre-shift to arising the following morning. They therefore identify a group of individuals not centered around the daytime measures. Because arising PEFs tend to be the lowest in terms of circadian rhythm, these measures may capture the "lower" extreme, thus providing a larger range of response, so that the relationship with chronic sinus symptoms may be more visible.

The hypothesis that sinus symptoms may be associated with lower percent predicted FEV1 and FVC was also investigated. There was no evidence of such an association.

When considering associations with exposure, "work-related" sinus symptoms consistently demonstrated stronger relationships than did sinus symptoms as a whole. This provides more evidence that the question is successful at selecting out more of the "work-related" disease processes. If workers are accurately reporting symptoms caused by work exposures, we would expect to see stronger associations between the symptom and exposure. We cannot completely discount the possibility that more highly exposed individuals may report more symptoms because they are aware of their exposure levels.

It was interesting that other lower respiratory conditions such as bronchitis and various measures of shortness of breath, phlegm production and wheeze were all quite strongly associated with chronic sinus symptoms, as well. These findings are not surprising as each of these symptoms is related to pulmonary obstruction. All three upper respiratory symptoms measured- eye, nose and throat irritation were significantly associated with chronic sinus symptoms. Nose symptoms, as would be expected, had the strongest relationship, which was followed by eye irritation. This is not surprising because of the anatomical proximity of these structures, as well as the obvious fact that particulate exposures which are capable of irritating mucous membranes are often eye irritants.

Publications

No publications to date.

✓

Prepared by Susan Sama, ScD
Safety and Health Assessment and Research for Prevention Program
Washington State Department of Labor and Industries

Chronic Sinusitis and Occupational Respiratory Disease

Final Report for
Grant Number 5 RO3 OH03404-02

| | |
|---------------------------------------------------------------------------------------|-----------|
| I. GENERAL INTRODUCTION | 4 |
| A. SINUSITIS: A PREVALENT CONDITION WITH MEASURABLE EFFECTS | 4 |
| B. SINUSITIS AND ASTHMA: PHYSIOLOGICALLY AND PATHOGENICALLY RELATED | 6 |
| C. SINUSITIS: AN UNDER-APPRECIATED OCCUPATIONAL RESPIRATORY DISEASE | 7 |
| D. LITERATURE CITED | 10 |
| II. AN INVESTIGATION OF SINUS SYMPTOMS IN METAL WORKING FLUID EXPOSED WORKERS | 14 |
| A. INTRODUCTION | 14 |
| 1. ANALYSES OF METAL WORKING FLUID DATA SET | 14 |
| B. METHODS AND STUDY POPULATION | 15 |
| 1. POPULATION | 15 |
| 2. CROSS-SECTIONAL STUDY | 15 |
| 3. SIX DAY LONGITUDINAL PEF DATA | 16 |
| 4. EXPOSURE ASSESSMENT | 17 |
| 5. SINUS SYMPTOMS AND RESPIRATORY OUTCOMES | 17 |
| C. RESULTS | 20 |
| 1. SINUS SYMPTOMS AND ASTHMA | 20 |
| 2. SINUS SYMPTOMS AND CHRONIC RESPIRATORY SYMPTOMS RELATED TO ASTHMA | 21 |
| 3. OTHER RESPIRATORY SYMPTOMS | 22 |
| 4. SINUS SYMPTOMS AND MWF EXPOSURE | 22 |
| 5. SINUS SYMPTOMS AND BASELINE PULMONARY FUNCTION | 23 |
| 6. SINUS SYMPTOMS AND SERIAL PEF | 24 |
| D. DISCUSSION | 25 |
| 1. SINUS SYMPTOMS IN THE MWF COHORT | 25 |
| 2. SINUS SYMPTOMS AND THE DEFINITION OF SINUSITIS | 29 |
| 3. SINUSITIS IN OTHER OCCUPATIONS | 29 |
| 4. RECOMMENDATIONS | 31 |
| E. TABLES | 34 |
| F. LITERATURE SITED | 39 |
| III. EVALUATION OF SINUSITIS IN THE 1988 NATIONAL HEALTH INTERVIEW SURVEY DATA | 44 |
| A. INTRODUCTION AND DATA SET CONSTRUCTION | 44 |
| B. METHODS AND STUDY POPULATION | 45 |
| 1. POPULATION DEMOGRAPHICS | 45 |
| 2. CONDITIONS OF INTEREST | 45 |
| 3. ANALYSES | 46 |
| C. RESULTS | 47 |
| 1. DESCRIPTIVE ANALYSES | 47 |
| 2. MODELS: | 52 |
| 3. CONDITION ONSET | 55 |
| 4. JOB HISTORY DATA TO IDENTIFY OCCUPATION AND INDUSTRY AT TIME OF CONDITION ONSET | 56 |
| D. DISCUSSION | 58 |
| E. TABLES | 61 |

IV. INVESTIGATION OF SINUSITIS IN A LIME EXPOSED COHORT **94**

| | | |
|-----------|-------------------------------------|------------|
| A. | INTRODUCTION AND BACKGROUND | 94 |
| B. | METHODS AND STUDY POPULATION | 95 |
| 1. | POPULATION DEMOGRAPHICS | 95 |
| 2. | CONDITIONS OF INTEREST | 96 |
| 3. | ANALYSIS | 96 |
| C. | RESULTS | 97 |
| 1. | DESCRIPTIVE ANALYSES | 97 |
| 2. | MODELS | 99 |
| D. | DISCUSSION | 101 |
| E. | TABLES | 104 |
| F. | LITERATURE CITED | 123 |

V. INVESTIGATION OF SINUSITIS IN A BORAX EXPOSED COHORT **124**

| | | |
|-----------|-------------------------------------|------------|
| A. | INTRODUCTION AND BACKGROUND | 124 |
| B. | METHODS AND STUDY POPULATION | 126 |
| C. | RESULTS | 126 |
| 1. | DESCRIPTIVE ANALYSES | 126 |
| 2. | MODELS | 128 |
| D. | DISCUSSION | 130 |
| E. | TABLES | 131 |
| F. | LITERATURE SITED | 150 |

L GENERAL INTRODUCTION

A. SINUSITIS: A PREVALENT CONDITION WITH MEASURABLE EFFECTS

Sinusitis is a very prevalent problem in the general population. The National Institutes of Health estimate that chronic sinusitis affects as many as 30 million Americans (NIH Data Book, 1990). It is often associated with and initiated by rhinitis. Sinusitis is characterized by an inflammatory process of the mucous membranes in the various paranasal sinuses, which often occludes the small openings between the sinuses and the nose. This obstruction prevents adequate drainage of the sinus secretions leading to a build up of these fluids in the sinuses. This accumulation results in local inflammation and infection, often with coincident symptoms of pressure, pain, headache and fever. There are various treatments depending both on the severity and chronicity of the condition, ranging from steam inhalations and decongestants to surgery for improved drainage.

Acute sinusitis is usually a bacterial infection of the paranasal sinuses lasting from 7 to 14 days (Newman et al., 1994). Sinusitis is considered chronic when it persists for 3 months or more (Newman et al., 1994). These chronic infections are likely to result from a combination of various factors including impairment of mucociliary clearance, damage to the sinus mucosal lining and obstruction of the sinus ostia preventing adequate drainage. The chronic condition tends to involve less severe, low grade infections and is initially treated with antibiotics, decongestants and mucolytics. Diagnosis of chronic sinusitis is difficult because patients may be asymptomatic or they may have become accustomed to their level of disease. Diagnosis may involve sinus aspiration and culture, but is more likely to be done with sinus roentgenograms (Williams, 1993). Ultrasonography and computed tomography may also be used. Repeated infections can result in disease that is surprisingly resistant to these medical treatments. It is these cases that are likely to be referred for surgical interventions. These procedures are primarily designed to enlarge the openings between the sinus and the nose to prevent future blockages of these orifices. Persons advancing to this stage will generally have experienced considerable pain and discomfort, appreciable medical costs, and lost time.

Recently, a multidisciplinary Consensus Conference was held to expand the understanding of the physical and psychosocial sequelae of chronic rhinitis (Spector, 1995). They report that allergic

rhinitis affects 20% of the American population and accounts for over 11 million office visits a year. Rhinitis can cause significant impairment in one's quality of life and one's ability to function effectively in daily life. It is now believed to be a predisposing factor for the development or exacerbation of asthma, sinusitis, nasal polyps and otitis media. The authors estimate that allergic rhinitis affects more than half of all asthmatics, that it contributes to 33% of all cases of chronic sinusitis and that its related medical costs for 1995 will reach 2 billion dollars. The cost could reach 10 billion dollars if all related airway diseases are accounted for. There appears to be a link between allergic rhinitis and chronic sinusitis, although the direct pathogenic mechanisms remain unclear.

Current estimates from the National Health Interview Survey for 1993 tabulates the number of work-loss days associated with acute conditions for "other acute upper respiratory infections" which include the following conditions: acute sinusitis, acute pharyngitis, acute tonsillitis, acute laryngitis and tracheitis, and acute upper respiratory infections of multiple or unspecified sites. (National Center for Health Statistics, 1994) In 1992, the estimated work-loss days per 100 currently employed persons 18 years of age and over was 9.3. Although this reflects losses due to several upper respiratory illnesses, it is likely that acute sinusitis makes up the large majority of these cases.

Another estimate of the lost work time due to sinusitis comes from a large automotive manufacturing corporation, which show that in 1992, well over 1200 days were lost due to acute sinusitis and well over 1650 days were lost because of chronic sinusitis (Personal communication, D. Wegman). On initial examination of sickness and accident leaves in this same corporation, absences for chronic and acute sinusitis were approximately equal to absences for asthma, bronchitis, and pneumonia.

Results from the 1992 National Health Interview Survey provide further evidence of the pervasiveness of chronic sinusitis (National Center for Health Statistics, 1994). It ranks as the most prevalent of the reported chronic conditions when all age groups are combined. It is followed by arthritis and deformity or orthopedic impairments including the back and upper and lower extremities. The prevalence of chronic sinusitis in all ages in 1992 was 145.8 per 1000 persons in the United States, with prevalence increasing with age to a maximum between the ages of 45-64. Chronic sinusitis is more prevalent in females than males and is more prevalent in whites than blacks. Although sinusitis may often be considered quite innocuous in comparison to other respiratory diseases, its relationship to diseases of the lower airways is intriguing and notably relevant.

3. SINUSITIS AND ASTHMA: PHYSIOLOGICALLY AND PATHOGENICALLY RELATED

Clinically, sinusitis has long been associated with asthma (Bullen 1932, Gottlieb 1925, Chobot 1930). It is unclear whether sinusitis or other upper respiratory tract inflammation actually contributes to the development of asthma, but the two are often present simultaneously. There are numerous examples in the clinical literature demonstrating that asthma improves, sometimes dramatically with the treatment of coincident sinusitis (Friedman et al., 1984, Phipatanakul and Slavin, 1974, Businco et al., 1981, Cummings et al., 1983, Rachelefsky et al., 1984, Friday, Fireman, 1988). Brugman and colleagues developed a rabbit model demonstrating that sinusitis and lower airways responsiveness are associated (Brugman et al., 1993). They postulate that this association primarily results from the post-nasal dripping of cells or cell products into the lower airway. In reviewing the literature discussing the association between sinusitis and asthma, four mechanisms are hypothesized (Slavin, 1982). The first is hypersensitivity to the bacteria or bacterial products in the sinuses. The second is actual bacterial seeding from the sinuses to the lungs. The third is a reflex of the sympathetic nervous system via the vagal nerve resulting in bronchospasm. And the fourth is related to a blocking of the β -adrenergic receptors promoting constriction of the bronchial smooth muscle.

Rachelefsky and colleagues studied 48 children who had radiographic indications of sinus disease and chronic asthma that was difficult to manage (Rachelefsky, 1984). Various treatments were then administered to resolve the sinusitis in these children and their asthma was then re-evaluated. Seventy nine percent of the children (38) were able to discontinue use of bronchodilators. The investigators concluded that sinus disease may aggravate reactive airway disease in children. They encouraged proper, aggressive treatment of sinusitis, suggesting it may improve a significant portion of the "difficult to manage" asthmatic cases. Other researchers including Slavin and Phipatanakul provide evidence that supports an etiologic relationship between sinusitis and asthma (Sluder 1919, Blumgart 1924, Gottlieb 1925, Phipatanakul and Slavin 1974). Slavin and colleagues described case reports of 15 adults with bronchial asthma in whom paranasal sinusitis was considered to play an etiologic role. Each of these asthmatic patients had been treated with bronchodilator therapy for management of their asthma without success. However, after medical or surgical management of their paranasal sinusitis, these patients responded well to medical management of their asthma. Their medication requirements decreased significantly and their asthma was under much better control (Slavin et al., 1980). They also documented cases of patients who developed wheezing after

paranasal sinusitis (Phipatanakul, Slavin, 1974). Again, treatment of these cases of sinusitis resulted in prompt and quite marked improvement and in some cases resolution of bronchial asthma.

C. SINUSITIS: AN UNDER-APPRECIATED OCCUPATIONAL RESPIRATORY DISEASE

Sinusitis has also been demonstrated to be associated with occupation. Sinusitis may be associated with particulate exposure, although this has not been well-studied. Increased prevalence of chronic sinusitis has been reported in cotton workers, nickel workers, furriers, glassblowers and those working in a vegetable pickling and mustard producing facility (Hoult et al., 1993, Mastromatteo, 1988, Zuskin et al., 1988, 1993). It has also been observed in workers exposed to wood dust, grain and flour dusts, man made mineral fibers, and cutting oils (Tatken, 1987, Awad El Karin et al., 1986, Moulin et al., 1988, Kriebel, 1994). In most of these investigations, history of sinusitis was assessed by modified versions of the American Thoracic Society or British Medical Research Council questionnaire on respiratory symptoms. Some included review of medical records in addition to the questionnaire. Exposed groups had a two- to four-fold increase in risk of sinusitis when compared to unexposed groups.

Asthma is a debilitating, prevalent disease that appears to be increasing in both incidence and severity (Blanc, 1993, LaPlante, 1988, Ries 1986, Centers for Disease Control, 1992, Evans et al., 1987). It affects people of all ages, but is especially prevalent in those of working ages. It is therefore one of the leading causes of lost work days and limitations of work abilities. Because both the severity and incidence are increasing, the cost of asthma, both in terms of quality of life and economics will likely become even more significant. Perhaps more thorough recognition and treatment of occupationally related sinus disease is a relevant part of the asthma prevention strategy. Sinusitis may also be related to chronic airway obstruction or acute airway responsiveness currently measured by reductions in baseline or cross-shift Forced Expiratory Volume in the First Second (FEV1). Some of these responses that have been observed in occupational cohorts with exposures to respiratory irritants may in part be explained by one or more of the four postulated mechanisms relating the paranasal sinuses to bronchoconstrictive responses.

It is both appropriate and necessary to further explore the relationship between sinus problems, respiratory exposures and respiratory responses. It would also be quite useful to demonstrate how one or more of the currently postulated mechanisms could be initiated by, or at the very least,

associated with occupational exposures. The data to be investigated in the proposed work do not allow specification of mechanisms, but the current mechanisms can be considered in relation to occupational exposures. The relationship between exposure to respiratory irritants and the pathogenesis of sinus symptoms is also likely to have relevance when considering other respiratory sequelae. Currently, little importance is bestowed upon chronic sinusitis. It is mentioned in studies as if it were simply a respiratory irritant symptom unrelated to other forms of respiratory morbidity. Since this is not likely to be the case, perhaps we can take advantage of the fact that upper respiratory symptoms such as sinusitis, are relevant to lower airway disease.

Some of the occupational cohorts with increased prevalences of sinusitis also have increased rates of sino-nasal cancer. These groups include metal workers and workers exposed to nickel, wood dust and possibly cutting oils (Tomatis 1990, Higginson 1992, Roush 1980). There are at least two potential links between sinusitis and this rare neoplasm. First, it is possible that repeated inflammation in the sinuses and nose from exposure to these irritants and carcinogens results in hyperplastic cellular changes of the epithelial lining. These morphologic changes may eventually lead to the development of sino-nasal cancer. Second, it is also likely that chronic inflammation in these respiratory passages impairs the normal mechanisms designed to remove foreign toxins and particulate from the sino-nasal mucosa. The nose and paranasal sinuses are lined with ciliated respiratory epithelium. This ciliated surface is covered with two layers of mucus. Clearance is accomplished by the trapping of particulate in the mucus and subsequent movement of this contaminated mucus via the beating of the cilia. The flow of the mucous is bilateral. Close to the nostril openings, mucus is directed outward, while in the interior portions of the upper airways, flow is posterior and inferior towards the pharynx; where the mucus can be swallowed. Exposure to irritants and carcinogens including nickel, formaldehyde, cutting oil, and wood dust, have been demonstrated to diminish ciliary beating, decrease numbers of ciliated cells, and/or reduce rates of mucociliary clearance (Mastromatteo 1988, Irlander et al. 1980, Tatken 1987). This impairment of the removal of toxins increases contact time, which is likely to translate into higher effective tissue doses of these irritants and carcinogens. Because the incidence of sino-nasal cancer is rare, monitoring sinusitis in hopes of predicting cancer is not very useful. It is however, further compelling evidence that chronic insults to the upper respiratory tract ought to be considered more seriously and indicates that identification and treatment of chronic sinus inflammation is important.

Relationships between occupational exposures to dusts and chronic respiratory symptoms have been successfully assessed in previous community-based investigations. Korn and associates demonstrated significant associations between occupational exposure to dust and chronic respiratory symptoms including chronic cough, chronic phlegm, persistent wheeze and breathlessness in a large population-based study (Korn et al., 1987). In dust exposed individuals, the adjusted odds ratios for these symptoms ranged from 1.32 to 1.60. When comparing dust exposed individuals to unexposed subjects, there was evidence of a higher prevalence of chronic obstructive pulmonary disease as measured by a low FEV1/FVC ratio (<0.60). Chronic non-specific lung disease (CNSLD) was examined using a job exposure matrix in the Zutphen Study, a subset of the Seven Countries Study (Heederik, 1989). Diagnosis of CNSLD by a physician and previous treatment for bronchitis and/or emphysema were most strongly associated with exposure to fumes, organic dust, paint, adhesives, heat and outdoor work. The authors concluded that organic dust seemed to be an important factor in the development of CNSLD. In a third study of dust exposure and chronic lung disease, Kauffman and colleagues observed an accelerated rate of decline in FEV1 in workers exposed to organic and inorganic dust among Parisian workers followed for 12 years (Kauffman, 1982).

It is important to reframe the manner in which sinusitis or sinus symptoms are considered in occupational studies. There are known occupational exposures that are associated with the development of asthma. Flour dust and machining fluids are just two examples. The relationship between asthma and sinusitis has also been well documented in the clinical literature. In the case of each of several of these occupational exposures, there is also evidence of increase prevalence of sinusitis. It is therefore possible that some fractions of these incident cases of asthma develops secondarily to, or are exacerbated by, chronic sinus infections. Unfortunately, this fraction remains unknown, as it has not been explored in occupational cohorts. It is important to better define the relationship between sinusitis and asthma in the occupational health literature, as it could result in more effective prevention and treatment of upper and lower airways diseases. If our hypothesis is correct, and we see associations between sinusitis and lower airways diseases, we may be able to make better use of reports of chronic sinusitis and sinus trouble. We may be able to recommend that questions relating to sinus symptoms be included in future investigations of occupational exposures to respiratory irritants. This work may begin to develop the framework or backdrop against which sinus

symptoms can be considered work related and can be considered in the context of their relation to lower airway diseases.

D. LITERATURE CITED

Awad El Karim MA, Gad El Rab MO, Omer AA, El Haimi YAA. Respiratory and Allergic Disorders in Workers Exposed to Grain and Flour Dusts. *Archives of Environmental Health*. 1986; 41:297-301.

Blanc PD, Jones M, Besson C, Katz P, Yelin E. Work disability among adults with asthma. *Chest*. 1993; 104:1371-1377.

Blumgart HL. A study of the mechanisms of absorption of substances from the nasopharynx. *Arch Intern Med*. 1924; 33:415.

Brugman SM, Larsen GL, Henson PM, et al.: Increased Lower Airways Responsiveness Associated with Sinusitis in a Rabbit Model. *Am Rev Respir Dis*. 1993; 147:314-20.

Bullen SS. Incidence of asthma in 400 cases of chronic sinusitis. *J. Allergy*. 1932; 402-407.

Businco L, Fiore L, Frediani T, Artuso A, et al.: Clinical and therapeutic aspects of sinusitis in children with bronchial asthma. *Int J Pediatr Otorhinolaryngol* 1983; 3:287-94.

Centers for Disease Control. Asthma-United States, 1980-1990. *MMWR* 1992; 41:733-35.

Chobot R. Asthma in children: An analysis of 84 cases. Incidence of sinusitis in asthmatic children. *Am J Dis Child* 1930; 39:257-63.

Cummings NP, Lere JL, Wood R, Adinoff A. Effect of treatment of sinusitis on asthma and bronchial reactivity: results of a double-blind study (abstract). *J Allergy Clin Immunol* 1983; 73 (Suppl): 143.

Cummings NP, Wood RW, Lere JL, Adinoff AD. Effect of Treatment of Rhinitis/Sinusitis on Asthma: Results of a Double Blind Study. *Ped Res*. 1983; 17:373A.

Evans R, Mullally D, Wilson R, Gergen PJ, Rosenberg HM, Grauman JS, et al. National trends in the morbidity and mortality of asthma in the US: prevalence, hospitalization, and death from asthma over two decades: 1965-1984. *Chest*. 1987; 91:65s-74s.

Friday Jr. GA, Fireman P. Sinusitis and asthma: Clinical and pathogenic relationships. *Clinics in Chest Medicine*. 1988; 9:557-565.

Friedman R, Ackerman M, Wald E, Casselbrant M, Friday G, Fireman P. Asthma and bacterial sinusitis in children. *J Allergy Clin Immunol*. 1984; 74:185-189.

Gottlieb MF. Relation of intranasal disease in the production of bronchial asthma. *JAMA*. 1925; 85:105-107.

Heederik D, Pouwels H, Kromhout H, Kromhout D. Chronic Non-Specific Lung Disease and Occupational Exposures Estimated by Means of a Job Exposure Matrix: The Zutphen Study. *Int J of Epidemiology*. 1989; 18:382-389.

Higginson J, Muir CS, Munoz N. Human cancer: Epidemiology and environmental causes. Cambridge Monographs on Cancer Research, Cambridge University Press, 1992.

Hoult B, Sigsgaard T, Tuxford AF. A Comparison of Micro-organisms, Endotoxin Levels and Respiratory Symptoms in Wool Mills and Cotton Mills. 1993 Proceedings, Beltwide Cotton Council of America, Memphis, TN, 281-284.

Irlander K, Hellquist H, Edling C, Odkvist L. Upper airway problems in industrial workers exposed to oil mist. *Acta Otolaryngol*. 1980; 90:452-459.

Kauffman F, Drouet D, Lellouch J, Brille D. Occupational exposure and 12-year spirometric changes among Paris area workers. *Br J Ind Med*. 1982; 39:221-232.

Korn EL, Whittemore AS. Methods for analyzing panel studies of acute health effects of air pollution. *Biometrics*. 1979; 35:795-802.

Korn RJ, Dockery DW, Speizer FE, Ware JH, Ferris Jr. BG. Occupational Exposures and Chronic Respiratory Symptoms: A Population Based Study. *Am Rev Respir Dis*. 1987; 136:298-304.

Kriebel D, Eberiel D, Eisen E, Moure-Eraso R, Kumar S, Sama SR, Smith M, Virji MA, Woskie S, Hammond K, Christiani D, Milton D, Tolbert P. Final Report: Field investigations of the acute respiratory effects of machining fluids 1994 (unpublished).

LaPlante M. Data on disability from the National Health Interview Survey 1983-1985: an InfoUse report. Washington DC: US National Institute on Disability and Rehabilitation Research, 1988.

Mastromatteo E. Nickel and Its Compounds. *Occupational Medicine: Principles and Practical Applications*, Second Edition, C. Zenz, Editor; Chicago, Year Book Medical Publishers, Inc. 1988;597-608.

Moulin JJ, Wild P, Mur JM, Caillard JF, Massin N, Meyer-Bisch C, Toamain JP, Hanser P, Liet S, DuRoscoat MN, Segala A. Respiratory health assessment by questionnaire of 2024 workers involved in man-made mineral fiber production. *Int Arch Occup Environ Health*. 1988; 61:171-178.

National Center for Health Statistics. Current Estimates from the National Health Interview Survey, 1993. Hyattsville, MD: Series 10, no. 190. DHHS publication PHS 95-1518.

Newman LJ, Platts-Mills TAE, Phillips CD, Hazen KC, Gross CW. Chronic sinusitis: Relationship of computed tomographic findings to allergy, asthma, and eosinophilia. *JAMA*. 1994; 271:363-367.

Nguyen KL, Corbett ML, Garcia DP, Eberly SM, Massey EN, Le HT, Shearer LT, Karibo JM, Pence HL. Chronic sinusitis among pediatric patients with chronic respiratory complaints. *J Allergy Clin Immunol.* 1993; 92:824-830.

NIH Data Book 1990. Bethesda, MD:US Dept of Health and Human Services; 1990:table 44. Publication 90-1261.

Phipatanakul CS, Slavin RG. Bronchial asthma produced by paranasal sinusitis. *Arch Otolaryngol.* 1974; 100:109-12.

Rachelefsky GS, Goldberg M, Katz RM, Boris G, Gyepes MT, Shapiro MJ, Mickey MR, Finegold SM, Siegel SC. Sinus disease in children with respiratory allergy. *J. Allergy Clin Immunol.* 1978; 61:310-314.

Rachelefsky GS, Katz RM, Siegel SC. Chronic sinus disease with associated reactive airway disease in children. *Pediatrics.* 1984; 73:526-529.

Ries PN. Current estimates from the National Health Interview Survey, United States 1984. DHHS Publication No. (PHS) 86-1584. Hyattsville, MD: US Department of Health and Human Services, 1986.

Roush GC, Meigs JW, Kelly J, Flannery JT, Burdo H. Sinonasal cancer and occupation: case-control study. *Amer J Epidemiol.* 1980; 111:183-193.

Slavin RG, Cannon RE, Friedman WH, Palitang E, Sundaram M. Sinusitis and bronchial asthma. *J Allergy Clin Immunol.* 1980; 66: 250-257.

Slavin RG. Relationship of nasal disease and sinusitis to bronchial asthma. *Annals of Allergy.* 1982; 49:76-80.

Slavin RG. Asthma and sinusitis. *J Allergy Clin Immunol.* 1992; 90:534-537.

Sluder G. Asthma as a nasal reflex. *JAMA.* 1919; 73:589.

Spector SL. The chronic airway disease connection: Redefining rhinitis, Consensus conference statement. Office of Continuing Medical Education, UCLA School of Medicine, April, 1995.

Tatken RL. Health Effects of Exposure to Wood Dust. A Summary of the Literature. US Department of Health and Human services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Standards Development and Technology Transfer, 1987.

Tomatis L. Cancer: Causes, Occurrence and Control. International Agency for Research on Cancer, IARC publication number 100, Oxford University Press, New York, 1990.

Williams JW Jr, Simel DL. Does this patient have sinusitis? Diagnosing acute sinusitis by history and physical examination. *JAMA*. 1993; 270:1242-1246.

Zuskin E, Skuric Z, Kanceljak B, Pokrajac D, Schachter EN, Witek TJ. Respiratory symptoms and lung function in furriers. *Am J Indus Medicine*. 1988; 14:189-196.

Zuskin E, Butkovic D, Schachter EN, Mustajbegovic J. Respiratory Function in Workers Employed in the Glassblowing Industry. *Am J Indus Medicine*. 1993; 23:835-844.

Zuskin E, Mustajbegovic J, Schachter EN, Rienzi N. Respiratory symptoms and ventilatory capacity in workers in a vegetable pickling and mustard production facility. *Int Arch Occup Environ Health*. 1993; 64:457-461.

II. AN INVESTIGATION OF SINUS SYMPTOMS IN METAL WORKING FLUID EXPOSED WORKERS

A. INTRODUCTION

Sinusitis is a prevalent condition in the general population (NIH Data Book 1990). It has also been anecdotally reported to be prevalent in occupationally exposed cohorts. Often the condition is preceded by and initiated by rhinitis (an inflammation of the nasal passages, which may or may not be allergic in nature). Clinically sinusitis is well recognized to be associated with the exacerbation and or development of asthma (Blumgart 1924, Bullen 1932, Gottleib 1925, Chobot 1930, Friedman et al., 1984, Phipatanakul and Slavin, 1974, Businco et al., 1981, Cummings et al., 1983, Rachelefsky et al., 1984, Friday and Fireman, 1988, Sluder 1919). There has not been much epidemiologic examination of these relationships in occupational cohorts. Most investigations of occupational respiratory exposures do not report rates of sinus symptoms. The standard respiratory health questionnaires do not ask questions about sinus symptoms. Given the clinical relationship that has been established between asthma and sinusitis, it is relevant to explore the nature of the relationship between these two conditions in an occupationally exposed cohort. Data collected in a metal working fluid (MWF) exposed cohort provide an opportunity to do this in addition to relating sinus symptoms to other measures of respiratory disease (symptoms and cross-shift decline in FEV₁).

1. Analyses of Metal Working Fluid Data Set

A study of respiratory health among automotive workers exposed to metal working fluids (MWF) provided an opportunity to investigate the associations between the presence of sinus symptoms and the presence of respiratory health outcomes in an occupationally exposed cohort. Data were collected on history of asthma, sinus symptoms, measures of lung function, reports of lower respiratory symptoms and "work-related" sinus symptoms, as measured by questions derived from Rylander's organic dust questionnaire. The relationships between sinus symptoms (overall and "work-related")

and these various measures of pulmonary health were then evaluated in this cohort of metal working fluid (MWF) exposed workers.

B. METHODS AND STUDY POPULATION

1. Population

The study was conducted in a large transmission manufacturing facility in the midwestern United States. Two separate pieces of this study are utilized in these analyses: data collected cross-sectionally on the entire cohort and data collected from a subcohort who performed peak expiratory flow maneuvers for six consecutive days. The primary cohort consisted of 386 hourly day-shift workers. Two hundred and sixteen were machinists exposed either to soluble or straight MWF (not synthetic MWF), while 170 were working in assembly, tool and gauge rooms or office areas.

The machinists represented 87% of the eligible day-shift workers, while the non-machinists represented 70%. The population was primarily white (86.5%) and male (88.9%) with a mean age of 42.2 years and included 34 asthmatics. Smoking history revealed: 32.9% current smokers, 32.6% ex-smokers, 34.5% never smokers. Mean duration of employment was 16.9 years.

2. Cross-Sectional Study

The 386 participants in the cross-sectional study were tested with spirometry and a standardized respiratory symptom questionnaire on a single day, both pre- and post-shift. Spirometry was conducted by technicians who had successfully completed a NIOSH-certified training course. An eight-liter water seal survey spirometer (W.E. Collins Co., Braintree, MA) was used in conjunction with O.M.I. spirometric software (O.M.I., Houston, TX), which interpreted the flow-volume data collected from the spirometer. The spirometers were calibrated with a three-liter syringe before both the pre- and post-shift test sessions. The American Thoracic Society criteria for standardization of spirometric measures of pulmonary function were employed for all spirometric tests (ATS, 1987; Ferris, 1978). The maximal forced expiratory volume in the first second (FEV₁) from an acceptable maneuver was used in all analyses. Cross-

shift change in FEV₁ was calculated as post-shift FEV₁ minus pre-shift FEV₁ as a fraction of pre-shift FEV₁.

The American Thoracic Society Questionnaire was administered to the participants by technicians. It was augmented with an irritant symptom matrix designed for use in studies of organic dusts (Rylander, 1990). The matrix allowed the identification of "regular" symptoms (apart from colds), sinus symptoms, and eye, nose and throat irritation. The questions also asked whether the symptom was work related, if the symptom was better while on holiday, and if the symptom was worse the first day back to work after holidays. If an individual had a positive response to any one of these questions the symptom in question was considered "work-related". Of the "work-related" symptoms being reported, these analyses only include sinus symptoms.

3. Six Day Longitudinal PEF Data

A subset of the cross-sectional study was recruited for a longitudinal PEF study. They included those participants who experienced a cross-shift decline in FEV₁ greater than or equal to 4%, supplemented by participants who reported a specific constellation of symptoms, which as a group, were more associated with cross-shift FEV₁ decrement.

The symptoms were usual cough, usual phlegm, wheeze without cold, and throat irritation.

Participants were trained in the use of a mini-Wright peak flow meter (Clement Clarke, Columbus, OH). They were asked to perform the PEF maneuvers five times a day: upon arising, starting work, lunch time, leaving work, and bedtime. They were asked to perform three to five blows per session, with a goal of obtaining three blows within 20 liters per minute of their highest effort. Participants were asked to record all their measurements in a diary noting the time of each session as well as responses to questions regarding the presence of a cold, flu, asthma or allergy symptoms.

Participants were encouraged to do their blows at the same time each day. The maximum PEF from each session was used in these analyses.

4. Exposure Assessment

Personal samples as well as descriptive industrial hygiene data on the work stations were collected for each participant. Personal inhalable mass aerosol concentrations were collected for each individual on their day of study. A seven hole sampler was used on the face of a filter cassette to collect the airborne particulate (Health and Safety Executive, 1986). The filter cassette was attached to a personal sampling pump (Gilian Instruments) that was running at 2 liters per minute. The filters were analyzed gravimetrically. Elemental analysis for sulfur was completed on a subset of these samples. Descriptive environmental data collected at the work station/machine of each individual included such things as: type of MWF used, type of metal working operation, type of base metal being machined, proximity of the worker to the source of the MWF, number of hours of machining, number of parts machined, cycle time to machine one part, temperature and humidity.

5. Sinus Symptoms and Respiratory Outcomes

Cross-sectional analyses: Initially, descriptive analyses were performed. Simple stratified analyses were then completed by constructing two by two tables. Crude risk ratios were calculated for these analyses. Sinus symptoms were evaluated as a whole in addition to being restricted to only those reported as "work-related". Logistic and linear regression models were also constructed, beginning with simple univariate and bivariate analyses and ending with more complex models. Prevalence ratios were estimated using Breslow-Cox modeling. This method of estimating the risk ratio was more appropriate than logistic regression in these data, as the condition being studied is not rare (Axelson, 1994). Lee and Axelson have demonstrated that with a common outcome, the odds ratio tends to overestimate the risk ratio (Axelson, 1994; Lee and Chia, 1994). Because this approach is somewhat new, logistic models were also fit, and results compared.

The outcome variable was a dichotomous term indicating the presence or absence of regularly reported sinus symptoms. Explanatory variables included selected respiratory function measures, chronic respiratory symptoms and potential confounders. The

explanatory variables were treated as both continuous and dichotomous forms. The spirometric measures that were evaluated included FEV₁, FVC, percent predicted of FEV₁ below 80%, percent predicted of FVC below 80% and the FEV₁-FVC ratios below 0.70 and 0.60. The percent decline across the work shift in each of these measures was also calculated. These variables were considered as dichotomous in the following ways: % in cross shift FEV₁, PEF dichotomized above and below 5%, amplitude percent mean (APM=daily maximum PEF- daily minimum PEF/daily mean) above and below 20%, percent predicted values of FVC and FEV₁ above and below 80%, and FEV/FVC ratios below 0.75 and 0.60.

In order to investigate the hypothesis that those with more recent onset of the disease may be more likely to report chronic sinus symptoms, asthma was evaluated in 2 different ways. It was dichotomized into asthma that was diagnosed prior to employment at the automotive plant (pre-hire asthma) versus that which was diagnosed after employment (post-hire asthma). A second stratification divided the asthmatic cases by the number of years since the onset of the disease. Two divisions were made: diagnosis within the past 10 years (>10 years) and diagnosis more than 10 years ago (>10 years). In each of these cases, the reference group included only non-asthmatics.

The other respiratory symptoms treated dichotomously as explanatory variables included: doctor diagnosed bronchitis, doctor diagnosed chronic bronchitis, ever having wheezed to shortness of breath, ever having been treated for wheezing, ever wheezing with colds, ever wheezing apart from colds. Potential confounders such as age, gender, race, and smoking were also evaluated. An example of the generic form of the models follows:

$$\text{Sinus Symptoms} = \beta_0 + \beta_1 \text{ Respiratory health outcome} + \beta_2 \text{ Age} + \beta_3 \text{ Gender} \\ + \beta_4 \text{ Packyears} + \beta_5 \text{ Current Smokers} + \beta_6 \text{ Ex-Smokers}$$

Longitudinal PEF Analysis: Because the PEF data collected over the six day longitudinal period included repeated measures (within subject), the analytical method used needed to account for the non-independence of these observations. SAS Mixed

models were used for this purpose (SAS Institute Inc., 1992). These models are mixed analysis of variance (ANOVA) models with both fixed and random effects. Because the day-to-day correlations between individual PEF measurements were low and relatively constant in these data the models presented specified a "simple" or "exchangeable" working correlation structure. This structure based the model around the assumption that the correlation between any pair of PEF measurements for a person was the same as that for any other pair of measurements regardless of the time at which the measurements were taken.

The following PEF outcomes were evaluated as outcomes of the mixed ANOVA models: cross-shift change in PEF (absolute and as a percent of pre-shift PEF), change in PEF from pre-shift to arising the following day (absolute and as a percent of pre-shift PEF), daily amplitude or amplitude percent mean, and arising amplitude or anchored amplitude percent mean. Explanatory variables included a dichotomous term indicating presence or absence of sinus symptoms and potential confounders such as age, gender, race, asthma (for PFT outcomes) smoking and exposure to inhalable mass aerosol concentration.

Background: On average, aerosol exposures to MWF were lower (Kriebel et al., 1996; Woskie et al., 1995) than in previously studied machining environments (Kennedy et al., 1989; Milton et al., 1995; Robins et al., 1995). There were, however clear differences between the machining and non-machining exposures; for example, machinists had higher average inhalable aerosol mass concentrations ($GM=0.18 \text{ mg/m}^3$) than did non-machinists ($GM=0.05 \text{ mg/m}^3$). Sulfur was present in the highest concentration of all of the elements that were measured for the study. There was evidence of an association between cross-shift decline in FEV_1 and both mass aerosol concentration and sulfur exposure (Sama, et al., 1996). Baseline pulmonary function was normal in both machinists and non-machinists, although machinists with exposure to soluble MWF had an average FEV_1 that was 115 ml lower than that of non-machinists ($p=0.05$). The general demographics of the population are as follows: mean age of 42 years, 86.5%

male, 88.9% male, smoking status (current, ex and never) divided the population roughly into thirds, mean duration of employment was 16.9 years and mean duration of exposure was 11.4 years.

C. RESULTS

Approximately 43% of the population reported sinus symptoms. Women tended to report more sinus symptoms than did men (55% versus 42%) (Table 1). Sinus symptoms appeared to be more prevalent in the younger workers. Fifty percent of those under age 35 reported sinus symptoms, while only 38% of those older than 45 reported it. The prevalence of sinus symptoms was roughly equal in both races (44% in blacks and 37% in whites) and in the three smoking categories (current-41%, ex-45%, never-43%). The prevalence of sinus symptoms tended to decrease with increasing tenure at the plant. For example, those who had been employed at the facility for 15 or more years had a sinus symptom prevalence of 37%, while 47% of those who had seniority less than 15 years reported regular sinus symptoms.

1. Sinus Symptoms and Asthma

There was little evidence (Table 2) of an overall relationship between doctor diagnosed asthma and sinus symptoms (PR 1.3, 95% CI 0.7-2.5, $p=0.38$). Because we hypothesized that work related exposures might initiate sinusitis which would then be associated with asthma, we expected that the relationship between sinus symptoms and asthma might be different in cases where asthma was diagnosed after employment versus those that were diagnosed before employment. We therefore divided asthma into pre- and post-employment asthma and the relationship with sinus symptoms was then reassessed, again using non-asthmatics as the reference group. There was no association between sinus symptoms and pre-employment asthma (PR 1.1, 95% CI 0.5-2.3, $p=0.86$), however for post-employment asthma, there was suggestive evidence of an association (PR 2.7, 95% CI 0.7-10.0, $p=0.14$).

In an attempt to address potential selection bias and possible recall bias an alternative approach to examining the effects of time since asthma diagnosis was utilized. Asthma was stratified on years since onset of the disease, greater or less than 10 years (Table

2). Among those with asthma onset in the last 10 years, there was a strongly increased prevalence of sinus symptoms, while for those with asthma of more than 10 years' duration, there was essentially no relationship with asthma. Work-related sinus symptoms demonstrated even stronger associations with both post-hire asthma and years since asthma onset. Of the two stratifications, those cases of asthma diagnosed within the past 10 years had the strongest association with work-related sinus symptoms (PR=6.6, 95% CI 1.1-42.0).

2. Sinus Symptoms and Chronic Respiratory Symptoms Related to Asthma

The relationships between sinus symptoms and other respiratory symptoms associated with obstructive lung disease were also evaluated. These symptoms included doctor diagnosed bronchitis and chronic bronchitis, ever having wheezed to shortness of breath, ever having been treated for wheeze, ever wheeze with colds and ever wheeze occasionally apart from colds (Table 3). Positive associations were observed for each of these symptoms. The relationship to bronchitis was the strongest (PR 1.5, 95% CI 1.1-2.0, $p=0.004$). "Ever having been treated for wheeze" was also associated with sinus symptoms although it had a wide confidence interval (PR 1.5, 95% CI 0.84-2.6, $p=0.18$). This symptom is likely to identify the asthmatics in the population.

When these analyses are restricted to those reporting "work-related" sinus symptoms, most of the associations were stronger (Table 3). Those reporting "work-related" sinus symptoms were 62 percent more likely to have had doctor diagnosed bronchitis ($p=0.006$). They had an 88 percent higher risk of having had doctor diagnosed chronic bronchitis ($p=0.07$) and of ever having been treated for wheeze ($p=0.05$).

These relationships were investigated for possible confounding by stratification and then by including potential confounders and modifiers in the models. These factors included age, race, gender, smoking status, asthma status and exposure. Breslow Cox proportional hazards models demonstrated similar findings. Potential confounders and modifiers including age, smoking status, asthmatic status, and exposure were evaluated in these models. These factors did not confound or modify the observed associations.

Logistic models were also constructed to evaluate these associations and to compare results with the less conventional Breslow-Cox models (data not shown). In all cases the results were similar, and as expected the logistic models produced results with larger point estimates and narrower confidence intervals. This is expected when the disease outcomes being evaluated are not rare, which is the case in these data.

3. Other Respiratory Symptoms

Sinus symptoms were also evaluated in relation to other respiratory symptoms using Breslow-Cox models. Those reporting regular eye, nose or throat irritation had high prevalence of sinus symptoms. Those reporting phlegm production also had a high prevalence of sinus symptoms. Age, smoking, and exposure were not modifying or confounding these relationships.

4. Sinus Symptoms and MWF Exposure

The relationships between MWF exposures and chronic sinus symptoms were assessed (Table 4). Machinists were more likely to report sinus symptoms than were non-machinists (PR 1.2, 95% CI 1.0-1.6, $p=0.09$). Among machinists, those working with straight MWF had a thirty percent higher prevalence than non-machinists and those using soluble MWF demonstrated a 20 percent excess prevalence (PR 1.3, 95% CI 1.0-1.8, $p=0.08$ versus PR 1.2, 95% CI 0.9-1.5, $p=0.24$). When exposure was stratified trichotomously, there was evidence of increased prevalence of sinus symptoms with medium ($0.08-0.24 \text{ mg/m}^3$) and high ($>0.24 \text{ mg/m}^3$) exposures compared to those with low ($<0.08 \text{ mg/m}^3$) exposure although there was no evidence of a trend (data not shown). Those with medium exposure had a 22 percent increase in prevalence (95% CI 0.90-1.6, $p=0.18$) of having sinus symptoms, while those with high exposure had a 15 percent excess prevalence (95% CI 0.90-1.5, $p=0.35$). Duration of MWF exposure was not associated with excess risk of sinus symptoms. Neither duration of exposure to MWF for more than 5 years (PR=0.93 95% CI 0.71-1.22) nor more than 10 years (PR=0.88 95% CI 0.69-1.12) was associated with excess prevalence of sinus symptoms. These associations were not found to be confounded or modified by symptoms or demographic variables.

When the relationship between exposure and "work-related" sinus symptoms was evaluated, a similar, but stronger picture emerged (Table 4). Again machinists were more likely than non-machinists to report sinus symptoms (PR 1.5 95% CI 1.2-1.8, $p=0.001$). Those machinists working with straight MWF (PR 2.1 95% CI 1.2-3.4, $p=0.005$) demonstrated higher risk than those working with soluble MWF (PR 1.7 95% CI 1.1-2.6, $p=0.03$). Analyses using trichotomous cuts of inhalable mass aerosol concentration showed a two-fold risk of prevalent sinus symptoms in those with medium (PR 2.1 95% CI 1.2-3.6, $p=0.008$) and (PR 2.0 95% CI 1.2-3.5, $p=0.009$) high MWF exposure compared to those with low exposures. The risk had both a larger magnitude and greater strength in each of these analyses when compared to analyses of all sinus symptoms, without regard to work relatedness of the symptom. Duration of MWF exposure of five years or more demonstrated a positive association with work-related sinus symptoms (PR=1.3, 95% CI 1.1-1.6).

The following seven operations were evaluated in relation to chronic sinus symptoms: broach, chuck, drill, grind, multiple drill, turn and a mixture of various operations. The prevalence of sinus symptoms ranged from 41% for drill to 50% for broach and the mixed category. Aluminum, iron and steel were the part metals evaluated, and the prevalence of sinus symptoms ranged from 44% for steel to 51% for iron. In neither case (operation or part metal) was there evidence suggestive of an association of increased prevalence of sinus symptoms. Those reporting sinus symptoms had similar exposures when compared to those not reporting sinus symptoms, in terms of mean number of years spent working with MWF, mean number of assembly years, mean number of years of employment, and mean duration of MWF years.

5. Sinus Symptoms and Baseline Pulmonary Function

There was essentially no evidence suggesting that those with sinus symptoms were more likely to have a percent predicted FEV₁ below 80% or an FEV₁-FVC ratio below 0.60. These findings were similar when sinus symptoms were restricted to those that were reported to be work related. There was no evidence that confounding by symptoms or demographic variables was obscuring these associations.

Sinus symptoms and cross-shift change in pulmonary function:—There was no evidence of a relationship between cross-shift decline in FEV₁ and sinus symptoms (PR 0.88, 95% CI 0.5 -1.5) even when work-related sinus symptoms were selected out (PR 1.02 , 95% CI 0.5 - 2.0). Again, there was no indication that negative confounding might be masking sinus symptom-cross-shift FEV₁ associations.

6. Sinus Symptoms and Serial PEF

All 48 machinists who either demonstrated a cross-shift decrement in FEV₁ or reported a specific constellation of symptoms participated in an intensive serial peak expiratory flow study for six consecutive days. The 48 who participated in the six day longitudinal study were approximately 88% of those eligible to participate. Only one diary could not be included in the analyses and two others submitted data for 3 days or less. These longitudinally collected PEF data were evaluated in relation to sinus symptoms to investigate the hypothesis that chronic sinus symptoms were related to various measures of PEF including: cross-shift change in PEF, a change in PEF from pre-shift to arising the next day, amplitude percent mean (daily max PEF – daily min PEF/ daily mean PEF) and an anchored amplitude percent mean (daily max PEF – arising PEF/ daily mean PEF).

There was no evidence of an association between sinus symptoms and daily amplitude in PEF or with cross shift change in PEF (whether measured in absolute terms or in percentage of pre-shift value) (data not shown). There was only weak evidence of associations between "arising amplitude" (change in PEF from pre-shift to arising the following day) and reports of sinus symptoms. However, these relationships were found to be quite different in smokers and non-smokers. Among current and ex-smokers the presence of sinus symptoms was not associated with increased amplitude, while among never smokers, "next-day" amplitude (change in PEF from pre-shift to arising the next day) was considerably lower in those reporting sinus symptoms. Exposure, asthma and various demographic variables did not confound or modify this association.

D. DISCUSSION

1. Sinus Symptoms in the MWF Cohort

The primary purpose of this investigation was to evaluate the relationship between chronic sinus symptoms and asthma in an occupational cohort. Secondary objectives were to investigate potential associations with other lower respiratory conditions or measures that also relate to obstructive processes of the lower airways. The design of the sinus question, in the form of a matrix, allowed the symptom to be classified as work-related or not. This led to a set of analyses that enabled comparisons between work-related and non-work-related sinus symptoms. Various respiratory measures outcomes were studied for this purpose including: cross-shift change in FEV₁, percent predicted FEV₁, FVC and PEF. Respiratory symptoms often associated with lower respiratory disease processes included measures of: bronchitis, chronic bronchitis, wheeze, cough, phlegm, shortness of breath, and chest tightness. Three upper respiratory symptoms, eye, nose and throat irritation were also evaluated in relation to chronic sinus symptoms. Because this was an occupationally exposed cohort, the relationship between chronic sinus symptoms and exposure was also evaluated using the following variables: duration of employment, machining versus non-machining, type of MWF (straight or soluble), mass aerosol concentration, operation type and part metal being machined.

Cross-sectional data present some difficulties in terms of calculating rates of disease. This problem is even further complicated in studies of working populations because of selection pressures that result in the movement of workers away from jobs or exposures that are causing them discomfort or illness (healthy worker selection). Because cross-sectional data in effect, provide a snapshot of disease processes in a population, one has to make assumptions in terms of the timing of the relationship between exposure and disease. The picture is also likely to be somewhat inaccurate because some of the cases are no longer among the population or have changed their exposure status because of their discomfort or illness. These factors were problematic in these analyses when considering the relationship between asthma and sinus symptoms. Two separate

approaches were used to address these problems. The first was based on the hypothesis that asthma which developed after employment in the plant was more likely to be related to exposure and therefore sinus symptoms than pre-employment asthma. The second approach (dichotomizing asthma cases into those diagnosed within the past 10 years versus more than 10 years ago) speaks more to the purported selection of asthmatics away from exposures that exacerbate or lead to their conditions. Although most of the post-hire asthmatics are contained in this group, the categorization further restricts the post hire asthmatics to those most recently diagnosed. This in effect should streamline the exposure-related cases and make the relationship between sinus symptoms and asthma even more visible or apparent.

There was little evidence of a relationship between all cases of physician diagnosed asthma and chronic sinus symptoms. We hypothesized that the newer onset cases were more likely to be related to sinus symptoms if exposure was largely responsible for causing irritation and creating chronic sinus symptoms. This chronic inflammation via one of the postulated mechanisms would then lead to the development and/or exacerbation of asthma. Stronger relationships were indeed observed with asthma of more recent onset (Table 2). However, because the number of post hire asthmatics was small, the risk ratios were associated with wide confidence intervals.

It was hypothesized that evaluation of the work-relatedness of sinus symptoms would provide the opportunity to more accurately identify those individuals who were developing chronic sinus symptoms from irritating work exposures. If this were true, one would expect that those individuals reporting both work-related sinus symptoms and asthma of recent onset would demonstrate the strongest association between sinus symptoms and asthma. This in fact, is what we observed (Table 2). Strong associations were observed between post-hire asthma as well as for asthma that began within the 10 years of the survey . This is an interesting finding because, it supports several theories. The first is that the asthma-sinus relationship can be observed in an occupationally exposed cohort. The second is that it is likely that occupational exposures which result in sinus irritation may also result in the development and/or the

exacerbation of asthma. These observations in addition to the exposure response relationship (Table 4) may suggest that workers are accurately reporting the work-relatedness of their disease.

Unfortunately, time of onset of sinus symptoms was not assessed, and so it cannot be more directly related to exposure or to the time of onset of the asthma. It would be useful to be able to examine both exposure and time of onset in an occupationally exposed cohort. These data provide enough evidence to support further investigation of this relationship.

It was hypothesized that chronic sinus symptoms would be related to cross-shift decline in FEV₁, a measurement of acute airway responsiveness. However, these data provided no evidence of such a relationship. It is possible that cross-shift decline in FEV₁ of at least 5% is not a sensitive enough measure of obstructive disease. Perhaps acute obstruction, which is presumed to be reversible is not as related to chronic sinus symptoms as are chronic obstructive disease processes such as asthma.

Hypotheses linking chronic sinus symptoms and various measures of PEF were also investigated. Asthmatics have more daily variation in PEF and increases in measures of amplitude in PEF have been associated with asthma (Hetzel and Clark, 1980; Burge et al., 1979; Burge, 1993). It was suspected that chronic sinus symptoms might be related to increases in measures of PEF amplitude because of their postulated associations with various measures of pulmonary obstruction. In the longitudinally collected serial PEF data, there was evidence suggestive of an association between sinus symptoms and anchored amplitude percent mean $((PEF_{\text{daily max}} - PEF_{\text{arising}})/PEF_{\text{daily mean}})$. Mixed models estimated that never smokers with sinus symptoms had, on average, a 3% larger anchored amplitude percent mean than did those without sinus symptoms ($p=0.19$). Increased amplitude is a measure of the lability of the airways and is often used to identify occupational asthma. Three percent is a relatively small increase in amplitude as Hendy and colleagues suggest that 15-20% amplitudes are consistent with asthma. Although in this cohort of never smokers,

asthma was only associated with a 5% increase in amplitude ($p=0.04$). The mean amplitude of the asthmatics in this cohort (7 asthmatics in 46 participants) was 13% ($sd=0.15$).

There was also some evidence of an association between sinus symptoms and "nextday change" in PEF in absolute terms ($PEF_{\text{arising next day}} - PEF_{\text{pre-shift}}$) as well as in percent of pre-shift PEF ($(PEF_{\text{arising next day}} - PEF_{\text{pre-shift}}) / PEF_{\text{pre-shift}}$). Mixed models estimated a 2% decline in PEF from pre-shift to arising the following morning in this cohort of never smokers ($p=0.07$). Nextday change allows for a lag in time of response by measuring decline in PEF from pre-shift to arising the following morning. They therefore identify a group of individuals not centered around the daytime measures. Because arising PEFs tend to be the lowest in terms of circadian rhythm, these measures may capture the "lower" extreme, thus providing a larger range of response, so that the relationship with chronic sinus symptoms may be more visible.

The hypothesis that sinus symptoms may be associated with lower percent predicted FEV_1 and FVC was also investigated. There was no evidence of such an association.

When considering associations with exposure, "work-related" sinus symptoms consistently demonstrated stronger relationships than did sinus symptoms as a whole. This provides more evidence that the question is successful at selecting out more of the "work-related" disease processes. If workers are accurately reporting symptoms caused by work exposures, we would expect to see stronger associations between the symptom and exposure. We cannot completely discount the possibility that more highly exposed individuals may report more symptoms because they are aware of their exposure levels.

It was interesting that other lower respiratory conditions such as bronchitis and various measures of shortness of breath, phlegm production and wheeze were all quite strongly associated with chronic sinus symptoms, as well. These findings are not surprising as each of these symptoms is related to pulmonary obstruction. All three upper respiratory

symptoms measured- eye, nose and throat irritation were significantly associated with chronic sinus symptoms. Nose symptoms as would be expected, had the strongest relationship, which was followed by eye irritation. This is not surprising because of the anatomical proximity of these structures as well as the obvious fact that particulate exposures which are capable of irritating mucous membranes are often eye irritants.

2. Sinus Symptoms and the Definition of Sinusitis

It is important to be able to relate the reporting of chronic sinus symptoms to the diagnosis of chronic sinusitis that is discussed in the clinical literature. It is likely that a significant subset of those reporting "regular" or chronic sinus symptoms do in fact have chronic sinusitis, but this fraction remains unknown. It is important to recognize that even the clinical diagnosis of chronic sinusitis can be difficult for two reasons. First, patients who have chronic sinusitis often become accustomed to their level of disease, and may even be asymptomatic. Second, various diagnostic tools are used including roentgenograms, ultrasonography, computed tomography and sinus aspiration and culture. Despite this array of diagnostic tools, sinusitis is often diagnosed based on symptoms alone. The National Center for Health Statistics defines chronic sinusitis as the reporting of "sinus trouble" that has a duration of at least 3 months. Newman also defines the chronicity of the condition using a three month time period (Newman et al., 1994). Our question did not ask about the duration of symptoms but rather the persistence of the sinus trouble (Do you regularly, apart from colds have sinus trouble?). It would be useful to have both the clinical diagnosis and responses to various sinus questions so that the questions could be validated.

3. Sinusitis in Other Occupations

Sinusitis has also been demonstrated to be associated with occupation, but on the whole is an under-appreciated occupational respiratory disease. Sinusitis may be associated with particulate exposure. Increased prevalence of chronic sinusitis has been reported in cotton workers, nickel workers, furriers, glassblowers and those working in a vegetable pickling and mustard producing facility (Hoult et al., 1993, Mastromatteo, 1988, Zuskin et al., 1988, 1993). It has also been observed in workers

exposed to wood dust, grain and flour dusts, man made mineral fibers, and cutting oils (Tatken, 1987, Awad El Karin et al., 1986, Moulin et al., 1988). In most of these investigations, history of sinusitis was assessed by modified versions of the American Thoracic Society or British Medical Research Council questionnaire on respiratory symptoms. Some included review of medical records in addition to the questionnaire. Exposed groups had a two- to four-fold increase in risk of sinusitis when compared to unexposed groups.

Some of the occupational cohorts with increased prevalence of sinusitis also have increased rates of sino-nasal cancer. These groups include metal workers and workers exposed to nickel, wood dust and possibly cutting oils (Tomatis 1990, Higginson 1992, Roush 1980). There are at least two potential links between sinusitis and this rare neoplasm. First, it is possible that repeated inflammation in the sinuses and nose from exposure to these irritants and carcinogens results in hyperplastic cellular changes of the epithelial lining. These morphologic changes may eventually lead to the development of sino-nasal cancer. Second, it is also likely that chronic inflammation in these respiratory passages impairs the normal mechanisms designed to remove foreign toxins and particulate from the sino-nasal mucosa. The nose and paranasal sinuses are lined with ciliated respiratory epithelium. This ciliated surface is covered with two layers of mucus. Clearance is accomplished by the trapping of particulate in the mucus and subsequent movement of this contaminated mucus via the beating of the cilia. The flow of the mucous is bilateral. Close to the nostril openings, mucus is directed outward, while in the interior portions of the upper airways, flow is posterior and inferior towards the pharynx; where the mucus can be swallowed. Exposure to irritants and carcinogens including nickel, formaldehyde, cutting oil, and wood dust, have been demonstrated to diminish ciliary beating, decrease numbers of ciliated cells, and/or reduce rates of mucociliary clearance (Mastromatteo 1988, Irlander et al. 1980, Tatken 1987). This impairment of the removal of toxins increases contact time, which is likely to translate into higher effective tissue doses of these irritants and carcinogens. Because the incidence of sino-nasal cancer is rare, monitoring sinusitis in hopes of predicting cancer is not very useful. It is however, further evidence that chronic insults to the upper

respiratory tract ought to be considered more seriously and indicates that identification and treatment of chronic sinus inflammation is important.

Relationships between occupational exposures to dusts and chronic respiratory symptoms (but not sinusitis) have been successfully assessed in previous community-based investigations. Korn and associates demonstrated significant associations between occupational exposure to dust and chronic respiratory symptoms including chronic cough, chronic phlegm, persistent wheeze and breathlessness in a large population-based study (Korn et al., 1987). In dust exposed individuals, the adjusted odds ratios for these symptoms ranged from 1.32 to 1.60. When comparing dust exposed individuals to unexposed subjects, there was evidence of a higher prevalence of chronic obstructive pulmonary disease as measured by a low FEV₁/FVC ratio (<0.60). Chronic non-specific lung disease (CNSLD) was examined using a job exposure matrix in the Zutphen Study, a subset of the Seven Countries Study (Heederik, 1989). Diagnosis of CNSLD by a physician and previous treatment for bronchitis and/or emphysema were most strongly associated with exposure to fumes, organic dust, paint, adhesives, heat and outdoor work. The authors concluded that organic dust seemed to be an important factor in the development of CNSLD. In a third study of dust exposure and chronic lung disease, Kauffman and colleagues observed an accelerated rate of decline in FEV₁ in workers exposed to organic and inorganic dust among Parisian workers followed for 12 years (Kauffman, 1982). To date, these associations cannot be further explored to examine the potential role of sinusitis because this condition was either not included in the surveys, or the findings were not presented in the published results. Had sinus symptoms been included in the assessment or analyses, they may have lead to clearer understandings of the physiologic mechanisms involved with CNLSD and reductions in FEV₁.

4. Recommendations

It is important to reframe the manner in which sinusitis or sinus symptoms are considered in occupational studies. There are known occupational exposures that are associated with the development of asthma. Flour, dust, isocyanates and machining

fluids are examples. The relationship between asthma and sinusitis has also been well documented in the clinical literature. In the case of each of several of these occupational exposures, there is also evidence of increased prevalence of sinusitis. It is therefore possible that some fraction of these incident cases of asthma develop secondary to, or were exacerbated by chronic sinus infections. Unfortunately, this fraction remains unknown as it has not been explored in occupational cohorts. It is important to better define the relationship between sinusitis and lower airways diseases such as asthma in the occupational health literature, as it could result in more effective prevention and treatment of upper and lower airways diseases. This work may begin to develop the framework or backdrop against which sinus symptoms can be considered work related and can be considered in the context of their relation to lower airway diseases.

These analyses provide consistent evidence that chronic sinus symptoms are related to lower respiratory conditions. The relationship observed with asthma of more recent onset is consistent with the hypothesis being investigated. Asthma is a debilitating, prevalent disease that appears to be increasing in both incidence and severity (Reis, 1986, Evans et al., 1987, LaPlante, 1988, Centers for Disease Control, 1992, Blanc, 1993, Weiss et al., 1993). It is possible that perhaps a fraction of these cases of asthma were initiated or exacerbated by the chronic sinus condition. Although it is not clear what fraction of asthma is resulting from occupational exposures, perhaps more thorough recognition and treatment of occupationally related sinus disease is a relevant part of the asthma prevention strategy. Sinusitis may also be related to chronic airway obstruction or acute airway responsiveness currently measured by reductions in baseline or cross-shift forced expiratory volume in the first second (FEV₁). In either case, these data, in addition to those cited in the clinical literature, suggest some means of intervention. Those subjects developing chronic sinus symptoms in occupational environments ought to be identified and treated and their exposures ought to be evaluated and reduced. This could reduce the chronicity of the disease process, and thereby decrease the costs in terms of health care and lost work time. This could also

potentially reduce the number of incident cases of asthma or other chronic obstructive conditions in these occupational cohorts.

We recommend that sinus questions be incorporated into the standardized respiratory health questionnaires. These questions should be asked in a format that enables one to distinguish the "work-relatedness" of the symptoms, as this judgement appears to be both valid and to result in identification of conditions more related to both exposure and various respiratory symptoms. The design implemented by the Rylander matrix seems an appropriate means by which to identify work related sinus symptoms. The time of onset and perhaps recent exacerbations should be incorporated into the questions to allow time sequencing to be determined regarding the development of asthma (proposed questions in Table 5).

Including these questions in the standardized respiratory questionnaire will allow the identification of those occupational cohorts with high prevalences of sinus problems. It would be interesting to know if these industries/occupations also have higher rates of asthma. It would provide the first opportunity to investigate the hypothesis relating sinusitis to asthma in occupational cohorts using appropriate time data. This might be a very important contribution to the occupational health literature and may provide valuable insight to the increasing rates of occupational asthma. Chronic sinus trouble is a significant health outcome in itself, as it is uncomfortable for those with the condition(s) and costs significant amounts of money both in terms of lost work days (NHIS 1993) and in terms of medical treatments and surgical interventions (Spector, 1995). For both of these reasons, the associations demonstrated in these data support the further investigation of chronic sinusitis and its relationship to asthma and other commonly monitored lower respiratory conditions.

E. TABLES

Table I: Prevalence of chronic sinus symptoms by various population descriptors

| Variable | | % with Sinus Symptoms (n) |
|----------------------|-------------|---------------------------|
| Age | <35 years | 50 (24) |
| | 35-45 years | 44 (94) |
| | >45 years | 38 (45) |
| Gender | Male | 42 (140) |
| | Female | 55 (23) |
| Race | Black | 44 (18) |
| | White | 37 (145) |
| Years Employed | ≤15 | 47 (103) |
| | >15 | 37 (60) |
| Smoking Status | Current | 41 (51) |
| | Ex | 45 (56) |
| | Never | 43 (56) |
| Dr. Diagnosed Asthma | | 50 (17) |
| Non-asthmatics | | 42 (146) |
| Pre-hire Asthmatics | | 44 (11) |
| Post-hire Asthmatics | | 67 (6) |
| Hayfever | Yes | 56 (54) |
| | No | 38 (107) |

Table II: Asthma in those with sinus symptoms versus those without sinus symptoms

| Variable | Prevalence ratio for reporting sinus symptoms | | | | | |
|--------------------------|-----------------------------------------------|----------|---------|-----------------------------|-----------|---------|
| | All Sinus Symptoms | | | Work-related Sinus Symptoms | | |
| | PR* | 95% CI** | p-value | PR* | 95% CI** | p-value |
| Asthma (Dr. dx)*** | 1.3 | 0.7-2.5 | 0.38 | 1.7 | 0.8-3.5 | 0.18 |
| Pre-hire Asthma**** | 1.1 | 0.5-2.3 | 0.86 | 1.0 | 0.4-2.3 | 0.94 |
| Post-hire Asthma**** | 2.7 | 0.7-10.0 | 0.14 | 4.6 | 1.3-16.5 | 0.02 |
| Years Since Asthma Onset | | | | | | |
| ≤10 years | 4.0 | 0.9-17.2 | 0.06 | 6.6 | 1.1-42.0 | 0.04 |
| >10 years | 1.0 | 0.6-1.6 | 0.99 | 0.2 | 0.05-0.76 | 0.02 |

*Prevalence Ratio

**95% Confidence Interval

***Reported physician diagnosed asthma, regardless of time of onset. Reference group is non-asthmatics.

****Pre- and post-hire asthma are subjects of the variable "asthma".

*Work-Related defined by Rylander matrix-(related to work or improves away from work or worse when return to work from holiday)

Table III: Chronic respiratory symptoms among those reporting sinus symptoms versus those with no sinus symptoms

| Variable | Prevalence ratio for chronic respiratory symptoms | | | | | |
|-------------------------------|---------------------------------------------------|-----------|---------|-----------------------------|-----------|---------|
| | All Sinus Symptoms | | | Work-related Sinus Symptoms | | |
| | PR* | 95% CI** | p-value | PR* | 95% CI** | p-value |
| Bronchitis*** | 1.5 | 1.14-2.00 | 0.004 | 1.6 | 1.15-2.29 | 0.006 |
| Chronic Bronchitis**** | 1.4 | 0.76-2.58 | 0.28 | 1.9 | 0.95-3.71 | 0.07 |
| Wheeze to SOB | 1.3 | 0.82-2.02 | 0.27 | 1.7 | 1.00-2.79 | 0.05 |
| Wheeze: ever been treated for | 1.5 | 0.84-2.53 | 0.18 | 1.9 | 1.01-3.51 | 0.05 |
| Wheeze with colds | 1.2 | 0.96-1.43 | 0.13 | 1.2 | 0.94-1.56 | 0.14 |
| Wheeze apart from colds | 1.3 | 0.86-2.06 | 0.20 | 1.4 | 0.79-2.35 | 0.26 |

*Prevalence Ratio

**95% Confidence Interval

***Doctor diagnosed

Table IV: Exposure in those with sinus symptoms versus those without sinus symptoms

| Variable | Prevalence ratio for reporting sinus symptoms | | | | | |
|---------------|-----------------------------------------------|-----------|---------|-----------------------------|----------|---------|
| | All Sinus Symptoms | | | Work-related Sinus Symptoms | | |
| | PR* | 95% CI** | p-value | PR* | 95% CI** | p-value |
| Machinists*** | 1.2 | 0.97-1.55 | 0.09 | 1.5 | 1.2-1.8 | 0.001 |
| Straight MWF | 1.3 | 0.97-1.80 | 0.08 | 2.1 | 1.2-3.4 | 0.005 |
| Soluble MWF | 1.2 | 0.90-1.53 | 0.24 | 1.7 | 1.1-2.6 | 0.03 |

*Prevalence Ratio

**95% Confidence Interval

***Reference group is non-machinists

Table V: Proposed Sinus Question

| | | | | | | | | |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|----|---------------------|----|-------------------------|----|--------------------------------|----|
| <p>1. Have you ever had sinusitis? Yes / No If Yes: 1a. Was it diagnosed by a doctor? Yes / No 1b. If Yes, when? _____ 1c. Did it last for at least 3 months? Yes / No 1d. Did you take medication for it? Yes / No</p> | | | | | | | | |
| <p>2. Do you have regular (apart from colds) sinus trouble? Yes / No If Yes: 2a. Have you ever had sinus trouble for 3 consecutive months or more? Yes / No 2b. Have you ever been diagnosed by a physician with chronic sinusitis? Yes / No 2c. If Yes, when? _____</p> | | | | | | | | |
| <p>3. IF YES TO QUESTIONS 1 OR 2:</p> | | | | | | | | |
| | Related to work | | Interfere with work | | Improve during holidays | | Worse first day after holidays | |
| | Yes | No | Yes | No | Yes | No | Yes | No |
| Sinusitis | | | | | | | | |
| Regular sinus trouble | | | | | | | | |

F. LITERATURE SITED

American Thoracic Society: Snowbird workshop on standardization of spirometry. *Am Rev Respir Dis* 136:1285-1298, 1987.

American Thoracic Society: Lung function testing: Selection of reference values and interpretative strategies. *Am Rev Respir Dis* 144:1202-1208, 1991.

Awad El Karim MA, Gad El Rab MO, Omer AA, El Haimi YAA. Respiratory and Allergic Disorders in Workers Exposed to Grain and Flour Dusts. *Archives of Environmental Health*. 1986; 41:297-301.

Axelsson O. (1994) Some recent developments in occupational epidemiology. *Scand J Work Environ Health*; 20(special issue):9-18.

Blanc PD, Jones M, Besson C, Katz P, Yelin E. Work disability among adults with asthma. *Chest*. 1993; 104:1371-1377.

Blumgart HL. A study of the mechanisms of absorption of substances from the nasopharynx. *Arch Intern Med*. 1924; 33:415.

Brugman SM, Larsen GL, Henson PM, et al.: Increased Lower Airways Responsiveness Associated with Sinusitis in a Rabbit Model. *Am Rev Respir Dis* 1993; 147:314-20.

Bullen SS. Incidence of asthma in 400 cases of chronic sinusitis. *J. Allergy* 1932; 402-407.

Burge PS. Use of serial measurements of peak flow in the diagnosis of occupational asthma. *Occup Med: State of the Art Reviews* 1993; 8:279-294.

Burge PS, O'Brien IM, Harries MG. Peak flow rate records in the diagnosis of occupational asthma due to colophony. *Thorax* 1979; 34:308-316.

Businco L, Fiore L, Frediani T, Artuso A, et al.: Clinical and therapeutic aspects of sinusitis in children with bronchial asthma. *Int J Pediatr Otorhinolaryngol* 1983; 3:287-94.

Centers for Disease Control. Asthma-United States, 1980-1990. *MMWR* 1992; 41:733-35.

Chobot R. Asthma in children: an analysis of 84 cases. Incidence of sinusitis in asthmatic children. *Am J Dis Child* 1930; 39:257-63.

Cummings NP, Wood RW, Lere JL, Adinoff AD. Effect of Treatment of Rhinitis/Sinusitis on Asthma: Results of a Double Blind Study. *Ped. Res.* 1983; 17:373A.

Cummings NP, Lere JL, Wood R, Adinoff A. Effect of treatment of sinusitis on asthma and bronchial reactivity: results of a double-blind study (abstract). *J Allergy Clin Immunol* 1983; 73 (Suppl): 143.

Evans R, Mullally D, Wilson R, Gergen PJ, Rosenberg HM, Grauman JS, et al. National trends in the morbidity and mortality of asthma in the US: prevalence, hospitalization, and death from asthma over two decades: 1965-1984. *Chest*. 1987; 91:65s-74s.

Ferris B. Epidemiology standardization project. *Am Rev Respiratory Disease* 1978; 118:1-120.

Friday Jr. GA, Fireman P. Sinusitis and asthma: Clinical and pathogenic relationships. *Clinics in Chest Medicine*. 1988; 9:557-565.

Friedman R, Ackerman M, Wald E, Casselbrant M, Friday G, Fireman P. Asthma and bacterial sinusitis in children. *J Allergy Clin Immunol*. 1984; 74:185-189.

Gottlieb MF. Relation of intranasal disease in the production of bronchial asthma. *JAMA* 1925; 85:105-7.

Health and Safety Executive. General methods for the gravimetric determination of respirable and total inhalable dust. MDHS14. Health and Safety Executive, London, 1986.

Heederik D, Pouwels H, Kromhout H, Kromhout D. Chronic Non-Specific Lung Disease and Occupational Exposures Estimated by Means of a Job Exposure Matrix: The Zutphen Study. *Int J of Epidemiology*. 1989; 18:382-389.

Hendy MS, Beattie BE, Burge PS. Occupational asthma due to an emulsified oil mist. *Br J Industr Med* 1985; 42:51-54.

Hetzel MR, Clark TJH. Comparison of normal and asthmatic circadian rhythms in peak expiratory flow rate. *Thorax* 1980; 35:732-738.

Higginson J, Muir CS, Munoz N. Human cancer: Epidemiology and environmental causes. Cambridge Monographs on Cancer Research, Cambridge University Press, 1992.

Hoult B, Sigsgaard T, Tuxford AF. A Comparison of Micro-organisms, Endotoxin Levels and Respiratory Symptoms in Wool Mills and Cotton Mills. 1993 Proceedings, Beltwide Cotton Council of America, Memphis, TN, 281-284.

Irlander K, Hellquist H, Edling C, Odkvist L. Upper airway problems in industrial workers exposed to oil mist. *Acta Otolaryngol*. 1980; 90:452-459.

Kauffman F, Drouet D, Lellouch J, Brille D. Occupational exposure and 12-year spirometric changes among Paris area workers. *Br J Ind Med*. 1982; 39:221-232.

Kennedy SM, Greaves IA, Kriebel D, Eisen EA, Smith TJ, Woskie SR. (1989) Acute pulmonary responses among automobile workers exposed to aerosols of machining fluids. *Am J Industrial Med*;15:627-641.

Korn EL, Whittemore AS. Methods for analyzing panel studies of acute health effects of air pollution. *Biometrics* 1979; 35: 795-802.

Korn RJ, Dockery DW, Speizer FE, Ware JH, Ferris Jr. BG. Occupational Exposures and Chronic Respiratory Symptoms: A Population Based Study. *Am Rev Respir Dis.* 1987; 136:298-304.

Kriebel D, Eberiel D, Eisen E, Moure-Eraso R, Kumar S, Sama SR, Smith M, Virji MA, Woskie S, Hammond K, Christiani D, Milton D, Tolbert P. Final Report: Field investigations of the acute respiratory effects of machining fluids 1994 (unpublished).

LaPlante M. Data on disability from the National Health Interview Survey 1983-1985: an InfoUse report. Washington DC: US National Institute on Disability and Rehabilitation Research, 1988.

Lee J. (1986) Regression estimate of the adjusted risk ratio [letter]. *Br J Ind Med*;43:356-357.

Lee J, Chia KS. (1993) Estimation of prevalence rate ratios for cross sectional data: an example in occupational epidemiology. *Br J Ind Med*; 50:861-862.

Lee J, Chia KS. (1994) Use of the prevalence rate ratio versus the prevalence odds ratio as a measure of risk in cross sectional studies. *Occ & Envir Med*; 51:841.

Liang K-Y, Zeger SL. (1986) Longitudinal data analysis using generalized linear models. *Biometrika*;73:13-22.

Mastromatteo E. Nickel and Its Compounds. *Occupational Medicine: Principles and Practical Applications*, Second Edition, C. Zenz, Editor; Chicago, Year Book Medical Publishers, Inc. 1988;597-608.

Milton D, Wypij D, Kriebel D, Walters WD, Hammond SK, Evans JS. Endotoxin exposure-response in a fiberglass manufacturing facility. (1995) *Am J Ind Med*, in press.

Moulin JJ, Wild P, Mur JM, Caillard JF, Massin N, Meyer-Bisch C, Toamain JP, Hanser P, Liet S, DuRoscoat MN, Segala A. Respiratory health assessment by questionnaire of 2024 workers involved in man-made mineral fiber production. *Int Arch Occup Environ Health.* 1988; 61:171-178.

National Center for Health Statistics. Current Estimates from the National Health Interview Survey, 1993. Hyattsville, MD: Series 10, no. 190. DHHS publication PHS 95-1518.

National Institute for Occupational Safety and Health: National Occupational Health Survey, Vol. III, pp. 216-229. Survey Analysis and Supplemental Tables. DHEW/NIOSH Pub. No. 78-114. NIOSH, Cincinnati, OH (1977).

Newman LJ, Platts-Mills TAE, Phillips CD, Hazen KC, Gross CW. Chronic sinusitis: Relationship of computed tomographic findings to allergy, asthma, and eosinophilia. *JAMA*. 1994; 271:363-367.

NIH Data Book 1990. Bethesda, MD:US Dept of Health and Human Services; 1990:table 44. Publication 90-1261.

Phipatanakul CS, Slavin RG. Bronchial asthma produced by paranasal sinusitis. *Arch Otolaryngol* 1974; 100:109-12.

Rachelefsky GS, Katz RM, Siegel SC. Chronic Sinus Disease with Associated Reactive Airway Disease in Children. *Pediatrics* 1984; 73: 526-529.

Ries PN. Current estimates from the National Health Interview Survey, United States 1984. DHHS Publication No. (PHS) 86-1584. Hyattsville, MD: US Department of Health and Human Services, 1986.

Robins T, Seixas N, Franzblau A, Burge H, Abrams L. Association of cross-shift decrements in pulmonary function with machining fluid exposure [abstract]. *Am J Respir Crit Care Med* 1995; 151:A420.

Roush GC, Meigs JW, Kelly J, Flannery JT, Burdo H. Sinonasal cancer and occupation: case-control study. *Amer J Epidemiol*. 1980; 111:183-193.

Rylander R, Peterson Y, Donham KJ. Questionnaire evaluating organic dust exposure. *Am J Ind Med* 1990; 17:121-126.

SAS Institute Inc., SAS Technical Report P-229, SAS/STAT© Software: Changes and Enhancements, Release 6.07, Cary, NC:SAS Institute Inc.,1992. 288-364.

Slavin RG, Cannon RE, Friedman WH, Palitang E, Sundaram M. Sinusitis and bronchial asthma. *J Allergy Clin Immunol*. 1980; 66: 250-257.

Slavin RG. Relationship of nasal disease and sinusitis to bronchial asthma. *Annals of Allergy*. 1982; 49:76-80.

Slavin RG. Asthma and sinusitis. *J Allergy Clin Immunol*. 1992; 90:534-537.

Sluder G. Asthma as a nasal reflex. *JAMA*. 1919; 73:589.

Spector DM, Lippman M, Thurston GD, et. al. Effects of ambient ozone on respiratory function in healthy adults exercising outdoors. *Am Rev Respir Dis* 1988; 138 (4): 821-828.

Tatken RL. Health effects of exposure to wood dust. A summary of the literature. US Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Standards Development and Technology Transfer, 1987.

Tomatis L. Cancer: Causes, Occurrence and Control. International Agency for Research on Cancer, IARC publication number 100, Oxford University Press, New York, 1990.

Woskie SR, Virji MA, Kriebel D, Sama S, Eberiel D, Milton DK, Hammond SK. Exposure assessment for a field investigation of the acute respiratory effects of machining fluids. I. Summary of findings. Submitted AIHAJ, December, 1995.

Zuskin E, Skuric Z, Kanceljak B, Pokrajac D, Schachter EN, Witek TJ. Respiratory symptoms and lung function in furriers. *Am J Indus Medicine*. 1988; 14:189-196.

Zuskin E, Butkovic D, Schachter EN, Mustajbegovic J. Respiratory Function in Workers Employed in the Glassblowing Industry. *Am J Indus Medicine*. 1993; 23:835-844.

Zuskin E, Mustajbegovic J, Schachter EN, Rienzi N. Respiratory symptoms and ventilatory capacity in workers in a vegetable pickling and mustard production facility. *Int Ach Occup Environ Health*. 1993; 64:457-461.

III. EVALUATION OF SINUSITIS IN THE 1988 NATIONAL HEALTH INTERVIEW SURVEY DATA

A. INTRODUCTION AND DATA SET CONSTRUCTION

The National Health Interview Survey is a nationwide survey of civilian non-institutionalized citizens living in the United States. It is designed to collect a variety of information regarding estimates of acute conditions, injuries, restricted activities, prevalence of and limitations resulting from chronic conditions, and the use of medical services. NHIS defines a chronic condition as one that was first noticed 3 months or more prior to the week of the interview or one that by definition is a chronic disease such as diabetes, regardless of when it was diagnosed. The survey includes a series of respiratory questions some of which include bronchitis, asthma (self report and physician diagnosed), sinus trouble, and hayfever. Descriptive information regarding age, gender, race, smoking, family income, geographic region, working, educational and health status, occupation and industry is also collected. Summaries of these data are available in various publications and these data are available on CD-ROM and can be used to conduct more specialized analyses. Current estimates of the prevalence of chronic chronic sinusitis, asthma, chronic bronchitis and hayfever (without asthma) are reviewed in the adult population (ages 18 and over) as a whole, as well as in various subsets to identify relationships by age, gender, race, occupation, industry and other variables of interest. Occupations are classified by Standard Occupational Classification (SOC), and industries by Standard Industrial Classification (SIC).

The 1988 NHIS data set was used for these analyses as it included a special occupational health supplement (OHS) that is not included in the following survey years. A data set was constructed using the 1988 NHIS CD ROM. The Sets program contained on the CD was used to extract the variables of interest. The extraction was restricted to include those with age greater than or equal to 18 years and to those who had been administered the Respiratory Condition Questionnaire, which contained the respiratory variables of interest. Data extracts were made from three separate data sets (Person, Condition, and Occupation) and the extracts were then merged into one data set that was used for analyses. The variables selected for inclusion are listed in Appendix A.

The final data set included a total number of observations 14,817 and close to 450 variables. The data set included information regarding chronic sinusitis, asthma, bronchitis, atopy (hayfever), relevant demographic characteristics, industry and occupation. Although initial plans included combining four years of the survey data, it was decided early on in the project to focus only on the 1988 data as it contained job history information as a part of the occupational health supplement. Discussions with mentors indicated that adding the future years would not likely add significant power to the analyses and that resources would be better spent to work in more detail with the Occupational Health Supplement contained in the 1988 data. This data is not included in any of the other survey years. Because this job history data afforded the opportunity to conduct analyses that could potentially evaluate industry and occupation information at the onset of the conditions of interest, resources would be better spent focusing on the 1988 data. This advantage would be key in addressing issues of healthy worker selection bias that is problematic in cross-sectional occupational epidemiologic investigations. Examination of the hypothesized associations could be accomplished without sacrificing the integrity of the analyses. Because the job history data was time consuming to analyze, resources allocated to this portion of the project did not allow the analyses of subsequent years of NHIS data.

B. METHODS AND STUDY POPULATION

In all cases both when conducting simple cross-tabulations and the more complex modeling, the initial analyses were conducted using SAS for preliminary analysis and then using SUDAAN so that weighting would be handled properly.

1. Population Demographics

The demographics of the population were described including distributions of: age, gender, race, smoking status (when possible—this variable only available for 50% of the population), employment status, health status, occupation, industry, education, and working class. Industry and occupation were evaluated at the 2-digit level.

2. Conditions of Interest

Each of six respiratory conditions was evaluated: chronic sinusitis, chronic bronchitis, asthma, hayfever without asthma, nasal polyps, and deviated nasal septum. It is

important to note that the variable hayfever, by definition was mutually exclusive of asthma (there were, however 26 observations that were associated with asthma and hayfever). Because there were limited cases of nasal polyps and deviated nasal septum cross-tabulations were the only analyses conducted for these variables. They were not included in the modeling analyses.

3. Analyses

Descriptive: Simple descriptive analyses were designed to evaluate the relationships between the conditions and the variables described above. This primarily involved the tabulations and cross-tabulations of the conditions of interest, the various demographic variables and potential confounders. Two by two, tables were constructed for all of the conditions, each one against the others. Prevalence ratios were calculated for each of these relationships. The prevalence of the conditions of interest were calculated and were stratified by: age category, gender, race, smoking, employment and health status, industry, occupation, education and working class. Some of these relationships were further evaluated using multiple stratifications of age; race, gender and smoking status. Similar analyses were conducted for those reporting multiple conditions including: chronic sinusitis and asthma, chronic sinusitis and chronic bronchitis, chronic sinusitis and hayfever, asthma and bronchitis. 1988 BLS estimates for hours reported in the non-agricultural industrial sectors and overall prevalence (generated by these analyses) estimates by industrial sector were used to approximate expected national prevalence of chronic sinusitis by major industrial sector for 1988.

Modeling: Logistic regression models were also used to examine: 1) the relationships between the conditions and 2) the relationship between the conditions and other variables of interest. Simple univariate analyses were conducted initially. These models then progressed to more complicated multivariate analyses including significant variables to control for confounding. The outcome variable was a dichotomous term representing the presence or absence of chronic sinusitis. Explanatory variables included the other respiratory conditions (asthma, chronic bronchitis, and hayfever),

age, gender, race, smoking, health and employment status. Occupation and industry were not included in the modeling process.

$$\text{Chronic Sinusitis (1/0)} = \beta_0 + \beta_1 \text{ Age} + \beta_2 \text{ Gender} + \beta_3 \text{ Race} + \dots + \beta_4 \text{ Smoker} + \beta_5 \text{ Ex-smoker} + \beta_6 \text{ Asthma} + \text{Error}$$

Onset of Conditions: For a subset of the population, job history information was available. We conducted analyses in this subset to determine the industry and occupation held at the time chronic sinusitis, asthma or bronchitis was reported to have begun. These cases represent incident cases as opposed to prevalent cases. In those reporting chronic sinusitis, asthma and chronic bronchitis, cross-tabulations of industry and occupation were conducted. BLS estimates for hours reported in the non-agricultural industrial sectors and these "incidence estimates" by industrial sector were used to approximate the expected national incidence of chronic sinusitis by major industrial sector in 1988.

C. RESULTS

1. Descriptive Analyses

Demographics of the population: Distributions of demographic variables including: age, race, gender, smoking status, employment status (in the past two weeks), health status, industry, occupation, education and working class (Tables 1-3). Age was restricted to those 18 and older and 57% of the population were between the ages of 18 to 44. The mean age of the population was 44.2 years. In the analyses age was trichotomized into age groups 18-34, 35-54 and greater than or equal to 55 years.

The population was about 86% white and 11% black, with the remainder falling into other race categories. For analytical purposes, a "non-white" category was created that combined the black and other race categories into one category which represented about 15% of the population. The population was 53% female. Smoking information was only available for half of the population. In this subset, 28% were current smokers, 24% were former smokers and the remainder had never smoked.

Close to sixty four percent of the population reported that they had worked in the past two weeks. Over sixty percent of the population reported their health status to be at least excellent or very good. The remainder fell into categories of good (25%), fair (9%) or poor (4%). Health status was trichotomized by collapsing Excellent, Very Good and Good health statuses into one category while keeping Fair and Poor separate.

Thirty two percent of the population reported that they were not in the labor force. Of those in the labor force, the majority works in the following sectors: Professional and Related Services; Manufacturing; and Retail Trade. The most frequently reported occupations include: Administrative Support Occupations, including Clerical; Professional Specialty Occupations; Executive, Administration and Managerial Occupations; Precision, Production Craft and Repair Occupations; and Sales Occupations. Thirty eight percent of the population had graduated from high school, while 19% had completed at least four years of college. For analytical purposes, educational status was collapsed into four groups: High School or less, 1-3 years of college, 4 years-college graduate and 5+ years-post college. Forty-eight percent of the population worked in the private sector, while only about 10% of the population worked for either federal, state or local government.

Prevalence of Conditions: Chronic sinusitis was the most prevalent of all the conditions of interest (16.8%). Asthma and chronic bronchitis had similar prevalences, 3.8% and 4.8% respectively (Table 1). Nasal polyps and deviated nasal septum were reported in less than 1% of the population. These two variables were not included in further analysis. Hayfever, by definition was mutually exclusive of asthma ("hayfever without asthma") was reported in 10% of the population, although 26 cases reported both conditions.

Age, Gender, Race, Smoking: These prevalence data were then stratified to evaluate the potential effects of the demographic variables described above (Tables 1-4d). The prevalence of chronic sinusitis increased with age, when comparing the youngest age category to each of the older. Each of the older categories had roughly a twenty

percent increase in risk of chronic sinusitis that were statistically significant. Overall, chronic bronchitis was slightly more prevalent than asthma and appears to gradually increase with age (Linear test for trend in proportions, $p < 0.01$).

Asthma prevalence appears to be lower in the 45-54 year age group when compared to the other age groups, this difference is of borderline significance when comparing to the younger age group ($p = 0.10$) and is statistically significant when the reference group is the older. Each of the conditions is more frequently reported by females than males (chronic sinusitis-19.5% versus 13.7% $p < 0.01$); asthma 4.3% versus 3.3% $p < 0.01$; bronchitis 6.0% versus 3.4% $p < 0.01$). Stratification by race demonstrated that asthma may have been more frequently reported in Non-Whites although this relationship had borderline significance (4.9 versus 3.7 $p < 0.20$), while chronic sinusitis and chronic bronchitis were more prevalent in whites (17.4 versus 15.5 $p < 0.01$); 4.9 versus 4.1 $p = 0.04$). Asthma prevalence was not associated with smoking status.

Chronic sinusitis was slightly more prevalent in current smokers when compared to never smokers ($p = 0.14$), while chronic bronchitis was strongly associated with current and ex-smokers when compared to never smokers ($p < 0.01$ in each case). Those with chronic sinusitis, asthma and hayfever who reported that they were either not in the labor force or that they did not work and did not have a job had higher prevalences of each of the conditions when compared to those who reported that they had worked in the past two weeks or had not worked during this time period, but did hold a job. These associations were of borderline significance ($p = 0.18$, $p = 0.12$, $p = 0.13$ respectively). Those with chronic sinusitis were 2 times as likely to report poor health status rather than excellent health status ($p < 0.01$), while those with asthma or were 6 times as likely to report poor health status rather than excellent health status ($p < 0.01$). Chronic bronchitis showed a pattern very similar to that seen for asthma.

Industry and Occupation: In order to evaluate the relationship between the select conditions and industry and occupation, several comparisons were made. For each condition, three industries with the highest prevalences and those not in the labor force

(four groups in total) were each compared in turn to a reference group that collapsed the remaining observations (from all the other industries) into one group. T-Statistics were calculated for each of these comparisons. The same method was used to evaluate occupations (Tables 5a-5d).

Chronic sinusitis was most frequently reported in the Mining (25.8%), Entertainment and Recreation Services (21.8%), Public Administration (18.3%) and Business and Repair Services (18.0%) industrial sectors. T-Tests demonstrated that Mining and Entertainment and Recreation Services had associations of borderline significance ($p=0.11$, $p=0.14$ respectively). The occupations most associated with reports of chronic sinusitis include: Administrative Support Occupations, including Clerical (18.6), Professional Specialty Occupations (18.4%) and Technicians and Related Support Occupations (18.2%). Only Professional Specialty Occupations and Administrative Support Occupations demonstrated strong associations ($p=0.01$, $p<0.01$, respectively).

The Entertainment and Recreation Services (9.4%), Agriculture, Forestry and Fisheries (4.4%) and Professional and Related Services (4.1%) industrial sectors were most associated with reports of asthma. There was a relatively strong association with those in the Professional and Related Services sector and borderline association for those in the Entertainment and Recreation Services sector ($p=0.06$ and $p=0.13$ respectively). Asthma appeared to be most prevalent in Private Household Occupations (5.4%), Service Occupations, except Protective and Household (3.9%) and Farming, Forestry, Fishing Occupations (3.9%). Only Private Household Occupations had borderline significance ($p=0.12$).

Chronic bronchitis was more likely to be reported in the Mining (10.7%), Business and Repair Services (5.2%), Entertainment and Recreation Services (4.8%), Personal Services (4.7) and Professional and Related Services (4.6%) sectors. Mining and Entertainment and Recreation Services each had borderline associations ($p=0.12$, $p=0.14$ respectively). Bronchitis was most prevalent in the following occupations: Technicians and Related Support Occupations (5.1%), Administrative Support

Occupations including Clerical (5.1%) and Professional Specialty Occupations (4.9%). Only the latter two had strong associations ($p=0.01$ and $p<0.01$ respectively). Those reporting that they were not in the labor force for industry were also more likely to report having chronic sinusitis, asthma and chronic bronchitis. In each case, these associations were strong ($p\leq 0.01$ in each case). Similar results were seen for those reporting that they were not in the labor force for occupation.

Education and Working Class: Chronic sinusitis and asthma did not appear to be associated with education. Chronic bronchitis on the other hand, was slightly more prevalent in those in the educational category of "High School or Less" when compared to those with the highest level of education in the univariate logistic regression model. As mentioned previously, these conditions are strongly associated with those reporting that they are not in the labor force. Government employees reported the highest prevalence of chronic sinusitis (19%), while asthma and chronic bronchitis were seen most in incorporated businesses (6.0% and 5.4%, respectively).

Prevalence Ratios for Multiple Conditions: Prevalence ratios (PR) were calculated to assess the relationships between each of the conditions (Table 9). Prevalence Ratios were calculated for each condition against all the others in a series of two by two tables. Confidence intervals for each PR were also calculated. Chronic bronchitis and asthma were the most strongly associated (P.R.=4.69, 95%, $p<0.000$) followed by chronic bronchitis and chronic sinusitis (P.R.=2.37, 95%, $p<0.000$) and chronic sinusitis and asthma (P.R.=1.50, 95%, $p<0.000$).

Multiple Conditions: Distributions of reports of multiple conditions by each of the demographic variables are summarized in Tables 7-9. Those reporting both chronic sinusitis and asthma tend to be in the age categories between 55 and 74, are more likely to be female (1.2% versus 0.62%) and black (1.2% versus 0.92%). These conditions were more likely to be present in current and former smokers as compared to never smokers. People reporting both chronic sinusitis and asthma were likely to report a poor health status and that they were either not in the labor force or that they did not

work, had no job and were either looking for work or were on layoff. Similar patterns were observed for those reporting that they had chronic sinusitis and chronic bronchitis, as well as for those reporting both asthma and chronic bronchitis.

2. Models:

Univariate and multivariate logistic regression models were constructed in SUDAAN to evaluate chronic sinusitis as a dichotomous outcome variable (Table 10a). Each of the other respiratory conditions and potential confounders including age, race, gender, smoking, health and educational status were included in these models as explanatory variables. Similar models were constructed for the three other conditions of interest, although respiratory conditions were not included in these models (Tables 11a, 12a, 13a). Several interaction terms were created and evaluated to investigate the possibility of interaction effects (race*gender, age*gender, health status*gender). Only race and gender demonstrated interaction effects. This variable is included in the multivariate analyses, when warranted.

Several multivariate models were then constructed including each of the other conditions of interest (asthma, chronic bronchitis and hayfever) and the variables that demonstrated significance in the univariate models (Tables 10b-10k). Similar multivariate models were constructed for each of the other conditions (Tables 11b-11d, 12b-12e, 13b).

Chronic Sinusitis: Each of the conditions were significantly associated with chronic sinusitis, with chronic bronchitis having the strongest association. Females were 53% and whites 41% more likely more likely to report chronic sinusitis (OR=1.53, $p<0.001$ and OR=1.41, $p<0.001$, respectively). Individuals between 35 and 54 years of age reported chronic sinusitis 31% more often than those 18 to 34. Similarly, those 55 years and above were 22% more likely to report chronic sinusitis. These relationships were statistically significant. Both fair and poor health status were strongly associated with chronic sinusitis (OR=1.62 $p<0.001$, OR=1.74, $p<0.001$, respectively). Current smokers were slightly more likely to report chronic sinusitis although this relationship had only

borderline statistical significance (OR=1.12, p=0.14). Educational level was not associated with chronic sinusitis. When all the significant explanatory variables were included in one multivariate model only the dummy representing those aged 55 and older lost statistical significance. When age was included continuously, it demonstrated that the risk of chronic sinusitis increased by 1 percent with each additional year of age.

Multivariate models: Several multivariate models were evaluated. The final multivariate model was constructed with two separate versions: one model had age continuously and the other had age categorically. The final explanatory variables included asthma, chronic bronchitis, hayfever, age, race, gender, an interaction variable race*gender and health status. Though each condition was associated with chronic sinusitis, bronchitis was demonstrated the strongest relationship. Age was only significant when it was considered categorically. Those aged 35-54 were 27% more likely to report chronic sinusitis than those younger than 35 (p<0.01). As seen in the univariate models, women and whites were significantly more likely to report chronic sinusitis (OR=1.41, OR=1.30). The interaction term representing white females had borderline significance in this model (OR=1.33, p<0.06).

Asthma: Women were 33% more likely to report having asthma as compared to males (OR=1.33, p<0.01). The relationship between race (non-white versus white) and asthma was weak (OR=1.16, p=0.19). When age was considered categorically, those in the 35-54 year age group were less likely to report asthma than were those under age 35 (OR=0.84, p=0.10). There was not much difference in prevalence between those over 55 years of age and those under 35 although the data suggest that those in the older category may be slightly more likely to report asthma, though this relationship was very weak (OR=1.10, p=0.36). Age was not significant when considered continuously. Smoking and education were not associated with asthma. As with chronic sinusitis, both fair and poor health status were strongly associated with reports of asthma (OR=2.15, p<0.01; OR=4.47, p<0.01 respectively).

Multivariate model: The significant explanatory variables that were included in the final model with asthma as the dependent variable included: age (categorical), race, gender and health status. In this model race lost significance, but was included because it is so often a significant predictor of asthma. Each of the age categories were negatively associated with asthma, demonstrating that the lowest age group (ages < 35) was significantly more likely to report asthma than were the two older age groups. Those reporting fair and poor health status were significantly more likely to report asthma than were those reporting excellent, very good and good health. These relationships were of similar magnitude as those seen in the univariate models, though the odds ratio for those with poor health status increased to 4.96 ($p < 0.01$).

Chronic Bronchitis: Chronic bronchitis is strongly associated with gender, race, age and smoking status. Women (OR=1.82, $p < 0.01$), whites (OR=1.28, $p = 0.04$) and those 55 and over (OR=1.72, $p < 0.01$) and current smokers as compared to never smokers (OR=1.57, $p < 0.01$) are strongly associated. X years and older were significantly less likely to report asthma

those under 35 (OR=0.71, $p < 0.01$). The continuous version of age is negatively

associated with this condition. This relationship is strong (OR=0.99, $p<0.01$). Current smokers are significantly less likely to report hayfever without asthma than were never smokers (OR=0.80, $p=0.02$) as are those reporting poor health status as opposed to excellent, very good and good health status (OR=0.71, $p=0.05$). Unlike the other conditions, education is strongly associated with this condition. Risk of reporting hayfever without asthma decreases linearly with decreasing education level. These relationships are all of statistical significance.

Multivariate model: The final multivariate model with hayfever (without asthma) as an outcome variable included the following explanatory variables: age (continuous), race, gender, an interaction term race*gender, health status, and education status. Poor health status is the only explanatory variable that lost significance. Age and educational status were significantly negatively associated with hayfever (without asthma). Women, whites and white women were all more likely to report hayfever (without asthma) (OR=1.2, $p<0.01$, OR=1.3 $p=0.01$ and OR=1.41, $p=0.04$, respectively). Unlike in the univariate model, fair health status was associated with hayfever (without asthma) (OR=1.22, $p=0.05$) in the multivariate model.

3. Condition Onset

The onset of conditions was evaluated in various ways (Tables 14-17).

Analyses: The variable describing the onset and status of each of the conditions was evaluated. Simple analyses were conducted in SAS to evaluate the distribution of onset and status of conditions. These tabulations were then stratified by age, gender, race and smoking status. The variable indicating the timing of the onset of the conditions was also explored to determine if chronic sinusitis preceded asthma and chronic bronchitis.

Results: Not surprisingly, the onset of each of the conditions were most associated with onsets of more than five years. Age, gender, race and smoking status did not appear to affect this relationship. The prevalence of these conditions was higher in women. In cases where subjects reported having chronic sinusitis and asthma, only five (four

females and one male) of the 144 cases reported that the chronic sinusitis had preceded asthma. When chronic bronchitis was evaluated in the same manner only 12 of the 264 individuals reported the chronic sinusitis occurring before the chronic bronchitis. Because there were so few cases of chronic sinusitis that could be identified as having preceded asthma or bronchitis, no further analyses were completed on these data.

4. Job History Data to Identify Occupation and Industry at Time of Condition Onset

The Occupational Health Supplement contains a job history that was used to try and identify the industry and occupation a worker held at the onset of one of the three study conditions. Unfortunately, the design of the questionnaire did not include a complete job history for every observation. The set of questions only allowed the identification of industry and occupation at the time of a condition onset for a subset of the population. Analyses were completed on this subset, even though it was apparent that the power of the analyses would be less than optimal. Distributions for industry of onset and occupation of onset were calculated for each condition (Tables 15-16).

Results: We could only identify industries of asthma onset for 19 individuals. Those industries most associated with the onset of asthma were Manufacturing (6/19=32%); Professional and Related Services (6/19=32%); and Business and Repair Services (3/19=16%). Occupations of onset were identified for 29 individuals. The four occupations most associated with the onset of asthma were Administrative Support Occupations, Including Clerical (24.1%); Executive, Administrative, and Managerial Occupations (17.2%); Machine Operators, Assemblers and Inspectors (10.3%); and Sales Occupations (10.3%).

The onset of chronic bronchitis (89 industries of onset identified) was most associated with the following industries: Professional and Related Services (29.9%); Manufacturing (21.3%); Transportation, Communications and Other Public Utilities (10.1%); and Retail Trade (10.1%). The occupations most associated with the onset of chronic bronchitis

were Administrative Support Occupations, Including Clerical (25.2%); Professional Specialty Occupations (20.0%); Machine Operators, Assemblers and Inspectors (9.6%); and Sales Occupations (8.7%).

The industries most associated with the onset of chronic sinusitis (190 cases identified) were Manufacturing (20%), Professional and Related Services (16.8%), Retail Trade (15.8%), Business and Repair Services (10.5%); Construction (8.4%). One hundred ninety eight occupations associated with the onset of chronic sinusitis were identified. The occupations most associated with the onset of chronic sinusitis were Administrative Support Occupations, Including Clerical (21.5%); Professional Specialty Occupations (15.6%); Precision Production, Craft and Repair Occupations (10.5%); Executive, Administrative, and Managerial Occupations (10.5%); Service Occupations, Except Protective and Household (10.2%).

A cross-tabulation of industry and occupation in this small subset (Table 17) highlighted the following industry/occupation combinations based solely on frequency: Professional and Related Services/Professional Specialty Occupations (n=16); Manufacturing/Machine Operators, Assemblers and Inspectors (n=10); Construction/Precision Production, Craft and Repair Occupations (n=9); and Retail Trade/Sales Occupations (n=9).

National Estimates by Industry Sector: Tables 18-20 were developed to calculate national sinusitis estimates by industry. Tables 18 and 19 apply the sinusitis and asthma prevalence estimates from NHIS to the National BLS estimates of full time employees in each industrial sector. Table 20 approximates incidence as best we could, given the NHIS data. We used the onset of sinusitis by industry to develop "incidence like estimates" then applied them to the BLS data. It must be noted that these estimates were the closest we could get to a measure that resembled incidence. They do not represent actual incidence rates. These estimates both prevalence and the approximation to incidence, help portray the magnitude of these conditions. They affect many thousands of individuals.

D. DISCUSSION

The overall objective of this research was to use the National Health Interview Survey (NHIS) data to investigate the relationship between chronic sinusitis and industry and occupation, as well as between sinusitis and chronic lower airway conditions, namely asthma, chronic bronchitis and hayfever. In addition, we were able to evaluate other demographic characteristics such as age, gender, race, education, smoking, and health status, working class. We focused on the 1988 NHIS data as it contained an occupational health supplement with job history information that was used to determine industry and occupation at time of condition onset.

As with any such study, the cross-sectional nature of these analyses make assertions of some of the associations tenuous. For example, we are looking at primarily chronic conditions, most of which began 5 years or more ago and associating them with current industry, occupation, health, smoking, and educational status, which are likely to have changed over time. In addition, selection effects, where workers move away from jobs that are making them ill and the healthy worker effect must also be taken into account when considering the limitations of these analyses and interpreting these results. In an attempt to control for selection effects, job history data were used to identify the industry and occupation at the time of disease onset. Unfortunately, this was only possible for a small subset of the cohort so sophisticated or robust analysis were not able to be conducted.

The data, once stratified by industry and occupation at the crudest (2 digit) level were sparse and did not allow further stratification by age, gender, race, smoking status, or to the 4-digit SIC and SOC level. This makes interpretation very difficult and also seriously limited the capacity to conduct any job exposure matrix analyses, as originally planned. The identification of high-risk industries and occupations at the more specific, higher digit levels is not possible in this data set. It is however, encouraging that we did see some evidence of increased risk in industries such as Mining and in industry/occupation combinations including Precision, Production Craft & Repair occupations in the Construction industry and Machine Operators, Assemblers & Inspectors in the Manufacturing sector. The association

of Entertainment and Recreation Services with chronic sinusitis, asthma, and chronic bronchitis was unexpected and the explanation for this unclear.

It is interesting that Mining was associated with both chronic sinusitis and chronic bronchitis. One could surmise that this is a possible result of dust or particulate exposures, but as mentioned earlier, the small number (n=59) of observations falling into this sector make it impossible to do further analysis. This limited data may have also obliterated the chance of observing an association with asthma if it were of moderate magnitude, assuming one exists.

As was expected, women were more likely to develop each of the investigated conditions. The relationship between age and the conditions varied. Risk of chronic sinusitis and chronic bronchitis increased with age, whereas asthma was most frequently reported by those ages 35-54 and risk of hayfever decreased with age. Whites were more likely to report each of the conditions, except for asthma, which was more prevalent in non-whites. In earlier analyses it was significantly associated with blacks as compared to whites (data not shown). Current smokers were more likely to report each of the conditions except for asthma. This finding is not surprising.

Chronic sinusitis is strongly associated with each of the conditions we investigated. The magnitude of the association was largest for chronic bronchitis and asthma followed by that for chronic bronchitis and chronic sinusitis. The nature of the questionnaire limited the ability to identify detailed information regarding time of onset for the great majority of the observations once again making further analysis impossible. For example, of the 149 who reported having both sinusitis and asthma only 5 developed asthma prior to chronic sinusitis. This group of 149 eliminated everyone who had developed disease five or more years before the survey. This represents a significant problem especially when evaluating chronic diseases.

It seems that chronic sinusitis and chronic bronchitis had similar relationships to each of the variables investigated, whereas asthma differed somewhat. This is interesting because all of these conditions are so closely associated to each other. Hayfever (without asthma) as

an outcome is difficult to interpret as the variable was designed to exclude those who also had asthma. The reason for this is unclear. The group would represent atopic individuals, but omits asthmatics therefore changing the aspects of comparison. Interestingly, hayfever was the only condition for which education was a significant explanatory variable. One possible explanation for this was the manner in which the variable was categorized. If the variable were stratified so that the lower levels of education were separated out more distinctly and compared to those having any college education (1+ years), perhaps another picture would have emerged.

Overall, these analyses demonstrate a strong relationship between these four diseases though the direct nature of these relationships is not entirely clear. Chronic sinusitis, chronic bronchitis and asthma are often coincident but the limited condition onset information prevented the ability to observe the progression of the development of the disease process. In other words, we were unable to determine which diseases began first or diagram the disease process in cases where multiple conditions were affecting individuals.

A longitudinal study would be the best way to approach this situation. Designing a longitudinal study would allow one to follow the natural progression of these disease processes and could also account for time varying explanatory variables such as industry occupation, education, health and smoking status. An alternative would be to ask more refined questions about the onset of conditions to collect more detailed information. Recall bias would, of course be a problem with this approach. A more thorough job history matrix in the Occupational Health Supplement would also be beneficial. The current design does not allow thorough analysis of the data.

E. TABLES

Table 1: Frequencies and Descriptives for Variables of Interest, Compared by Condition

| Variable | Sinusitis | Asthma | Chronic Bronchitis | Hayfever | Total |
|-----------------------------------------------------|-------------|-----------|--------------------|-------------|--------------|
| Overall Prevalence* | 16.8 (2485) | 3.8 (575) | 4.8 (699) | 10.4 (1525) | |
| Age years, mean (s.d.) | | | | | 44.2 (17.8) |
| Age Categories, % (n) | | | | | |
| 18-34 | 14.6 (792) | 3.8 (208) | 3.8 (206) | 11.0 (601) | 36.7 (5434) |
| 35-55 | 18.5 (927) | 3.5 (173) | 4.3 (216) | 11.2 (565) | 33.8 (10440) |
| >55 | 17.5 (766) | 4.4 (194) | 6.3 (277) | 8.2 (359) | 29.5 (4374) |
| Race, % (n) | | | | | |
| White | 17.4 (2129) | 3.8 (460) | 4.9 (603) | 10.8 (1322) | 82.4 (12214) |
| Gender% (n) | | | | | |
| Male | 13.8 (951) | 3.2 (222) | 3.3 (230) | 9.6 (658) | 47.0 (6884) |
| **Smoking Status | | | | | |
| Never | 17.25 (605) | 4.2 (146) | 3.3 (115) | 12.0 (422) | 47.8 (3507) |
| Former | 17.83 (310) | 4.4 (76) | 4.6 (80) | 11.2 (194) | 23.7 (1739) |
| Current | 18.97 (397) | 3.8 (80) | 7.0 (147) | 9.7 (203) | 28.5 (2093) |
| Employment Status in Past 2 weeks | | | | | |
| Worked in past 2 weeks | 16.2 (1514) | 3.2 (301) | 3.8 (356) | 10.9 (1016) | 63.0 (9331) |
| Not in labor force | 17.9 (869) | 5.1 (250) | 6.3 (306) | 9.0 (439) | 32.8 (4860) |
| ***Did not work, has job | 15.3 (42) | 3.3 (9) | 8.3 (23) | 12.4 (34) | 1.9 (275) |
| Did not work, no job, looking for work or on layoff | 17.2 (60) | 4.3 (15) | 4.0 (14) | 10.3 (36) | 2.3 (348) |
| Health Status | | | | | |
| Excellent, Very Good, Good | 15.8 (2023) | 3.2 (405) | 3.9 (495) | 10.5 (1339) | 86.9 (12807) |
| Fair | 23.5 (322) | 7.0 (96) | 8.9 (122) | 10.2 (140) | 9.3 (1373) |
| Poor | 24.1 (135) | 13.0 (73) | 14.3 (80) | 8.0 (45) | 3.8 (560) |

*Prevalence for nasal polyps and deviated nasal septum were under 1% (n=54 and n=111, respectively).

**Smoking information was only available for about half of the sample.

***Includes those 1) looking for work, 2) on layoff, 3) on layoff & looking for work, 4) unknown if looking or on layoff.

Table 1 (Continued): Frequencies and Descriptives for Variables of Interest, Compared by Condition

| Variable | Sinusitis | Asthma | Chronic Bronchitis | Hayfever | Total |
|-----------------------------|--------------|-----------|-----------------------|------------|--------------|
| Educational Status | | | | | |
| High School or Less | 16.93 (1531) | 4.1 (370) | 4.9 (443) | 8.3 (746) | 61.6 (9041) |
| 1-3 years of college | 17.0 (503) | 3.6 (108) | 4.7 (139) | 12.4 (365) | 20.1 (2953) |
| 4 years of college | 16.2 (248) | 3.5 (53) | 4.3 (66) | 13.8 (211) | 10.4 (1527) |
| 5 + years , post college | 16.8 (193) | 3.4 (39) | 4.1 (47) | 17.2 (198) | 7.8 (1150) |
| Working Class | | | | | |
| Not in Labor Force | 17.9 (869) | 5.0 (250) | 6.5 (306) | 9.2 (439) | 32.09 (4860) |
| Private Company | 16.1 (1129) | 3.2 (224) | 4.1 (283) | 10.1 (717) | 48.22 (7051) |
| Federal Government Employee | 21.5 (67) | 3.2 (10) | 4.3 (13) | 13.7 (42) | 2.08 (310) |
| State Government Employee | 18.8 (83) | 2.8 (11) | 2.0 (10) | 15.5 (63) | 3.06 (431) |
| Local Government Employee | 18.2 (145) | 3.3 (27) | 4.8 (37) | 15.5 (121) | 5.29 (797) |
| Incorporated Business | 14.5 (35) | 6.0 (15) | 5.4 (13) | 11.8 (30) | 1.77 (253) |
| Self-Employed | 15.0 (134) | 3.6 (34) | 3.4 (32) | 10.5 (96) | 6.12 (899) |
| Without pay | 13.8 (3) | 4.1 (1) | 4.1 (1) | 19.5 (4) | 0.14 (22) |
| Never worked | 10.5 (2) | 0.0 | 3.6 (1) | 15.0 (2) | 0.10 (16) |
| Unknown | 10.5 (18) | 1.9 (3) | 1.8 (1.04) | 7.0 (11) | 1.15 (177) |

Table 2: Frequencies and Descriptives for Industry (2digit level), Compared by Condition

| Industry | Sinusitis | Asthma | Chronic Bronchitis | Hayfever | Total |
|---------------------------------------------------------|------------------|---------------|-------------------------------|-----------------|--------------|
| Agriculture, forestry, fisheries | 15.0 (46) | 4.2 (13) | 3.3 (10) | 8.8 (27) | 2.1 (306) |
| Mining | 25.4 (15) | 3.4 (2) | 8.5 (5) | 13.6 (8) | 0.4 (59) |
| Construction | 13.2 (294) | 1.6 (11) | 2.7 (18) | 10.0 (68) | 4.6 (677) |
| Manufacturing | 15.7 (294) | 2.6 (49) | 3.6 (68) | 9.1 (170) | 12.7 (1878) |
| Transportation, communications & other public utilities | 15.2 (107) | 3.0 (21) | 3.4 (24) | 9.9 (170) | 4.8 (704) |
| Wholesale trade | 16.1 (53) | 2.1 (7) | 3.3 (11) | 13.3 (44) | 2.2 (330) |
| Retail trade | 16.4 (249) | 3.3 (50) | 4.1 (63) | 10.7 (162) | 10.3 (1520) |
| Finance, insurance, & real estate | 16.4 (103) | 4.0 (25) | 3.5 (22) | 10.7 (67) | 4.2 (628) |
| Business & repair services | 17.5 (105) | 4.2 (25) | 5.0 (30) | 10.0 (60) | 4.0 (599) |
| Personal services | 15.0 (61) | 3.2 (13) | 4.9 (20) | 10.8 (44) | 2.8 (408) |
| Entertainment & recreation services | 20.5 (26) | 8.7 (11) | 3.9 (5) | 8.7 (11) | 0.9 (127) |
| Professional & related services | 17.6 (350) | 4.2 (83) | 4.7 (93) | 13.0 (259) | 13.5 (1993) |
| Public administration | 19.4 (98) | 2.4 (12) | 3.6 (18) | 15.6 (79) | 3.4 (505) |
| Unknown | 9.1 (20) | 1.4 (3) | 2.7 (6) | 7.7 (17) | 1.5 (220) |
| Not in labor force | 17.9 (869) | 5.1 (250) | 6.3 (306) | 9.0 (439) | 32.8 (4860) |

Table 3: Frequencies and Descriptives for Occupation (two digit level), Compared by Condition

| Occupation | Sinusitis | Asthma | Chronic Bronchitis | Hayfever | Total |
|--------------------------------------------------------|------------|-----------|--------------------|------------|-------------|
| Executive, administration & managerial occupations | 16.4 (207) | 3.6 (45) | 3.7 (47) | 13.0 (164) | 8.5 (1264) |
| Professional specialty occupations | 18.4 (238) | 3.4 (44) | 4.9 (63) | 15.7 (203) | 8.7 (1291) |
| Technicians & related support occupations | 18.5 (57) | 3.2 (10) | 4.9 (15) | 12.9 (40) | 2.1 (309) |
| Sales occupations | 17.4 (191) | 3.4 (37) | 4.0 (44) | 11.3 (124) | 7.4 (1101) |
| Administrative support occupations, including clerical | 18.6 (276) | 3.4 (51) | 5.0 (74) | 10.8 (160) | 10.0 (1486) |
| Private household occupations | 10.0 (9) | 6.7 (6) | 3.3 (3) | 12.2 (11) | 0.6 (90) |
| Protective service occupations | 11.5 (19) | 1.7 (3) | 1.7 (3) | 16.3 (28) | 1.2 (172) |
| Service occupations, except protective & household | 15.2 (151) | 4.1 (41) | 4.2 (42) | 10.1 (100) | 6.7 (993) |
| Farming, forestry, fishing occupations | 13.9 (42) | 3.6 (11) | 3.3 (10) | 7.3 (22) | 2.0 (302) |
| Precision, production, craft & repair occupations | 15.6 (181) | 2.3 (27) | 3.1 (36) | 9.5 (110) | 7.8 (1158) |
| Machine operators, assemblers, inspectors | 12.6 (93) | 3.0 (22) | 3.1 (23) | 6.3 (46) | 5.0 (736) |
| Transportation & material moving occupations | 15.5 (71) | 3.5 (16) | 3.5 (16) | 6.8 (31) | 3.1 (457) |
| Handlers, equipment cleaners, helpers & laborers | 15.0 (58) | 2.1 (8) | 2.8 (11) | 7.5 (29) | 2.6 (386) |
| Unknown occupation (includes new workers) | 11.0 (23) | 1.9 (4) | 2.9 (6) | 8.6 (18) | 1.4 (209) |
| Not in labor force | 17.9 (869) | 5.1 (250) | 6.3 (306) | 9.0 (439) | 32.8 (4860) |

Table 4a: Contrasts for Chronic Sinusitis and Various Confounders

| Contrast: Sinusitis (1=Yes) by Confounders | | | | |
|---------------------------------------------------|-------------------|-----------|--------------------|----------------|
| | Difference | SE | T-Statistic | p-Value |
| Excellent - Good vs. Fair | -7.529 | 1.184 | -6.359 | 0.0000 |
| Excellent - Good vs. Poor | -8.816 | 1.950 | -4.522 | 0.0000 |
| Fair vs. Poor | -1.287 | 2.171 | -0.593 | 0.5533 |
| Excellent-Good vs. Fair/Poor | -8.172 | 1.193 | -6.850 | 0.0000 |
| Never vs. Ex-smoker | -0.594 | 1.242 | -0.479 | 0.6321 |
| Never vs. Current-smoker | -1.624 | 1.110 | -1.463 | 0.1435 |
| Ex-smoker vs. Current-smoker | -1.030 | 1.366 | -0.754 | 0.4510 |
| 18-34 vs.35-55 | -3.722 | 0.747 | -4.979 | 0.0000 |
| 18-34 vs.55+ | -2.660 | 0.781 | -3.406 | 0.0007 |
| 35-55 vs.55+ | 1.062 | 0.807 | 1.315 | 0.1885 |
| 18-34 vs.35-55/55+ | -3.191 | 0.649 | -4.915 | 0.0000 |
| With jobs(1,3) vs. No jobs (2,4) | -2.021 | 1.515 | -1.335 | 0.1820 |

Table 4b: Contrasts for Asthma and Various Confounders

| Contrast: Asthma (1=Yes) by Confounders | | | | |
|------------------------------------------------|-------------------|-----------|--------------------|----------------|
| Contrast Variable | Difference | SE | T-Statistic | p-Value |
| Excellent - Good vs. Fair | 3.401 | 0.665 | -5.117 | 0.0000 |
| Excellent - Good vs. Poor | -9.577 | 1.445 | -6.629 | 0.0000 |
| Fair vs. Poor | -6.176 | 1.633 | -3.781 | 0.0002 |
| Excellent-Good vs. Fair/Poor | -6.489 | 0.773 | -8.393 | 0.0000 |
| Never vs. Ex-smoker | -0.224 | 0.632 | -0.354 | 0.7236 |
| Never vs. Current-smoker | 0.527 | 0.522 | 1.010 | 0.3127 |
| Ex-smoker vs. Current-smoker | 0.750 | 0.645 | 1.163 | 0.2448 |
| 18-34 vs. 35-55 | 0.606 | 0.373 | 1.625 | 0.1042 |
| 18-34 vs. 55+ | -0.366 | 0.404 | -0.906 | 0.3650 |
| 35-55 vs. 55+ | -0.972 | 0.410 | -2.370 | 0.0178 |
| 18-34 vs. 35-55/55+ | 0.120 | 0.330 | 0.362 | 0.7171 |
| With jobs (1,3) vs. No jobs(2,4) | -1.315 | 0.854 | -1.541 | 0.1235 |

Table 4c: Contrasts for Chronic Bronchitis and Various Confounders

| Contrast: Bronchitis (1=Yes) by Confounders | | | | |
|----------------------------------------------------|-------------------|-----------|--------------------|----------------|
| Contrast Variable | Difference | SE | T-Statistic | p-Value |
| Excellent-Good vs. Fair | -5.600 | 0.864 | -6.479 | 0.0000 |
| Excellent-Good vs. Poor | -10.624 | 1.565 | -6.790 | 0.0000 |
| Fair vs. Poor | -5.024 | 1.717 | -2.925 | 0.0034 |
| Excellent-Good vs. Fair/Poor | -8.112 | 0.927 | -8.747 | 0.0000 |
| Never vs. Ex- smoker | -0.179 | 0.634 | -0.282 | 0.7778 |
| Never vs. Current-smoker | -2.316 | 0.624 | -3.712 | 0.0002 |
| Ex-smoker vs. Current-smoker | -2.137 | 0.758 | -2.821 | 0.0048 |
| 18-34 vs. 35-55 | -0.440 | 0.390 | -1.126 | 0.2600 |
| 18-34 vs. 55+ | -2.591 | 0.471 | -5.503 | 0.0000 |
| 35-55 vs. 55+ | -2.152 | 0.485 | -4.435 | 0.0000 |
| 18-34 vs. 35- 55/55+ | -1.515 | 0.358 | -4.233 | 0.0000 |
| With jobs (1,3) vs. No jobs (2,4) | 0.623 | 1.153 | 0.540 | 0.5889 |

Table 4d: Contrasts for Hayfever and Various Confounders

| Contrast: Hayfever (1=Yes) by Confounders | | | | |
|--------------------------------------------------|-------------------|-----------|--------------------|----------------|
| Contrast Variable | Difference | SE | T-Statistic | p-Value |
| Excellent - Good vs. Fair | 0.839 | 0.872 | 0.963 | 0.3358 |
| Excellent - Good vs. Poor | 2.815 | 1.248 | 2.255 | 0.0242 |
| Fair vs. Poor | 1.975 | 1.484 | 1.331 | 0.1831 |
| Excellent - Good vs. Fair/Poor | 1.827 | 0.780 | 2.341 | 0.0192 |
| Never vs. Ex-smoker | 1.023 | 0.921 | 1.111 | 0.2666 |
| Never vs. Current-smoker | 2.121 | 0.889 | 2.386 | 0.0170 |
| Ex-smoker vs. Current-smoker | 1.098 | 1.001 | 1.097 | 0.2728 |
| 18-34 vs. 35-55 | -0.139 | 0.666 | -0.209 | 0.8341 |
| 18-34 vs. 55+ | 3.030 | 0.679 | 4.460 | 0.0000 |
| 35-55 vs. 55+ | 3.169 | 0.674 | 4.701 | 0.0000 |
| 18-34 vs. 35-55/55+ | 1.445 | 0.582 | 2.482 | 0.0131 |
| With jobs (1,3) vs. No jobs (2,4) | 1.916 | 1.272 | 1.506 | 0.1320 |

Table 5a: Contrasts for Sinusitis: Three most prevalent industries and occupations against the remainder collapsed into one group

| | Difference | SE | T-Statistic | p-Value |
|------------------------|-------------------|-----------|--------------------|----------------|
| Industry | | | | |
| Mining vs. OTHER | -9.885 | 6.225 | -1.588 | 0.1123 |
| Enter/Rec vs. OTHER | -5.868 | 3.934 | -1.492 | 0.1358 |
| Pub. Adm. vs. OTHER | -2.411 | 1.830 | -1.318 | 0.1875 |
| Buss/Repair vs. OTHER | -2.050 | 1.633 | -1.255 | 0.2093 |
| Not in Labor vs. OTHER | -1.949 | 0.773 | -2.523 | 0.0117 |
| Occupation | | | | |
| Prof. Spec. vs. OTHER | -3.050 | 1.217 | -2.506 | 0.0122 |
| Technician vs. OTHER | -2.848 | 2.254 | -1.264 | 0.2064 |
| Adm. Support vs. OTHER | -3.300 | 1.143 | -2.886 | 0.0039 |
| Not in Labor vs. OTHER | -2.548 | 0.814 | -3.130 | 0.0018 |

*OTHER is the remaining industries collapsed into one group that is used for comparison.

Table 5b: Contrasts for Asthma: Three most prevalent industries and occupations against the remainder collapsed into one group

| | Difference | SE | T-Statistic | p-Value |
|-----------------------------|-------------------|-----------|--------------------|----------------|
| Industry | | | | |
| Enter./Rec vs. OTHER | -5.926 | 3.948 | -1.501 | 0.1334 |
| Agri/Forestry vs. OTHER | 0.553 | 2.147 | 0.257 | 0.7968 |
| Professional vs. OTHER | -1.890 | 1.024 | -1.846 | 0.0649 |
| Not in Labor vs. OTHER | -2.006 | 0.787 | -2.548 | 0.0108 |
| Occupation | | | | |
| Private Household vs. OTHER | 5.632 | 3.678 | 1.531 | 0.1257 |
| Service Occup. vs. OTHER | 0.853 | 1.281 | 0.666 | 0.5055 |
| Farming/Forestry vs. OTHER | 2.464 | 2.047 | 1.204 | 0.2286 |
| Not in Labor vs. OTHER | -1.370 | 0.772 | -1.776 | 0.0757 |

*OTHER is the remaining industries collapsed into one group that is used for comparison.

Table 5c: Contrasts for Chronic Bronchitis: Three most prevalent industries and occupations against the remainder collapsed into one group

| | Difference | SE | T-Statistic | p-Value |
|------------------------|------------|-------|-------------|---------|
| Industry | | | | |
| Mining vs. OTHER | -9.751 | 6.231 | -1.565 | 0.1176 |
| Buss./Repair vs. OTHER | -1.916 | 1.635 | -1.172 | 0.2411 |
| Enter./Rec. vs. OTHER | -5.735 | 3.934 | -1.458 | 0.1449 |
| Not in Labor vs. OTHER | -1.815 | 0.763 | -2.379 | 0.0174 |
| Occupation | | | | |
| Prof. Spec. vs. OTHER | -3.050 | 1.217 | -2.506 | 0.0122 |
| Technician vs. OTHER | -2.848 | 2.254 | -1.264 | 0.2064 |
| Adm.Support vs. OTHER | -3.300 | 1.143 | -2.886 | 0.0039 |
| Not in Labor vs. OTHER | -2.548 | 0.814 | -3.130 | 0.0018 |

*OTHER is the remaining industries collapsed into one group that is used for comparison.

Table 5d: Contrasts for Hayfever: Three most prevalent industries and occupations against the remainder collapsed into one group

| | Difference | SE | T-Statistic | p-Value |
|------------------------|------------|-------|-------------|---------|
| Industry | | | | |
| Mining vs. OTHER | -10.108 | 6.226 | -1.624 | 0.1045 |
| Professional vs. OTHER | -2.055 | 1.021 | -2.014 | 0.0441 |
| Pub. Adm. vs. OTHER | -2.634 | 1.812 | -1.454 | 0.1461 |
| Not in Labor vs. OTHER | -2.172 | 0.783 | -2.775 | 0.0055 |
| Occupation | | | | |
| Prof. Spec. vs. OTHER | -2.344 | 1.206 | -1.944 | 0.0520 |
| Technician vs. OTHER | -2.143 | 2.255 | -0.950 | 0.3421 |
| Protective vs. OTHER | 5.554 | 2.375 | 2.339 | 0.0194 |
| Not in Labor vs. OTHER | -1.843 | 0.787 | -2.342 | 0.0192 |

*OTHER is the remaining industries collapsed into one group that is used for comparison.

Table 6: Distribution and Relative Risks for Multiple Conditions.

| Condition 1 | Condition 2 | Number with Both Conditions | % of Those with Condition 1 That Have Condition 2 | % of Those with Condition 2 That Have Condition 1 | Relative Risks | Test of Association p-value |
|---------------------|--------------------|-----------------------------|---------------------------------------------------|---------------------------------------------------|----------------|-----------------------------|
| Asthma | Chronic sinusitis | 144 | 25.0 | 5.8 | 1.52 | 0.001 |
| Chronic sinusitis | Chronic bronchitis | 264 | 10.6 | 37.8 | 2.40 | 0.001 |
| Asthma | Chronic bronchitis | 113 | 19.7 | 16.2 | 4.94 | 0.001 |
| Chronic sinusitis | Hayfever | 387 | 15.6 | 25.4 | 1.61 | 0.001 |
| *Asthma | Hayfever | 26 | 1.7 | 4.5 | * | * |
| Chronic. bronchitis | Hayfever | 106 | 15.2 | 7.0 | 1.56 | 0.001 |

*asthma and hayfever without asthma are supposed to be mutually exclusive by definition.

**29% (n=4358) of the sample had at least one condition.

Table 7: Frequencies and Descriptives for Variables of Interest, Compared by Multiple Condition

| Variable | Sinusitis and Asthma | Sinusitis and Chronic Bronchitis | Sinusitis and Hayfever | Asthma and Chronic Bronchitis |
|--------------------------------|----------------------|----------------------------------|------------------------|-------------------------------|
| Age Categories, % (n) | | | | |
| 18-24 | 0.55 (13) | 1.33 (27) | 2.48 (47) | 0.68 (15) |
| 25-34 | 0.91 (31) | 1.47 (50) | 3.12 (104) | 0.43 (15) |
| 35-44 | 0.79 (23) | 1.4 (43) | 2.74 (86) | 0.62 (19) |
| 45-54 | 0.84 (19) | 2.08 (39) | 3.08 (62) | 0.79 (17) |
| 55-64 | 1.10 (22) | 2.58 (48) | 2.61 (45) | 1.07 (21) |
| 65-74 | 1.80 (29) | 2.54 (41) | 1.67 (27) | 1.09 (18) |
| >75 | 0.80 (7) | 1.70 (16) | 1.79 (16) | 0.82 (8) |
| <i>Total</i> | <i>0.94 (144)</i> | <i>1.79 (264)</i> | <i>2.65 (387)</i> | <i>0.72 (113)</i> |
| Race, % (n) | | | | |
| White | 0.92 (116) | 1.92 (237) | 2.72 (326) | 0.70 (89) |
| Black | 1.21(25) | 1.12 (24) | 2.49 (52) | 1.03(22) |
| Other | 0.51 (3) | 0.55 (3) | 1.53 (9) | 0.43 (2) |
| <i>Total</i> | <i>0.94 (144)</i> | <i>1.79 (264)</i> | <i>2.56 (387)</i> | <i>0.72 (113)</i> |
| Gender, % (n) | | | | |
| Male | 0.62 (44) | 1.00 (72) | 1.92 (130) | 0.42 (31) |
| Female | 1.22 (100) | 2.48 (192) | 3.29 (257) | 0.99 (82) |
| <i>Total</i> | <i>0.94 (144)</i> | <i>1.79 (264)</i> | <i>2.65 (387)</i> | <i>0.720 (113)</i> |
| **Smoking Status, % (n) | | | | |
| Never | 0.78 (28) | 1.74 (58) | 2.84 (102) | 0.55 (22) |
| Former | 1.14 (21) | 1.26 (22) | 2.24 (39) | 0.74 (13) |
| Current | 1.07 (23) | 2.96(65) | 3.24 (68) | 1.25 (28) |
| Unknown/Missing | 0.93 (72) | 1.60 (121) | 2.49 (170) | 0.65 (50) |
| <i>Total</i> | <i>0.94 (144)</i> | <i>1.79 (264)</i> | <i>2.65 (387)</i> | <i>0.72 (113)</i> |

Table 8: Frequencies and Descriptives for Employment Status and Health Status, Compared by Multiple Condition

| Variable | Sinusitis and Asthma | Sinusitis and Chronic Bronchitis | Sinusitis and Hayfever | Asthma and Chronic Bronchitis |
|-----------------------------------------------------|----------------------|----------------------------------|------------------------|-------------------------------|
| Employment Status in Past 2 weeks | | | | |
| Worked in past 2 weeks | 0.70 (67) | 1.44 (135) | 2.61 (241) | 0.52 (52) |
| Not in labor force | 1.34 (68) | 2.46 (7) | 2.82 (134) | 1.20 (60) |
| ***Did not work, has job | 0.73 (2) | 1.93 (5) | 1.12 (3) | 0 (0) |
| Did not work, no job, looking for work or on layoff | 2.25 (7) | 1.86 (7) | 2.54 (9) | 0.28 (1) |
| <i>Total</i> | <i>0.94 (144)</i> | <i>1.79 (264)</i> | <i>2.45 (387)</i> | <i>0.72 (113)</i> |
| Health Status | | | | |
| Excellent | 0.32 (15) | 0.61 (29) | 1.97 (96) | 0.24 (12) |
| Very Good | 0.79 (32) | 1.59 (65) | 3.03 (121) | 0.41 (18) |
| Good | 1.19 (47) | 2.37 (86) | 2.58 (93) | 0.83 (32) |
| Fair | 1.66 (24) | 3.89 (52) | 4.03 (56) | 1.87 (25) |
| Poor | 4.61 (26) | 5.45 (31) | 3.51 (21) | 4.41 (26) |
| Unknown | 0 (0) | 1.24 (1) | 0 (0) | 0 (0) |
| <i>Total</i> | <i>0.94 (144)</i> | <i>1.79 (264)</i> | <i>2.65 (387)</i> | <i>0.72 (113)</i> |

*Prevalence for nasal polyps and deviated nasal septum were under 1% (n=54 and n=111, respectively).

**Smoking information was only available for about half of the sample.

***Includes those 1) looking for work, 2) on layoff, 3) on layoff & looking for work, 4) unknown if looking or on layoff.

Table 9: Prevalence Ratios for Select Conditions

| Conditions | Prevalence Ratio | 95% Confidence Interval | χ^2 | p - Value |
|----------------------------------|------------------|-------------------------|----------|-----------|
| Chronic bronchitis and asthma | 4.69 | 3.80-5.80 | 64.42 | 0.0000 |
| Asthma and chronic sinusitis | 1.50 | 1.28- 1.74 | 18.73 | 0.0000 |
| Chronic bronchitis and sinusitis | 2.37 | 2.12-2.64 | 94.53 | 0.0000 |
| Hayfever and sinusitis | 1.62 | 1.46-1.79 | 51.69 | 0.0000 |
| Hayfever and asthma** | 0.38 | 0.26-0.57 | 45.92 | 0.0000 |
| Hayfever and chronic bronchitis | 1.55 | 1.25-1.91 | 11.02 | 0.0009 |

**These conditions are supposed to be mutually exclusive by design of the survey tool. Hayfever is defined as "Hayfever without asthma."

Table 10a: Univariate Logistic Regression Models with Sinusitis as the Dependent Variable and Other Independent Terms.

| Variable | Univariate Logistic Regression Models with Sinusitis as the Dependent Variable | | | |
|---------------------|--------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| Asthma | 13394.44 | 1.66 | 1.36-2.02 | < 0.001 |
| Bronchitis | 13235.41 | 3.19 | 2.69-3.78 | < 0.001 |
| Hayfever | 13333.59 | 1.83 | 1.59-2.09 | < 0.001 |
| Race-(White) | 13391.67 | 1.41 | 1.23-1.59 | < 0.001 |
| Gender (female) | 13328.10 | 1.53 | 1.39-1.67 | < 0.001 |
| Age | 13404.19 | 1.00 | 1.00-1.01 | <0.001 |
| Age35-54 | 13389.90 | 1.31 | 1.18-1.45 | < 0.001 |
| Age ≥ 55 | | 1.22 | 1.09-1.36 | <0.001 |
| Fair Health Status | 13306.34 | 1.62 | 1.42-1.85 | <0.001 |
| Poor Health Status | | 1.74 | 1.42-2.13 | <0.001 |
| *Ex-Smokers | 6881.16 | 1.04 | 0.88-1.23 | 0.63 |
| Current Smokers | | 1.12 | 0.97-1.29 | 0.14 |
| Education Status | 13332.99 | 1.00 | 0.95-1.05 | 0.98 |
| Education Status | 13332.17 | | | |
| High School or Less | | 0.97 | 0.81-1.17 | 0.779 |
| 1-3 years College | | 0.99 | 0.81-1.20 | 0.928 |
| 4 years College | | 0.92 | 0.74-1.15 | 0.489 |
| 5+ years College | | 1.00 | - | - |

*Smoking data was only available for 50% of the population (n=7339)

Table 10b: Multivariate Logistic Regression Models with Sinusitis as the Dependent Variable and Significant Independent Terms—including all Conditions and a Categorical Age Term..

| Variable | Multivariate Logistic Regression Model with Sinusitis as the Dependent Variable | | | |
|--------------------|---------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| Asthma | 12942.30 | 1.35 | 1.09-1.68 | <0.01 |
| Bronchitis | | 2.65 | 2.21-3.18 | <0.001 |
| Hayfever | | 1.76 | 1.54-2.02 | <0.001 |
| Race-(White) | | 1.45 | 1.27-1.64 | <0.001 |
| Gender (female) | | 1.47 | 1.34-1.61 | <0.001 |
| Age35-54 | | 1.27 | 1.14-1.42 | <0.001 |
| Age ≥ 55 | | 1.04 | 0.93-1.17 | 0.50 |
| Fair Health Status | | 1.53 | 1.33-1.77 | <0.001 |
| Poor Health Status | | 1.61 | 1.28-2.03 | <0.001 |

Table 10c: Multivariate Logistic Regression Models with Sinusitis as the Dependent Variable and Significant Independent Terms—including only Asthma.

| Variable | Multivariate Logistic Regression Model with Sinusitis as the Dependent Variable | | | |
|--------------------|---------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| Asthma | 13299.81 | 1.51 | 1.23-1.85 | <0.001 |
| Race-(White) | | 1.52 | 1.32-1.72 | <0.001 |
| Age | | 1.00 | 1.00-1.00 | 0.608 |
| Gender (female) | | 1.52 | 1.37-1.67 | <0.001 |
| Fair Health Status | | 1.58 | 1.38-1.82 | <0.001 |
| Poor Health Status | | 1.73 | 1.40-2.15 | <0.001 |

Table 10d: Multivariate Logistic Regression Models with Sinusitis as the Dependent Variable and Significant Independent Terms—including only Chronic Bronchitis.

| Variable | Multivariate Logistic Regression Model with Sinusitis as the Dependent Variable | | | |
|--------------------|---------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| | 13044.41 | | | |
| Bronchitis | | 2.79 | 1.23-1.85 | <0.001 |
| Race-(White) | | 1.47 | 1.30-1.67 | <0.001 |
| Age | | 1.00 | 1.00-1.00 | 0.773 |
| Gender (female) | | 1.47 | 1.35-1.61 | <0.001 |
| Fair Health Status | | 1.51 | 1.31-1.74 | <0.001 |
| Poor Health Status | | 1.60 | 1.27-2.00 | <0.001 |

Table 10e: Multivariate Logistic Regression Models with Sinusitis as the Dependent Variable and Significant Independent Terms—including only Hayfever.

| Variable | Multivariate Logistic Regression Model with Sinusitis as the Dependent Variable | | | |
|--------------------|---------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| | 13105.32 | | | |
| Hayfever | | 1.80 | 1.57-2.07 | <0.001 |
| Race-(White) | | 1.47 | 1.28-1.67 | <0.001 |
| Age | | 1.00 | 1.00-1.00 | 0.373 |
| Gender (female) | | 1.52 | 1.37-1.64 | <0.001 |
| Fair Health Status | | 1.61 | 1.40-1.85 | <0.001 |
| Poor Health Status | | 1.83 | 1.40-1.85 | <0.001 |

Table 10f: Multivariate Logistic Regression Models with Sinusitis as the Dependent Variable and Significant Independent Terms—including only Asthma and an Interaction Term for Race*Gender.

| Variable | Multivariate Logistic Regression Model with Sinusitis as the Dependent Variable | | | |
|--------------------|---------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| | 13165.60 | | | |
| Asthma | | 1.50 | 1.23-1.84 | <0.001 |
| Age | | 1.00 | 1.00-1.00 | <0.604 |
| Race-(White) | | 1.35 | 1.16-1.59 | <0.001 |
| Gender (female) | | 1.47 | 1.33-1.61 | <0.001 |
| Race*Gender | | 1.33 | 0.990-1.82 | 0.058 |
| Fair Health Status | | 1.58 | 1.38-1.82 | <0.001 |
| Poor Health Status | | 1.73 | 1.40-2.15 | <0.001 |

Table 10g: Multivariate Logistic Regression Models with Sinusitis as the Dependent Variable and Significant Independent Terms—including only Chronic Bronchitis and an Interaction Term for Race*Gender.

| Variable | Multivariate Logistic Regression Model with Sinusitis as the Dependent Variable | | | |
|--------------------|---------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| | 13039.94 | | | |
| Bronchitis | | 2.80 | 2.35-3.34 | <0.001 |
| Age | | 1.00 | 1.00-1.00 | 0.769 |
| Race-(White) | | 1.32 | 1.12-1.54 | <0.001 |
| Gender (female) | | 1.43 | 1.30-1.56 | <0.001 |
| Race*Gender | | 1.37 | 1.01-1.85 | 0.043 |
| Fair Health Status | | 1.51 | 1.31-1.74 | <0.001 |
| Poor Health Status | | 1.60 | 1.27-2.00 | <0.001 |

Table 10h: Multivariate Logistic Regression Models with Sinusitis as the Dependent Variable and Significant Independent Terms—including only Hayfever and an Interaction Term for Race*Gender.

| Variable | Multivariate Logistic Regression Model with Sinusitis as the Dependent Variable | | | |
|--------------------|---------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| | 13101.62 | | | |
| Hayfever | | 1.80 | 1.57-2.07 | <0.001 |
| Age | | 1.00 | 1.00-1.00 | 0.371 |
| Race-(White) | | 1.33 | 1.14-1.56 | <0.001 |
| Gender (female) | | 1.45 | 1.32-1.61 | <0.001 |
| Race*Gender | | 1.33 | 0.98-1.79 | 0.068 |
| Fair Health Status | | 1.61 | 1.40-1.85 | <0.001 |
| Poor Health Status | | 1.83 | 1.47-2.27 | <0.001 |

Table 10i: Multivariate Logistic Regression Models with Sinusitis as the Dependent Variable and Significant Independent Terms—including all conditions and Continuous Age Term.

| Variable | Multivariate Logistic Regression Model with Sinusitis as the Dependent Variable | | | |
|--------------------|---------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| | 13101.62 | | | |
| Asthma | | 1.35 | 1.08-1.67 | 0.008 |
| Bronchitis | | 2.64 | 2.20-3.16 | <0.001 |
| Hayfever | | 1.78 | 1.55-2.04 | <0.001 |
| Age | | 1.00 | 1.00-1.00 | 0.415 |
| Race-(White) | | 1.45 | 1.27-1.64 | <0.001 |
| Gender (female) | | 1.45 | 1.33-1.59 | <0.001 |
| Fair Health Status | | 1.50 | 1.30-1.72 | <0.001 |
| Poor Health Status | | 1.56 | 1.24-1.97 | <0.001 |

Table 10j: Multivariate Logistic Regression Models with Sinusitis as the Dependent Variable and Significant Independent Terms—including only Chronic Bronchitis and an interaction term for Race*Gender.

| Variable | Multivariate Logistic Regression Model with Sinusitis as the Dependent Variable | | | |
|--------------------|---------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| | 13101.62 | | | |
| Asthma | | 1.34 | 1.08-1.67 | 0.009 |
| Bronchitis | | 2.64 | 2.20-3.17 | <0.001 |
| Hayfever | | 1.78 | 1.55-2.04 | <0.001 |
| Age | | 1.001 | 1.000-1.004 | 0.413 |
| Race-(White) | | 1.30 | 1.11-1.54 | <0.001 |
| Gender (female) | | 1.41 | 1.28-1.56 | <0.001 |
| Race*Gender | | 1.33 | 0.99-1.82 | 0.060 |
| Fair Health Status | | 1.50 | 1.30-1.72 | <0.001 |
| Poor Health Status | | 1.56 | 1.24-1.97 | <0.001 |

Table 10k: Multivariate Logistic Regression Models with Sinusitis as the Dependent Variable and Significant Independent Terms—including all conditions, categorical age and an interaction term for Race*Gender.

| Variable | Multivariate Logistic Regression Model with Sinusitis as the Dependent Variable | | | |
|--------------------|---------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| | 12938.52 | | | |
| Asthma | | 1.35 | 1.08-1.68 | 0.009 |
| Bronchitis | | 2.66 | 2.21-3.19 | <0.001 |
| Hayfever | | 1.76 | 1.54-2.02 | <0.001 |
| Age35 | | 1.27 | 1.14-1.42 | <0.001 |
| Age55 | | 1.04 | 0.93-1.18 | 0.493 |
| Race-(White) | | 1.31 | 1.12-1.54 | <0.001 |
| Gender (female) | | 1.42 | 1.29-1.57 | <0.001 |
| Race*Gender | | 1.33 | 0.99-1.80 | 0.064 |
| Fair Health Status | | 1.53 | 1.33-1.77 | <0.001 |
| Poor Health Status | | 1.61 | 1.28-2.03 | <0.001 |

Table 11a: Univariate Logistic Regression Models with Asthma as the Dependent Variable and Other Independent Terms.

| Variable | Univariate Logistic Regression Models with Asthma as the Dependent Variable | | | |
|---------------------|-----------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| Race-(Non-White) | 4786.15 | 1.16 | 0.93-1.46 | 0.195 |
| Gender (female) | 4777.04 | 1.33 | 1.11-1.59 | 0.003 |
| Age (continuous) | 4787.46 | 1.00 | 1.00-1.01 | 0.574 |
| Age35-54 | 4781.47 | 0.84 | 0.68-1.03 | 0.103 |
| Age ≥ 55 | | 1.10 | 0.90-1.34 | 0.364 |
| Fair Health Status | 4659.19 | 2.15 | 1.71-2.70 | <0.001 |
| Poor Health Status | | 4.47 | 3.40-5.88 | <0.001 |
| *Never Smokers | 2498.12 | 1.15 | 0.87-1.51 | 0.322 |
| Ex-Smokers | | 1.22 | 0.88-1.68 | 0.240 |
| Education Status | 4744.69 | | | |
| High School or Less | | 1.16 | 0.81-1.65 | 0.417 |
| 1-3 years College | | 1.03 | 0.70-1.50 | 0.893 |
| 4 years College | | 0.99 | 0.64-1.52 | 0.956 |
| 5+ years College | | 1.00 | - | - |

*Smoking data was only available for 50% of the population (n=7339); Reference population is current smokers.

Table 11b: Multivariate Logistic Regression Models with Asthma as the Dependent Variable and Gender and Health Status as Independent Terms.

| Variable | Multivariate Logistic Regression Model with Asthma as the Dependent Variable | | | |
|--------------------|------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| Gender (female) | 4650.12 | 1.30 | 1.09-1.56 | 0.005 |
| Fair Health Status | | 2.13 | 1.52-3.03 | <0.001 |
| Poor Health Status | | 4.45 | 3.45-5.88 | <0.001 |

Table 11c: Multivariate Logistic Regression Models with Asthma as the Dependent Variable and Age-continuous, Race, Gender and Health Status as Independent Terms.

| Variable | Multivariate Logistic Regression Model with Asthma as the Dependent Variable | | | |
|--------------------|------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| Age | 4641.12 | 0.992 | 0.987-0.998 | 0.004 |
| Race | | 0.996 | 0.79-1.25 | 0.969 |
| Gender (female) | | 1.31 | 1.10-1.59 | 0.004 |
| Fair Health Status | | 2.34 | 1.84-2.99 | <0.001 |
| Poor Health Status | | 5.24 | 3.85-7.13 | <0.001 |

•

Table 11d: Multivariate Logistic Regression Models with Asthma as the Dependent Variable and Age-categoricals, Race, Gender and Health Status as Independent Terms.

| Variable | Multivariate Logistic Regression Model with Asthma as the Dependent Variable | | | |
|--------------------|------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| Age35 | 4642.28 | 0.77 | 0.62-0.95 | 0.017 |
| Age55 | | 0.76 | 0.61-0.97 | 0.026 |
| Race | | 1.01 | 0.80-1.26 | 0.965 |
| Gender (female) | | 1.31 | 1.08-1.57 | 0.005 |
| Fair Health Status | | 2.26 | 1.77-2.88 | <0.001 |
| Poor Health Status | | 4.96 | 3.65-6.74 | <0.001 |

Table 12a: Univariate Logistic Regression Models with Chronic Bronchitis as the Dependent Variable and Other Independent Terms.

| Variable | Univariate Logistic Regression Models with Bronchitis as the Dependent Variable | | | |
|---------------------|---------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| Race-(White) | 5683.38 | 1.28 | 1.01-1.61 | 0.041 |
| Gender (female) | 5630.76 | 1.82 | 1.54-2.17 | <0.001 |
| Age (continuous) | 5657.95 | 1.01 | 1.01-1.02 | <0.001 |
| Age35-54 | 5650.56 | 1.12 | 0.92-1.36 | <0.262 |
| Age ≥ 55 | | 1.72 | 1.41-2.08 | <0.001 |
| Fair Health Status | 5524.11 | 2.58 | 2.08-3.20 | <0.001 |
| Poor Health Status | | 4.17 | 3.23-5.40 | <0.001 |
| *Ex-Smokers | 2911.28 | 1.04 | 0.78-1.39 | 0.776 |
| Current Smokers | | 1.57 | 1.25-1.97 | <0.001 |
| Education Status | 5642.62 | | | |
| High School or Less | | 1.27 | 0.94-1.72 | 0.124 |
| 1-3 years College | | 1.24 | 0.87-1.76 | 0.239 |
| 4 years College | | 1.07 | 0.73-1.56 | 0.737 |
| 5+ years College | | 1.00 | - | - |

*Smoking data was only available for 50% of the population (n=7339)

Table 12b: Multivariate Logistic Regression Models with Chronic Bronchitis as the Dependent Variable and Age-Continuous, Race, Gender and Health Status as Independent Terms.

| Variable | Multivariate Logistic Regression Model with Bronchitis as the Dependent Variable | | | |
|--------------------|----------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| Age | 5457.91 | 1.002 | 0.998-1.007 | 0.291 |
| Race (white) | | 1.47 | 1.15-1.89 | 0.002 |
| Gender (female) | | 1.82 | 1.52-2.13 | <0.001 |
| Fair Health Status | | 2.46 | 1.97-3.07 | <0.001 |
| Poor Health Status | | 4.22 | 3.19-5.57 | <0.001 |

Table 12c: Multivariate Logistic Regression Models with Chronic Bronchitis as the Dependent Variable and Age-Categorical, Race, Gender and Health Status as Independent Terms.

| Variable | Multivariate Logistic Regression Model with Bronchitis as the Dependent Variable | | | |
|--------------------|----------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| | 5455.35 | | | |
| Age35 | | 1.03 | 0.84-1.25 | 0.786 |
| Age55 | | 1.20 | 0.97-1.47 | 0.092 |
| Race (white) | | 1.47 | 1.15-1.87 | 0.003 |
| Gender (female) | | 1.80 | 1.52-2.14 | <0.001 |
| Fair Health Status | | 2.40 | 1.92-3.01 | <0.001 |
| Poor Health Status | | 4.08 | 3.09-5.38 | <0.001 |

Table 12d: Multivariate Logistic Regression Models with Chronic Bronchitis as the Dependent Variable and Age-Continuous, Race, Gender, Smoking and Health Status as Independent Terms.

| Variable | Multivariate Logistic Regression Model with Bronchitis as the Dependent Variable | | | |
|--------------------|----------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| | 2746.38 | | | |
| Age | | 1.01 | 1.00-1.01 | 0.044 |
| Race (white) | | 1.47 | 1.09-1.96 | 0.012 |
| Gender (female) | | 2.13 | 1.64-2.70 | <0.001 |
| *Never Smokers | | 0.57 | 0.44-0.73 | <0.001 |
| Ex-Smokers | | 0.62 | 0.46-0.84 | 0.002 |
| Fair Health Status | | 2.53 | 1.92-3.33 | <0.001 |
| Poor Health Status | | 4.43 | 3.12-6.30 | <0.001 |

*Reference group is current smokers.

Table 12e: Multivariate Logistic Regression Models with Chronic Bronchitis as the Dependent Variable and Age-Categorical, Race, Gender, Smoking and Health Status as Independent Terms.

| Variable | Multivariate Logistic Regression Model with Bronchitis as the Dependent Variable | | | |
|--------------------|----------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| | 2743.68 | | | |
| Age35 | | 1.00 | 0.76-1.31 | 0.985 |
| Age55 | | 1.36 | 1.02-1.81 | 0.037 |
| Race (white) | | 1.46 | 1.08-1.96 | 0.015 |
| Gender (female) | | 2.10 | 1.64-2.70 | <0.001 |
| *Never-Smokers | | 0.57 | 0.44-0.72 | <0.001 |
| Former Smokers | | 0.62 | 0.46-0.83 | 0.002 |
| Fair Health Status | | 2.48 | 1.89-3.27 | <0.001 |
| Poor Health Status | | 4.35 | 3.06-6.19 | <0.001 |

*Reference group is current smokers.

Table 13a: Univariate Logistic Regression Models with Hayfever as the Dependent Variable and Other Independent Terms.

| Variable | Univariate Logistic Regression Models with Hayfever as the Dependent Variable | | | |
|---------------------|-------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| Race-(White) | 9851.18 | 1.52 | 1.28-1.79 | <0.001 |
| Gender (female) | 9865.65 | 1.18 | 1.06-1.32 | 0.003 |
| Age (continuous) | 9844.36 | 0.99 | 0.99-0.99 | <0.001 |
| Age35-54 | 9842.10 | 1.01 | 0.89-1.15 | 0.834 |
| Age ≥ 55 | | 0.71 | 0.60-0.82 | <0.001 |
| Fair Health Status | 9850.51 | 0.91 | 0.75-1.10 | 0.350 |
| Poor Health Status | | 0.71 | 0.51-0.99 | 0.048 |
| *Ex-Smokers | 5114.99 | 0.90 | 0.76-1.08 | 0.272 |
| Current Smokers | | 0.80 | 0.67-0.96 | 0.019 |
| Education Status | 9695.97 | | | |
| High School or Less | | 0.44 | 0.37-0.52 | <0.001 |
| 1-3 years College | | 0.68 | 0.56-0.82 | <0.001 |
| 4 years College | | 0.77 | 0.62-0.96 | 0.021 |
| 5+ years College | | 1.00 | - | - |

*Smoking data was only available for 50% of the population (n=7339)

Table 13b: Multivariate Logistic Regression Models with Hayfever as the Dependent Variable and Age, Race, Gender, Health Status, Education Status and Gender*Race as Independent Terms.

| Variable | Multivariate Logistic Regression Model with Hayfever as the Dependent Variable | | | |
|----------------------------|--------------------------------------------------------------------------------|------------|-------------------------|---------|
| | -2 Log Likelihood | Odds Ratio | 95% Confidence Interval | p-value |
| | 9616.32 | | | |
| Age | | 0.99 | 0.99-1.00 | <0.001 |
| Race (white) | | 1.33 | 1.08-1.64 | 0.010 |
| Gender (female) | | 1.20 | 1.06-1.35 | 0.002 |
| Fair Health Status | | 1.22 | 1.00-1.49 | 0.050 |
| Poor Health Status | | 1.05 | 0.74-1.49 | 0.772 |
| Education Status | | | | |
| High School or Less | | 0.44 | 0.37-0.52 | <0.001 |
| 1-3 years College | | 0.65 | 0.54-0.79 | <0.001 |
| 4 years College | | 0.76 | 0.61-0.95 | 0.015 |
| 5+ years College (ref grp) | | 1.00 | - | - |
| Gender*Race (white/female) | | 1.41 | 0.51-0.99 | 0.044 |

Table 14 : Onset of Conditions

| Onset | % (n) Asthma | % (n) Chronic Sinusitis | % (n) Chronic Bronchitis | % (n) Hayfever (no asthma) |
|----------------------------|-----------------|----------------------------|-----------------------------|-------------------------------|
| During past 2 weeks | 0.2 (1) | * | * | 0.1 (1) |
| Over 2 weeks to 3 months | 1.0 (6) | * | * | 0.9 (14) |
| Over 3 Months to 12 Months | 5.2 (30) | 7.5 (186) | 38.2 (267) | 2.7 (41) |
| Over 1 Year to 5 Years | 13.6 (78) | 20.6 (511) | 18.6 (130) | 16.9 (258) |
| Over 5 years | 80.0 (460) | 72.0 (1788) | 43.2 (302) | 79.4 (1211) |

*Chronic Conditions are defined as those with a duration of at least 3 months

Table 15: Frequencies and Descriptives for Industry at Onset of Condition, Compared by Condition

| Industry | Sinusitis | Asthma | Chronic Bronchitis |
|---------------------------------------------------------|-----------|----------|--------------------|
| Agriculture, forestry, fisheries | 2.8 (7) | 3.6 (1) | 0.9 (1) |
| Mining | 0.4 (1) | - | 0.9 (1) |
| Construction | 6.5 (16) | - | 3.6 (4) |
| Manufacturing | 15.4 (38) | 21.4 (6) | 17.1 (19) |
| Transportation, communications & other public utilities | 3.3 (8) | - | 8.1 (9) |
| Wholesale trade | 1.2 (3) | - | 0.9 (1) |
| Retail trade | 12.2 (30) | 3.6 (1) | 8.1 (9) |
| Finance, insurance, & real estate | 4.5 (11) | 7.1 (2) | 5.4 (6) |
| Business & repair services | 8.1 (20) | 10.7 (3) | 3.6 (4) |
| Personal services | 2.4 (6) | - | 2.7 (3) |
| Entertainment & recreation services | 2.4 (6) | - | 0.9 (1) |
| Professional & related services | 13.0 (32) | 21.4 (6) | 23.4 (26) |
| Public administration | 4.9 (12) | - | 4.5 (5) |
| Unknown | 22.8 (56) | 32.1 (9) | 19.8 (22) |

Table 16: Frequencies and Descriptives for Occupation at Onset of Condition, Compared by Condition

| Occupation | Sinusitis | Asthma | Chronic Bronchitis |
|--------------------------------------------------------|-----------|----------|--------------------|
| Executive, administration & managerial occupations | 10.5 (27) | 17.2 (5) | 7.8 (9) |
| Professional specialty occupations | 15.6 (40) | 6.9 (2) | 20.0 (23) |
| Technicians & related support occupations | 3.5 (9) | 3.4 (1) | 5.2 (6) |
| Sales occupations | 9.4 (24) | 10.3 (3) | 8.7 (10) |
| Administrative support occupations, including clerical | 21.5 (55) | 24.1 (7) | 25.2 (29) |
| Private household occupations | 1.6 (4) | - | - |
| Protective service occupations | 0.8 (2) | - | 0.9 (1) |
| Service occupations, except protective & household | 10.2 (26) | 10.3 (3) | 8.7 (10) |
| Farming, forestry, fishing occupations | 2.3 (6) | 3.4 (1) | 0.9 (1) |
| Precision, production, craft & repair occupations | 10.5 (27) | 3.4 (1) | 6.1 (7) |
| Machine operators, assemblers, inspectors | 5.5 (14) | 10.3 (3) | 9.6 (11) |
| Transportation & material moving occupations | 2.7 (7) | 6.9 (2) | 3.5 (4) |
| Handlers, equipment cleaners, helpers & laborers | 4.7 (12) | 3.4 (1) | 3.5 (4) |
| Unknown occupation (includes new workers) | 0.4 (1) | - | - |
| Not in labor force | 0.8 (2) | - | - |

Table 17:: Frequencies for Cross-Tabulations of Industry against Occupation at Onset of Chronic Sinusitis

| | | Sinusitis Onset Occupation | | | | | | |
|---------------------------------------------------------|--|------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------|----------------------------|-----------------------------------------------------------|-------------------------------------------|--------------------------------------------|
| | | 01 Executive, Admin., & Managerial Occupations | 02 Professional Specialty Occupations | 03 Technicians & Related Support Occupations | 04 Sales Occupations | 05 Admin. Support Occupations, Incl. Clerical | 06 Private Household Occupations | 07 Protective Service Occupations |
| | | N | N | N | N | N | N | N |
| Sinusitis Onset Industry | | | | | | | | |
| Agriculture, Forestry, & Fisheries | | . | 2.00 | . | 1.00 | . | . | |
| Mining | | . | . | . | . | . | . | |
| Construction | | 2.00 | 1.00 | 1.00 | . | 1.00 | . | |
| Manufacturing | | 5.00 | 4.00 | . | 2.00 | 6.00 | 1.00 | |
| Transportation, Communications & Other Public Utilities | | 1.00 | 1.00 | . | 1.00 | 2.00 | . | |
| Wholesale Trade | | 1.00 | . | . | . | . | . | |
| Retail Trade | | 3.00 | 2.00 | . | 9.00 | 4.00 | . | |
| Finance, Insurance, & Real Estate | | 2.00 | 1.00 | 2.00 | 1.00 | 5.00 | . | |
| Business & Repair Services | | 2.00 | 1.00 | . | 4.00 | 8.00 | . | |
| Personal Services | | . | . | . | . | 1.00 | 1.00 | |
| Entertainment & Recreation Services | | . | 1.00 | . | . | 2.00 | . | |
| Professional & Related Services | | 3.00 | 16.00 | 1.00 | . | 5.00 | . | |
| Public Administration | | 3.00 | 3.00 | . | . | 5.00 | 1.00 | |
| Unknown (includes new workers) | | 3.00 | 10.00 | 3.00 | 4.00 | 14.00 | 2.00 | |

Table 17: (continued): Frequencies for Cross-Tabulations of Industry against Occupation at Onset of Chronic Sinusitis

| | Sinusitis Onset Occupation | | | | | | |
|---------------------------------------------------------|----------------------------------------------------------------------|---------------------------------------------------------|--------------------------------------------------------------------|-----------------------------------------------------------|---------------------------------------------------------------|--------------------------------------------------------------------|----------------|
| | 08 Service Occupations, Except Protective & Household | 09 Farming, Forestry, & Fishing Occupations | 10 Precision Production, Craft & Repair Occupations | 11 Machine Operators, Assemblers & Inspectors | 12 Transporta- tion & Material Moving Occupations | 13 Handlers, Equipment Cleaners, Helpers & Laborers | 16 Military |
| | N | N | N | N | N | N | N |
| Sinusitis Onset Industry | | | | | | | |
| Agriculture, Forestry, & Fisheries | 1.00 | 1.00 | 1.00 | . | . | 1.00 | . |
| Mining | . | . | 1.00 | . | . | . | . |
| Construction | . | . | 9.00 | . | 1.00 | 1.00 | . |
| Manufacturing | . | 1.00 | 6.00 | 10.00 | 2.00 | 1.00 | . |
| Transportation, Communications & Other Public Utilities | . | . | . | . | 2.00 | 1.00 | . |
| Wholesale Trade | . | . | 1.00 | . | . | 1.00 | . |
| Retail Trade | 7.00 | 1.00 | 2.00 | . | . | 2.00 | . |
| Finance, Insurance, & Real Estate | . | . | . | . | . | . | . |
| Business & Repair Services | 3.00 | . | 1.00 | . | . | . | 1.00 |
| Personal Services | 3.00 | . | . | 1.00 | . | . | . |
| Entertainment & Recreation Services | 3.00 | . | . | . | . | . | . |
| Professional & Related Services | 5.00 | . | . | 1.00 | 1.00 | . | . |
| Public Administration | . | . | . | . | . | . | . |
| Unknown (includes new workers) | 3.00 | 3.00 | 6.00 | 1.00 | 1.00 | 5.00 | 1.00 |

Table 18: Projected Prevalence of Sinusitis in Industries Nationwide Based on NHIS Prevalence estimates of Sinusitis and BLS data for 1988

| Industry | NHIS Sinusitis Prevalence Estimate (SUDAAN) | BLS National Estimate of Full Time Employees | Expected number of Prevalent Cases | 95% Confidence Intervals | Standard Error of SUDAAN estimate |
|-----------------------------------|---------------------------------------------|----------------------------------------------|------------------------------------|--------------------------|-----------------------------------|
| Mining | 25.8 | 713,000 | 183,954 | 183,942 - 183,966 | 6.28 |
| Construction | 12.9 | 5,098,000 | 657,642 | 657,639 - 657,645 | 1.31 |
| Manufacturing | 15.6 | 19,314,000 | 3,012,984 | 3,012,982 - 3,012,986 | 0.93 |
| Transportation | 15.1 | 5,512,000 | 832,312 | 832,309 - 832,315 | 1.41 |
| Wholesale Trade | 16.7 | 6,030,000 | 1,007,010 | 1,007,005 - 1,007,015 | 2.32 |
| Retail Trade | 16.4 | 19,023,000 | 3,119,772 | 3,119,770 - 3,119,774 | 1.04 |
| Finance | 16.7 | 6,630,000 | 1,107,210 | 1,107,207 - 1,107,213 | 1.57 |
| Business and Repair Services | 18.0 | 5,822,000 | 1,047,960 | 1,047,957 - 1,047,963 | 1.59 |
| Personal Services | 15.2 | 2,596,000 | 394,592 | 394,588 - 394,596 | 1.83 |
| Entertainment | 21.8 | 1,318,000 | 287,324 | 287-316 - 287,332 | 3.91 |
| Professional and Related Services | 17.8 | 15,130,000 | 2,693,140 | 2,693,138 - 2,693,142 | 0.99 |

Calculations: NHIS Prevalence x BLS estimate = Estimate of National Prevalence

(Mining: $0.258 \times 713,000 = 183,954$)

Confidence Intervals are calculated using Estimate of National Prevalence $\pm 1.96 \times$ standard error of the prevalence estimate

(Mining: $183,954 \pm (6.28 \times 1.96)$)

***BLS does not have estimates for the Agricultural Sector

Table 19: Projected Prevalence of Asthma in Industries Nationwide Based on NHIS Prevalence estimates of Sinusitis and BLS data for 1988

| Industry | 1988 NHIS Asthma Prevalence Estimate (SUDAAN) | 1988 BLS National Estimate of Full Time Employees | Expected Number of Prevalent Cases | 95% Confidence Intervals | Standard Error of SUDAAN estimate |
|-----------------------------------|-----------------------------------------------|---------------------------------------------------|------------------------------------|--------------------------|-----------------------------------|
| Mining | 3.3 | 713,000 | 23,529 | 23,525 - 23,533 | 2.26 |
| Construction | 1.6 | 5,098,000 | 81,568 | 81,567 - 81,569 | 0.51 |
| Manufacturing | 2.5 | 19,314,000 | 482,850 | 482,849 - 482,851 | 0.36 |
| Transportation | 3.3 | 5,512,000 | 181,896 | 181,894 - 181,898 | 0.78 |
| Wholesale Trade | 2.1 | 6,030,000 | 126,630 | 126,628 - 126,632 | 0.78 |
| Retail Trade | 3.4 | 19,023,000 | 646,782 | 646,781 - 646,783 | 0.50 |
| Finance | 3.9 | 6,630,000 | 258,570 | 258,569 - 258,571 | 0.75 |
| Business and Repair Services | 3.9 | 5,822,000 | 227,058 | 227,057 - 227,059 | 0.76 |
| Personal Services | 2.8 | 2,596,000 | 72,688 | 72,686 - 72,690 | 0.79 |
| Entertainment | 9.4 | 1,318,000 | 123,892 | 123,886 - 123,898 | 3.09 |
| Professional and Related Services | 4.1 | 15,130,000 | 620,330 | 620,329 - 620,331 | 0.45 |

Calculations: NHIS Prevalence x BLS estimate = Estimate of National Prevalence

Confidence Intervals are calculated using Estimate of National Prevalence $\pm 1.96 \times$ standard error of the prevalence estimate

***BLS does not have estimates for the Agricultural Sector

Table 20: Projected "Incidence Estimates" of Sinusitis in Industries Nationwide Based on NHIS Sinusitis Onset Estimates and BLS data for 1988

| Industry | NHIS Onset of Sinusitis Estimate (SAS) | BLS National Estimate of Full Time Employees | Expected Number of 'New Onset' Cases |
|-----------------------------------|----------------------------------------|----------------------------------------------|--------------------------------------|
| Mining | 0.53 | 713,000 | 3779 |
| Construction | 8.4 | 5,098,000 | 428,232 |
| Manufacturing | 20.0 | 19,314,000 | 3,862,800 |
| Transportation | 4.2 | 5,512,000 | 231,504 |
| Wholesale Trade | 1.6 | 6,030,000 | 106,080 |
| Retail Trade | 15.8 | 19,023,000 | 3,005,634 |
| Finance | 5.8 | 6,630,000 | 384,540 |
| Business and Repair Services | 10.5 | 5,822,000 | 611,310 |
| Personal Services | 3.2 | 2,596,000 | 83,072 |
| Entertainment | 16.8 | 1,318,000 | 221,424 |
| Professional and Related Services | 6.3 | 15,130,000 | 953,190 |

Calculation: NHIS Prevalence X BLS estimate

***BLS does not have estimates for the Agricultural Sector

Table 21: The Three Most Prevalent Industries for Chronic Sinusitis and Asthma

| Industry | n | Asthma | 95% Confidence Intervals | Chronic Sinusitis | 95% Confidence Intervals |
|-------------------------------------|------|------------|--------------------------|-------------------|--------------------------|
| Agriculture, Forestry, Fisheries | 306 | 1.16 (13) | 0.67-2.01 | | |
| Mining | 59 | | p=0.62 | 1.54 (15) | 0.97-2.45 |
| Entertainment & Recreation Services | 127 | 2.51 (11) | 1.34-4.71 | 1.30 (26) | 0.92-1.84 |
| Professional & Related Services | 1993 | 1.08 (83) | 0.86-1.36 | | p=0.20 |
| Public Administration | 505 | | p=0.51 | 1.09 (98) | 0.90-1.33 |
| Not in Labor Force | 4860 | 1.52 (250) | 1.29-1.79 | | p=0.38 |
| | | | p<0.000 | | |

P values for the to Mantel Haenszel Tests of Association chi-squares

Table 22: The Three Most Prevalent Occupations for Chronic Sinusitis and Asthma

| Occupation | n | Asthma | n | 95% Confidence Intervals | Chronic Sinusitis | n | 95% Confidence Intervals |
|--------------------------------------------------------|------|--------|-----|--------------------------|-------------------|-----|--------------------------|
| Professional specialty occupations | 1291 | | | | 1.10 | 238 | 0.98-1.25 |
| technicians & related support occupations | 309 | | | | 1.08 | 57 | 0.86-1.37 |
| administrative support occupations, including clerical | 1486 | 0.95 | 51 | 0.72-1.26 | 1.12 | 276 | 1.00-1.26 |
| not in labor force | 4860 | 1.52 | 250 | 1.29-1.79 | | | p=0.065 |
| | | | | p=0.74 | | | |
| | | | | p<0.000 | | | |

P values for the to Mantel Haenszel Tests of Assoc chi-squares

IV. INVESTIGATION OF SINUSITIS IN A LIME EXPOSED COHORT

A. INTRODUCTION AND BACKGROUND

This study was originally conducted to investigate the acute and chronic respiratory effects of quicklime (calcium oxide) and hydrated lime (calcium hydroxide) particulate exposures in the processing of mined limestone (Wegman, 1991). The initial investigation included 832 workers from 29 limestone quarries and lime mills. Work related chronic effects were assessed in terms of chronic deficits in pulmonary function and chronic respiratory symptom reports, as measured by spirometry and the administration of the American Thoracic Society standard questionnaire. The ATS questionnaire included a series of questions about chronic nose and sinus problems, which queried about the presence of a deviated nasal septum, nasal or sinus polyps, allergic rhinitis, chronic sinusitis, nose or sinus surgery and nose or sinus injuries. These questions were not analyzed. Past exposures were categorized in terms of type of lime exposure (quicklime, hydrated lime, both or neither) and years employed in each category. Current exposure was estimated for 363 employees, based on 422 environmental samples collected in 24 different plants. Roughly 290 workers, who were unexposed to lime dust were used as a comparison group. A calcium analysis was also performed on each total particulate sample to determine calcium concentrations. Seven hundred and twenty five of the 832 participants were included in the survey of acute health effects. Acute effects were assessed using peak expiratory flow rates in conjunction with symptom questionnaires that were collected at the beginning and end of a work shift. These data allowed the investigators to identify those acute respiratory irritant symptoms that occurred during workday exposures.

Investigation of chronic respiratory health effects provided evidence of an increased rate of dyspnea and chest tightness in those workers with more than fifteen years of hydrated lime exposure. The prevalence of asthma is slightly higher in exposed individuals when compared to unexposed workers (8.1% versus 6.1%). There was no real difference in the prevalence of bronchitis in the exposed and unexposed groups. Although the study did not identify any overall chronic changes in the pulmonary function of exposed workers, those reporting dyspnea did have 5% lower FEV₁ (percent predicted) than those without dyspnea.

When comparing baseline pulmonary function in the exposed and unexposed groups, FVC was similar, but FEV₁ was significantly lower among the exposed. This relationship was confounded by smoking and stratified analyses demonstrate this lower FEV₁ only among ever-smokers (Table 1). Those with past exposure to hydrated lime were significantly more likely to report more chronic cough, wheeze and chest tightness than the unexposed group (Table 2). When the data were stratified on smoking status these significant relative risks were even stronger in the never smokers (data not shown). In contrast to those in hydrated lime jobs, those exposed to quicklime did not demonstrate increased prevalence of these symptoms (data not shown).

Acute nose irritation, throat irritation and cough were significantly associated with hydrated lime jobs (Table 3). There was also evidence of an association between cough and total dust and calcium exposure. Because there is extensive respirator use in the industry, the results may in fact, be under-estimates of the true exposure response relationships for these compounds.

This is an interesting cohort in which to examine the relationships between sinusitis, dust exposure and the previously described respiratory outcomes. Sinusitis had not yet been evaluated in this data set. There is evidence that hydrated lime exposure is associated with both chronic and acute respiratory health outcomes. It appears to affect both the upper and lower airways. The size of the cohort provided sufficient power to examine the more general relationships between sinusitis and the chronic conditions and symptoms addressed in the ATS questionnaire. The questions administered also permitted investigation of other sinus-related conditions including history of sinus surgery.

B. METHODS AND STUDY POPULATION

1. Population Demographics

The demographics of the population have already been well-described in previous analyses (Wegman, 1991). Some of these analyses were repeated to ensure that the data set we used was in tact and represented that used for previous analyses.

2. Conditions of Interest

Symptoms and Conditions: Simple descriptive analyses were conducted on the conditions of interest including: chronic sinusitis, asthma, cough, wheeze, phlegm, chronic bronchitis, bronchitis, hay fever, deviated nasal septum, nasal or sinus polyp, allergic rhinitis, sinus surgery.

Pulmonary Function Measures: Outcomes of interest relating to pulmonary function included the following measures: FEV₁, FVC and PEF. Maximal values of each of these measures were used in the analyses.

3. Analysis

Descriptive and Modeling: Initially, simple descriptive statistics were completed, followed by logistic regression and Breslow-Cox prevalence ratio models. Adjusted odds ratios are typically used with data of this type to evaluate effect modification and control confounding. Potential confounders and modifiers were included in the models if they significantly changed the beta of the parameter of interest.

Axelsson recommends that a prevalence ratio rather than an odds ratio be calculated in cross-sectional investigations of prevalent conditions (Axelsson, 1994). His argument revolves around the observation that the odds ratio becomes a poor measure of effect in closed populations, when the health outcome is not rare. In these instances the odds ratios are less precise over-estimates of the "true effect". He recommends the use of the Cox proportional hazards model (modified by Breslow) to estimate effect (Breslow, 1974). Although this rate ratio can technically be calculated using logistic regression, it is not commonly done and more importantly the appropriate standard error is not estimated by logistic regression software. The Cox regression gives the risk ratio and its appropriate standard error (Lee, 1986, 1993, 1994). Because the Breslow-Cox approach is still infrequently used, we compared its results to those of logistic regression.

The dichotomous outcome variable was report of chronic sinusitis. Explanatory variables included exposure and the following potential confounders: age, gender, race, smoking and atopic status or hayfever.

Because current exposures in this data set were so well measured and because they are often well correlated with past exposures, current exposures were evaluated in these analyses. Two types of exposure variables were evaluated. Type of lime—quicklime, hydrated lime and mixed exposures— were compared to those without lime exposure. Total particulate level was trichotomized into three groups representing low (0-2.4 mg/m³), medium (2.5-4.9 mg/m³) and high (\geq 5 mg/m³) exposure. Dummies representing these variables were used in the analyses. Tests of linear trends in proportions were also calculated to measure dose response relationships. Each of these exposure variables was examined individually for an association with chronic sinusitis and the other conditions of interest. Exposure was considered continuously as well as dichotomously. Dose response relationships were also examined in this cohort.

C. RESULTS

1. Descriptive Analyses

Demographics of the population: The population was largely white (91%) and male (97%) and had a mean age of 38.8 years old (Table 4). Forty percent of the population was current smokers, while 32% had never smoked. Of all three exposure types the majority of the population for whom exposure measures were collected, were exposed to quicklime (52%). There were roughly equal proportions of workers exposed to each hydrated lime and to a mixture of both forms of lime (13%). When total particulate exposure was trichotomized into groups representing low (0-2.4 mg/m³), medium (2.5-4.9 mg/m³) and high (\geq 5 mg/m³) exposure categories, 55% of the population had low exposure as compared to 28% who had high exposure. Median exposure levels were as follows: Calcium oxide- 0.84 mg/m³; calcium hydroxide- 1.72 mg/m³; total particulate- 2.10 mg/m³; and dust line 24.

Prevalence of Conditions: Reports of usual phlegm, cough and bronchitis were the most prevalent of all the conditions ranging in prevalence from 24% to 15% (Table 4).

Hayfever, wheeze, asthma, and sinusitis were reported in similar proportions ranging from 10% to 6%, whereas rhinitis and chronic bronchitis only affected between 3 and 4 percent of the population.

Prevalence Ratios for Multiple Conditions: Prevalence ratios were calculated for pairs of each of the conditions under study (Tables 5a-5d). Overall, the conditions are very highly associated with each other. Sinusitis was most strongly associated with rhinitis (PR=7.97, $p<0.001$), chronic bronchitis (PR=4.48, $p<0.001$). Those reporting sinusitis were about twice as likely to report bronchitis, wheeze, cough, shortness of breath and hayfever. There were only borderline associations between sinusitis and asthma and chest tightness (PR=1.18, $p=0.10$; PR=1.38, $p=0.16$). Women reported sinusitis 12% more often than did males ($p=0.05$). Smoking status did not appear to be associated with sinusitis nor did age or type of exposure. Particulate level however demonstrated borderline associations with reports of sinusitis in those with exposures greater than or equal to 5 mg/m^3 when compared to those with exposures under 2.5 mg/m^3 . The test for linear trend in proportions also demonstrated borderline significance ($p=0.12$).

Those reporting asthma were about three times more likely to report bronchitis, chronic bronchitis, wheeze and hayfever. Cough and phlegm had borderline associations with asthma with prevalence ratios close to two. The association between gender and asthma could not be evaluated as no women reported asthma. Race did not appear to be associated with asthma, though the number of non-whites was minimal. Age was associated with asthma as were smoking status and exposure type. The mean age for those reporting asthma was 35.5 versus 39.0 for those without asthma ($p=0.02$). Never smokers were more likely to report smoking than were current or ex-smokers. Asthma prevalence appeared to be higher in those with quicklime or mixed exposures, though these relationships were based on only one case occurring in the unexposed group so they must be interpreted with caution. Total particulate level was not associated with asthma prevalence.

Chronic bronchitis was strongly associated with wheeze, phlegm and cough with prevalence ratios ranging from 3.2 to 5.4 ($p<0.01$ for each). Women were about three times more likely to report chronic bronchitis than were men, though this relationship had borderline significance ($p=0.14$). Current smokers when compared to never smokers may have increased risk of chronic bronchitis (PR=1.9, $p=0.18$). There was no relationship between exposure type and chronic bronchitis, but there was indication of a

borderline association between total particulate exposure, when comparing the high and low exposure groups. The test for linear trend also demonstrated a borderline dose response relationship ($p=0.18$).

Bronchitis, not surprisingly is most associated with chronic bronchitis (PR 7.9, $p<0.01$). It is also strongly associated with wheeze, cough and phlegm and has borderline associations with rhinitis and hayfever. It is more prevalent in whites (2.21, $p=0.05$) and in those with high total particulate level as compared to those with low exposure. There is a relatively strong dose response relationship with total particulate ($p=0.05$).

Measures of Pulmonary Function: There was no consistent pattern between the conditions investigated and the maximum values of FEV₁, FVC and PEFR.

2. Models

Univariate and multivariate models were constructed for each of four outcome variables: sinusitis, asthma, chronic bronchitis and bronchitis (Tables 7-13). Cox proportional hazards and logistic regression models were conducted side by side to ensure comparability. Only the Cox proportional hazards models are included in this report. Results were comparable for each model. The multivariate models were not very robust for several reasons: exposure measurements were limited, disease prevalence was lower than expected, and the cohort was predominantly white and male so that gender and race variables were difficult to evaluate. Only the univariate models were useful in evaluating chronic sinusitis (Table 7). The information gained from the multivariate models did not differ significantly from the univariate analyses.

Age, race and smoking status (Table 7) were not associated with chronic sinusitis, though packyears demonstrated a weak association (PR=1.01, $p=0.18$). Neither the type of lime exposure nor the dust line estimates were particularly associated with chronic sinusitis. When considering exposure to total particulate, there appears to be a weak dose-response relationship. Those in the high total particulate exposure category demonstrate a borderline association when compared to those in the low exposure group, (PR=2.26, $p=0.14$). Those in the medium exposure category did not demonstrate increased risk of disease (PR=1.56, $p=0.53$). Each of the conditions

investigated demonstrated strong associations with chronic sinusitis, except for those reporting usual phlegm. This association had borderline significance (PR=1.58, p=0.13).

Age was significantly associated with reports of doctor diagnosed asthma (Table 8). Asthma decreased with age in this population (PR=0.97, p=0.03). No women reported asthma in this population. Race was not predictive of disease state, though smoking status and packyears were negatively associated with reports of asthma. These relationships were of borderline significance. Mixed exposures and exposure to quicklime were more associated with asthma than was hydrated lime. Only exposure to mixed types of lime had a significant relationship. The results in this model are based on small numbers and should be interpreted with caution. When exposure was collapsed, comparing the exposed (quicklime, hydrated lime, and mixed) to the unexposed, there appeared to be a large increase in risk that was of borderline significance (PR=5.95, p=0.08). Dust line estimates and total particulate were not associated with reports of asthma. Asthma was strongly associated with chronic bronchitis and bronchitis, wheeze and hayfever, and borderline associations with cough, phlegm and rhinitis.

Multivariate models for asthma included age, smoking status and each of the conditions separately. These terms demonstrated associations univariately. Age and smoking status maintained borderline significance in these models. The symptoms: chronic bronchitis, bronchitis, and wheeze were significant in the multivariate models.

Risk of chronic bronchitis (Table 9) was greater for women (PR=2.81, p=0.16) though it was not associated with age, race or packyears. There was some evidence that current smokers were more likely to report chronic bronchitis. Type of lime exposure and the dust line estimates were not predictive of this disease. Those in the high total particulate exposure group were more likely to report chronic bronchitis when compared to those in the low exposure group. Each of the conditions evaluated was strongly associated with chronic bronchitis except for hayfever and rhinitis.

Multivariate models for chronic bronchitis included gender and packyears and each of the conditions separately. As with the other conditions under study, the multivariate models were not robust and gender and packyears retained only borderline significance in these models. When packyears and gender were included simultaneously, gender lost its significance completely. This implies the presence of confounding, but because of limited numbers, we did not explore this issue further.

Bronchitis (Table 10) was reported more frequently by whites than non-whites (PR=2.21, p=0.08). The risk of bronchitis increases with packyears of cigarettes smoked (PR=1.01, p=0.08) and is associated with those in the high total particulate exposure group when compared to those in the low exposure group. Bronchitis is strongly associated with asthma, chronic bronchitis, wheeze, cough and phlegm. It has borderline associations with hayfever and rhinitis.

D. DISCUSSION

The overall prevalence of chronic sinusitis was much lower than expected in this cohort. Chronic sinusitis had a prevalence of only 6%, which is two to three times lower than what is usually observed in working populations. It was striking to observe that asthma and bronchitis and chronic bronchitis were more prevalent than sinusitis. Because the population was so predominantly white and male, evaluation of race and gender effects was limited. Women were more likely to report sinusitis and chronic bronchitis, while whites were more likely to report bronchitis. However, further stratification on race and gender (by exposure or smoking status, for example) was not conducted. Never smokers were more likely to report asthma, while current smokers may have been more likely to report chronic bronchitis.

Exposure was evaluated in two different ways: by type of lime and by total particulate level. Asthma demonstrated some association with type of exposure. Unfortunately, there was only one observation in the unexposed group who reported asthma. This limits the strength of this finding. Total particulate exposures demonstrated more robust associations with sinusitis, bronchitis and chronic bronchitis. There was also evidence of dose response

relationships. There was a significant linear trend for total particulate and bronchitis and trends of borderline significance for sinusitis and chronic bronchitis.

This finding is very interesting as it may support the pathogenic mechanisms suggested in the literature. Namely, the respiratory epithelium responds to exposure to irritants and dusts by developing an inflammatory response. The epidemiologic literature relating sinusitis to occupation further supports the observed associations in this study. Studies have documented increased risk of chronic sinusitis in cotton workers, nickel workers, (Hoult et al. 1993, Mastromatteo 1988) and to those exposed to wood dust, grain and flour dusts, and man made mineral fibers (Tatken 1987, Awad El Karin et al. 1986). As mentioned previously, these results must be interpreted carefully as there was widespread respirator use in this cohort.

It is encouraging that sinusitis and chronic bronchitis and bronchitis were quite similar with respect to their associations with exposure. Asthma was not as closely related to sinusitis especially in terms of exposure. Asthma appeared to be more related to type of lime exposure as opposed to level of total particulate. The fact that chronic sinusitis and asthma were not very prevalent in this population limited our ability to further evaluate this association.

The authors of the final report state: "The findings based on the quantitative estimates of exposure need to be interpreted in light of the extensive respirator use in this population. It is possible that respirators were used only in response to irritation, and therefore do not distort the relationships we observed between dust, or calcium, level and irritation. On the other hand, it may be that the heavy respirator use in the higher exposure categories indicates that measured exposures over-estimate the actual dose received. The resulting misclassification of actual exposure would result in a blunting of the true exposure-response relationship, i.e. the true association would be stronger than what we have observed" (Wegman, 1991).

It is clear that the conditions investigated in this report are very closely related and that they are also related to exposure. Chronic sinusitis, bronchitis and chronic bronchitis seem to relate differently to exposure when compared to asthma. Given the acute irritant effects of

lime, and the respiratory effects of particulate exposure in general it is interesting to be able to document these effects on the respiratory system. Because these data are cross-sectional nature; one cannot necessarily presume that the acute exposures measured caused the observed chronic effects. However, current exposures were closely correlated with past exposures in this cohort. This does add weight to the argument. This may be supportive of much of Becklake's work relating repeated acute assaults/exposures to chronic outcomes (Becklake et al., 1986).

The cross sectional nature of these data also make following the natural history of these diseases unfeasible. Because the conditions under study are chronic, recall bias is also an issue. Though we cannot decipher which conditions preceded the others in relation to exposure, it is very clear that there is some relationship that needs to be better explored. A longitudinal study would be the optimal approach. Collecting condition onset and job exposure histories are crucial.

E. TABLES

Table 1: Baseline Pulmonary Function in Exposed and Unexposed Stratified by Smoking Status

| Spirometric Variable | Ever Smoked | | Never Smoked | |
|---------------------------|-----------------------------------------------|-------------------|-----------------------------------------------|------------------|
| | Exposed to CaO or Ca(OH) ₂ (n=323) | Unexposed (n=166) | Exposed to CaO or Ca(OH) ₂ (n=148) | Unexposed (n=84) |
| FEV ₁ (liters) | 3.65 ± 0.04 | 3.65 ± 0.06 | 3.92 ± 0.06 | 3.76 ± 0.08 |
| % Predicted | 91.8% ± 0.8% | 95.2% ± 1.2% | 95.2% ± 1.2% | 96.0% ± 1.2% |
| FVC (liters) | 4.74 ± 0.05 | 4.66 ± 0.07 | 4.85 ± 0.07 | 4.70 ± 0.09 |
| % Predicted | 98.8% ± 0.8% | 100% ± 1.1% | 97.4% ± 1.1% | 99.5% ± 1.2% |

Table 2 : Chronic Symptom Prevalence and Prevalence Ratio in Hydrated Lime Exposed Individuals (n=71).

| Symptom | Prevalence | Prevalence Ratio Compared to Unexposed |
|--------------------|------------|----------------------------------------|
| Chronic Cough | 35.7% | 1.7+ |
| Chronic Phlegm | 27.1% | 1.2 |
| Chronic Bronchitis | 14.3% | 1.2 |
| Wheeze | 18.5% | 2.5++ |
| Chest Tightness | 15.7% | 2.5++ |
| Dyspnea | 12.9% | 1.8 |

+ = $X^2 < 0.05$, ++ = $X^2 < 0.01$

Table 3: Incidence and Relative Risk of Acute Symptoms in Those Exposed to Hydrated Lime

| Symptom | Incidence | Relative Risk Compared to Unexposed |
|--------------------------|-----------|-------------------------------------|
| Eye Irritation (n=70) | 18.6% | 1.7 |
| Nose Irritation (n=58) | 31.0% | 6.0++ |
| Throat Irritation (n=71) | 15.5% | 3.4++ |
| Cough (n=62) | 27.4% | 2.7++ |

+ = $X^2 < 0.05$, ++ = $X^2 < 0.01$

Table 4: Demographics of the Lime Cohort

| Conditions | % (n) |
|-----------------------------------|--------------|
| Sinusitis | 5.9 (49) |
| Asthma | 7.0 (58) |
| Bronchitis | 14.7 (122) |
| Chronic Bronchitis | 3.0 (25) |
| Wheeze | 8.1 (65) |
| Rhinitis | 3.5 (29) |
| Cough | 19.8 (165) |
| Phlegm | 23.5 (195) |
| Hayfever | 9.5 (79) |
| Deviated Nasal Septum | 3.6 (30) |
| Nasal Polyp | 2.2 (18) |
| Nose/Sinus Operation | 4.9 (41) |
| Demographics | |
| Age (mean, sd) | 38.8 (10.8) |
| Race White | 90.8 (692) |
| Gender-Male | 96.7 (737) |
| Smoking Status | |
| Never Smoke | 32.0 (265) |
| Ex-Smoker | 28.2 (234) |
| Current Smoker | 39.8 (330) |
| Exposure Type | |
| Quicklime | 51.9 (195) |
| Hydrated Lime | 13.3 (50) |
| Mixed Exposure | 12.8 (48) |
| Unexposed | 22.1 (83) |
| Exposure Level: | |
| Total Dust (mg/m3) | |
| 0-2.4 | 54.6 (160) |
| 2.5-4.9 | 17.4 (51) |
| ≥5 | 28.2 (82) |
| Median Exposure Levels (n) | |
| CAO | 0.86 (244) |
| CAOH2 | 1.72 (51) |
| Total Dust | 2.10 (293) |
| Dust Line | 24.0 (297) |

Table 5a: Relative Risks for Sinusitis and conditions, symptoms, demographic and exposure variables of interest.

| Variable | Relative Risk | 95% Confidence Interval | p-value | Test for Linear Trend in Proportion |
|-------------------------------------------------|---------------|-------------------------|---------|-------------------------------------|
| Conditions | | | | |
| Asthma* | 1.18 | 0.44-3.16 | 0.100 | |
| Bronchitis* | 2.10 | 1.15-3.85 | 0.015 | |
| Chronic Bronchitis* | 4.48 | 2.10-9.53 | 0.001 | |
| Wheeze** | 2.30 | 1.55-5.64 | 0.002 | |
| Rhinitis | 7.97 | 4.55-13.94 | 0.001 | |
| Cough*** | 1.95 | 1.10-3.45 | 0.022 | |
| Phlegm*** | 1.58 | 0.89-2.81 | 0.119 | |
| Chest Tightness | 1.38 | 0.91-2.10 | 0.155 | |
| Shortness of Breath | 1.82 | 1.23-2.69 | 0.006 | |
| Hayfever* | 2.15 | 1.09-4.27 | 0.028 | |
| Demographics | | | | |
| Race-White | 1.12 | 0.41-3.02 | 0.821 | |
| Gender-Female | 2.67 | 1.04-6.84 | 0.050 | |
| Smoking Status | | | | |
| Ex- versus Never | 1.11 | 0.78-1.56 | 0.58 | |
| Current versus Never | 0.89 | 0.63-1.27 | 0.51 | |
| Exposure Type | | | | |
| Quicklime versus Unexposed | 0.86 | 0.33-2.20 | 0.75 | |
| Hydrated Lime versus Unexposed | 0.83 | 0.22-3.17 | 0.79 | |
| Mixed Exposure versus Unexposed | 0.58 | 0.12-2.74 | 0.49 | |
| Any Exposure versus Unexposed | 0.81 | 0.33-1.98 | 0.64 | |
| Exposure Level Total Particulate (mg/m3) | | | | |
| Medium (2.5-4.9) versus Low (0-2.4) | 1.56 | 0.40-6.01 | 0.51 | |
| High (≥ 5) versus Low (0-2.4) | 2.26 | 0.79-6.51 | 0.12 | P=0.12 |

*Diagnosis by physician

**Wheeze in the morning and at night

***Reports of Usual Cough/Phlegm

Table 5b: Relative Risks for Asthma and conditions, symptoms, demographic and exposure variables of interest

| Variable | Relative Risk | 95% Confidence Interval | p-value | Test for Linear Trend in Proportion |
|------------------------------------------------------------|---------------|-------------------------|---------|-------------------------------------|
| Conditions | | | | |
| Bronchitis* | 3.55 | 2.16-5.81 | 0.001 | |
| Chronic Bronchitis* | 3.04 | 1.33-6.95 | 0.010 | |
| Wheeze** | 3.19 | 1.77-5.73 | 0.001 | |
| Rhinitis | 2.04 | 0.79-5.25 | 0.145 | |
| Cough*** | 1.67 | 0.98-2.87 | 0.061 | |
| Phlegm*** | 1.14 | 0.65-2.00 | 0.659 | |
| Hayfever* | 2.47 | 1.37-4.47 | 0.003 | |
| Demographics | | | | |
| Race-White | 1.26 | 0.47-3.40 | 0.639 | |
| Gender-Female | + | + | + | |
| Smoking Status | | | | |
| Ex- versus Never | 0.52 | 0.27-1.01 | 0.049 | |
| Current versus Never | 0.62 | 0.35-1.08 | 0.090 | |
| Exposure Type | | | | |
| Quicklime versus Unexposed | 5.96 | 0.80-44.58 | 0.045 | |
| Hydrated Lime versus Unexposed | 3.32 | 0.31-35.68 | 0.295 | |
| Mixed Exposure versus Unexposed | 8.65 | 1.04-71.85 | 0.025 | |
| Any Exposure versus Unexposed | 5.95 | 0.81-43.57 | 0.041 | |
| Exposure Level Total Particulate (mg/m³) | | | | |
| Medium (2.5-4.9) versus Low (0-2.4) | 0.70 | 0.16-3.12 | 0.478 | |
| High (≥5) versus Low (0-2.4) | 1.30 | 0.48-3.53 | 0.606 | P=0.661 |

*Diagnosis by physician

**Wheeze in the morning and at night

***Reports of Usual Cough/Phlegm

+ No women reported having asthma

Table 5c: Relative Risks for Chronic Bronchitis and conditions, symptoms, demographic and exposure variables of interest.

| Variable | Relative Risk | 95% Confidence Interval | p-value | Test for Linear Trend in Proportion |
|-------------------------------------------------|---------------|-------------------------|---------|-------------------------------------|
| Conditions | | | | |
| Wheeze** | 5.37 | 2.41-11.97 | 0.001 | |
| Rhinitis | + | + | + | |
| Cough*** | 3.18 | 1.47-6.87 | 0.002 | |
| Phlegm*** | 4.15 | 1.92-8.99 | 0.001 | |
| Hayfever* | 0.86 | 0.21-3.60 | 0.840 | |
| Demographics | | | | |
| Race-White | 1.06 | 0.25-4.44 | 0.934 | |
| Gender-Female | 2.81 | 0.70-11.32 | 0.139 | |
| Smoking Status | | | | |
| Ex- versus Never | 0.94 | 0.29-3.05 | 0.923 | |
| Current versus Never | 1.87 | 0.73-4.81 | 0.184 | |
| Exposure Type | | | | |
| Quicklime versus Unexposed | 1.49 | 0.32-7.02 | 0.612 | |
| Hydrated Lime versus Unexposed | + | + | + | |
| Mixed Exposure versus Unexposed | 0.86 | 0.08-9.29 | 0.905 | |
| Any Exposure versus Unexposed | 1.13 | 0.25-5.23 | 0.873 | |
| Exposure Level Total Particulate (mg/m3) | | | | |
| Medium (2.5-4.9) versus Low (0-2.4) | + | + | + | |
| High (≥5) versus Low (0-2.4) | 2.44 | 0.67-8.84 | 0.16 | P=0.187 |

*Diagnosis by physician

**Wheeze in the morning and at night

***Reports of Usual Cough/Phlegm

+No report of rhinitis

Table 5d: Relative Risks for Bronchitis and conditions, symptoms, demographic and exposure variables of interest.

| Variable | Relative Risk | 95% Confidence Interval | p-value | Test for Linear Trend in Proportion |
|-------------------------------------------------|---------------|-------------------------|---------|-------------------------------------|
| Conditions | | | | |
| Chronic Bronchitis* | 7.90 | 6.45-9.66 | 0.001 | |
| Wheeze** | 2.82 | 1.95-4.08 | 0.001 | |
| Rhinitis | 1.68 | 0.86-3.27 | 0.146 | |
| Cough*** | 1.90 | 1.35-2.67 | 0.001 | |
| Phlegm*** | 1.65 | 1.17-2.32 | 0.004 | |
| Hayfever* | 1.44 | 0.90-2.32 | 0.136 | |
| Demographics | | | | |
| Race-White | 2.21 | 0.93-5.22 | 0.054 | |
| Gender-Female | 1.07 | 0.43-2.68 | 0.882 | |
| Smoking Status | | | | |
| Ex- versus Never | 0.97 | 0.62-1.52 | 0.899 | |
| Current versus Never | 1.22 | 0.83-1.80 | 0.309 | |
| Exposure Type | | | | |
| Quicklime versus Unexposed | 0.82 | 0.44-1.52 | 0.529 | |
| Hydrated Lime versus Unexposed | 0.77 | 0.31-1.89 | 0.560 | |
| Mixed Exposure versus Unexposed | 0.67 | 0.25-1.75 | 0.400 | |
| Any Exposure versus Unexposed | 0.78 | 0.44-1.41 | 0.420 | |
| Exposure Level Total Particulate (mg/m3) | | | | |
| Medium (2.5-4.9) versus Low (0-2.4) | 1.57 | 0.67-3.67 | 0.302 | |
| High (≥ 5) versus Low (0-2.4) | 1.95 | 0.98-3.98 | 0.056 | P=0.054 |

*Diagnosis by physician

**Wheeze in the morning and at night

***Reports of Usual Cough/Phlegm

Table 6: Sinusitis, Asthma and Chronic Bronchitis by various descriptor, exposure and pulmonary function measures.

| | Mean Yes | Mean No | T-Statistic | p-Value |
|------------------------------------|-------------|------------|-------------|---------|
| SINUSITIS | | | | |
| Age | 38.35 | 38.81 | 0.288 | 0.773 |
| Packyears of Cigarettes | 17.26 | 13.67 | 1.40 | 0.162 |
| Exposure | | | | |
| Total Dust | 18.99 | 6.27 | -2.81 | 0.005 |
| Dust Line Estimate | 30.90 | 27.83 | -0.66 | 0.510 |
| CAO | 8.12 | 2.59 | -2.66 | 0.008 |
| CAOH2 | 2.58 | 2.93 | 0.17 | 0.865 |
| Pulmonary Function Measures | | | | |
| FEV ₁ | 4.00 | 4.29 | 1.03 | 0.301 |
| FVC | 4.91 | 5.20 | 1.15 | 0.252 |
| PEFR | 9.00 | 9.82 | 0.664 | 0.507 |
| ASTHMA | | | | |
| Age | 35.51 | 39.02 | 2.30 | 0.021 |
| Packyears of Cigarettes | 10.82 | 14.10 | -1.42 | 0.156 |
| Exposure | | | | |
| Total Dust | 9.16 | 6.81 | -0.529 | 0.597 |
| Dust Line Estimate | 33.31 | 27.73 | -1.08 | 0.281 |
| CAO | 3.35 | 2.86 | -0.233 | 0.816 |
| CAOH2 | 3.37 | 2.87 | -0.283 | 0.778 |
| Pulmonary Function Measures | | | | |
| FEV ₁ | 3.98 | 4.29 | 1.20 | 0.232 |
| FVC | 5.06 | 5.19 | 0.542 | 0.588 |
| PEFR | 8.46 | 9.86 | 1.19 | 0.233 |
| CHRONIC BRONCHITIS | | | | |
| Age | 37.70 | 38.81 | 0.485 | 0.628 |
| Packyears of Cigarettes | 16.86 | 13.76 | 0.896 | 0.370 |
| Exposure | | | | |
| Total Dust | 4.94 | 7.01 | 0.343 | 0.731 |
| Dust Line Estimate | 33.86 | 27.89 | -0.775 | 0.439 |
| CAO | 1.21 | 2.94 | 0.654 | 0.514 |
| CAOH2* | 9.90 | 2.77 | -2.19 | 0.033 |
| Pulmonary Function Measures | | | | |
| FEV ₁ | 3.87 | 4.29 | 1.05 | 0.295 |
| FVC | 4.73 | 5.20 | 1.34 | 0.180 |
| PEFR | 8.95 | 9.79 | 0.480 | 0.631 |

*based on one case

Table 6 (Continued): Bronchitis by various descriptor, exposure and pulmonary function measures.

| | Mean Yes | Mean No | T-Statistic | p-Value |
|------------------------------------|-------------|------------|-------------|---------|
| BRONCHITIS | | | | |
| Age | 38.21 | 38.87 | 0.603 | 0.547 |
| Packyears of Cigarettes | 16.55 | 13.40 | 1.89 | 0.059 |
| Exposure | | | | |
| Total Dust | 8.12 | 6.79 | -0.417 | 0.677 |
| Dust Line Estimate | 29.03 | 27.90 | -0.316 | 0.752 |
| CAO | 2.63 | 2.91 | 0.185 | 0.853 |
| CAOH2 | 3.84 | 2.74 | -0.856 | 0.396 |
| Pulmonary Function Measures | | | | |
| FEV ₁ | 4.07 | 4.30 | 1.27 | 0.206 |
| FVC | 4.97 | 5.22 | 1.48 | 0.139 |
| PEFR | 9.62 | 9.79 | 0.211 | 0.833 |
| COUGH | | | | |
| Age | 37.14 | 39.18 | 2.08 | 0.038 |
| Packyears of Cigarettes | 18.99 | 12.62 | 4.26 | 0.001 |
| Exposure | | | | |
| Total Dust | 7.30 | 6.86 | -0.170 | 0.866 |
| Dust Line Estimate | 30.51 | 27.39 | -1.079 | 0.282 |
| CAO | 3.24 | 2.80 | -0.356 | 0.722 |
| CAOH2 | 3.30 | 2.73 | -0.558 | 0.580 |
| Pulmonary Function Measures | | | | |
| FEV ₁ | 4.30 | 4.27 | -0.147 | 0.883 |
| FVC | 5.31 | 5.16 | -0.963 | 0.336 |
| PEFR | 10.06 | 9.69 | -0.494 | 0.622 |

Table 7 : Univariate Cox Proportional Hazards Models with Sinusitis as the Dependent Variable.

| Variable | Univariate Cox Proportional Hazards Models with Sinusitis as the Dependent Variable | | | |
|-------------------------|-------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Age | 636.47 | 0.996 | 0.013 | 0.780 |
| Race-(White) | 636.50 | 1.12 | 0.522 | 0.829 |
| Gender-(Female) | 633.84** | 2.67 | 0.522 | 0.061 |
| Smoking Status | 656.60 | | | |
| Ex-smoker | | 1.20 | 0.348 | 0.593 |
| Current smoker | | 0.80 | 0.354 | 0.527 |
| Packyears | 596.63 | 1.01 | 0.007 | 0.175 |
| Exposure | | | | |
| Quicklime vs Unexposed | 272.14 | 1.17 | 0.500 | 0.755 |
| Hydrated vs Unexposed | | 1.20 | 0.707 | 0.792 |
| Mixture vs Unexposed | | 1.74 | 0.817 | 0.500 |
| Any lime vs Unexposed | 272.44 | 1.24 | 0.475 | 0.649 |
| Dustline | 227.36 | 1.01 | 0.010 | 0.523 |
| Total Particulate Level | 179.50 | | | |
| Medium versus Low | | 1.56 | 0.707 | 0.530 |
| High versus Low | | 2.26 | 0.556 | 0.142 |
| Asthma | 658.13 | 1.18 | 0.522 | 0.754 |
| Bronchitis | 653.58** | 2.10 | 0.324 | 0.022 |
| Chronic Bronchitis | 650.15** | 4.48 | 0.436 | 0.001 |
| Wheeze | 647.87** | 2.96 | 0.354 | 0.002 |
| Rhinitis | 634.11** | 7.97 | 0.342 | 0.001 |
| Cough | 653.98** | 1.95 | 0.305 | 0.029 |
| Phlegm | 656.10* | 1.58 | 0.305 | 0.134 |
| Hayfever | 654.34* | 2.15 | 0.369 | 0.038 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 8 : Univariate Cox Proportional Hazards Models with Asthma as the Dependent Variable.

| Variable | Univariate Cox Proportional Hazards Models with Asthma as the Dependent Variable | | | |
|-------------------------|----------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Age | 711.52** | 0.97 | 0.0138 | 0.028 |
| Race-(White) | 716.46 | 1.26 | 0.520 | 0.652 |
| Gender-(Female) | + | + | + | + |
| Smoking Status | | | | |
| Ex-smoker | 775.04* | 0.52 | 0.349 | 0.063 |
| Current smoker | | 0.62 | 0.297 | 0.018 |
| Packyears | 743.04* | 0.99 | 0.010 | 0.173 |
| Exposure | | | | |
| Quicklime vs Unexposed | 254.09* | 5.96 | 1.04 | 0.084 |
| Hydrated vs Unexposed | | 3.32 | 1.22 | 0.327 |
| Mixture vs Unexposed | | 8.65 | 1.10 | 0.049 |
| Any lime vs Unexposed | 255.54** | 5.95 | 1.02 | 0.082 |
| Dustline | 181.17 | 1.01 | 0.011 | 0.295 |
| Total Particulate Level | 192.47 | | | |
| Medium versus Low | | 0.70 | 0.782 | 0.645 |
| High versus Low | | 1.30 | 0.527 | 0.618 |
| Sinusitis | 779.03 | 1.18 | 0.518 | 0.756 |
| Bronchitis | 760.87** | 3.55 | 0.271 | 0.001 |
| Chronic Bronchitis | 775.62** | 3.04 | 0.468 | 0.017 |
| Wheeze | 726.30** | 3.19 | 0.326 | 0.001 |
| Rhinitis | 777.85 | 2.04 | 0.518 | 0.169 |
| Cough | 776.88* | 1.67 | 0.288 | 0.074 |
| Phlegm | 779.51 | 1.14 | 0.300 | 0.671 |
| Hayfever | 772.93** | 2.48 | 0.324 | 0.005 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

+No Females reported asthma

Table 9: Univariate Cox Proportional Hazards Models with Chronic Bronchitis as the Dependent Variable.

| Variable | Univariate Cox Proportional Hazards Models with Chronic Bronchitis as the Dependent Variable | | | |
|-------------------------|----------------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Age | 305.02 | 0.99 | 0.020 | 0.633 |
| Race-(White) | 305.25 | 1.06 | 0.74 | 0.935 |
| Gender-(Female) | 303.77 | 2.81 | 0.740 | 0.163 |
| Smoking Status | 333.34 | | | |
| Ex-smoker | | 0.94 | 0.606 | 0.924 |
| Current smoker | | 1.87 | 0.488 | 0.198 |
| Packyears | 318.63 | 1.01 | 0.011 | 0.378 |
| Exposure | | | | |
| Quicklime vs Unexposed | 115.28* | 1.49 | 0.802 | 0.619 |
| Hydrated vs Unexposed | | 0.00 | 1658 | 0.993 |
| Mixture vs Unexposed | | 0.87 | 1.22 | 0.905 |
| Any lime vs Unexposed | 118.57 | 1.13 | 0.791 | 0.874 |
| Dustline | 79.17 | 1.01 | 0.017 | 0.445 |
| Total Particulate Level | 97.03 | | | |
| Medium versus Low | | 0.00 | 1660 | 0.993 |
| High versus Low | | 2.44 | 0.671 | 0.184 |
| Sinusitis | 327.21** | 5.01 | 0.468 | 0.001 |
| Bronchitis | 252.12** | 142.86 | 1.02 | 0.001 |
| Asthma | 331.64* | 3.33 | 0.500 | 0.016 |
| Wheeze | 322.85** | 5.37 | 0.429 | 0.001 |
| Rhinitis | + | + | + | + |
| Cough | 328.71** | 3.17 | 0.403 | 0.004 |
| Phlegm | 323.96** | 4.15 | 0.403 | 0.001 |
| Hayfever | 322.53 | 0.86 | 0.739 | 0.842 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

+No cases of rhinitis reported in those with chronic bronchitis.

Table 10: Univariate Cox Proportional Hazards Models with Bronchitis as the Dependent Variable.

| Variable | Univariate Cox Proportional Hazards Models with Bronchitis as the Dependent Variable | | | |
|-------------------------|--------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Age | 1512.68 | 0.995 | 0.009 | 0.578 |
| Race-(White) | 1509.16** | 2.21 | 0.457 | 0.084 |
| Gender-(Female) | 1515.98 | 1.07 | 0.509 | 0.891 |
| Smoking Status | 1638.05 | | | |
| Ex-smoker | | 0.97 | 0.245 | 0.906 |
| Current smoker | | 1.22 | 0.214 | 0.349 |
| Packyears | 1553.69* | 1.01 | 0.005 | 0.082 |
| Exposure | | | | |
| Quicklime vs Unexposed | 580.37 | 0.82 | 0.342 | 0.558 |
| Hydrated vs Unexposed | | 0.77 | 0.494 | 0.589 |
| Mixture vs Unexposed | | 0.67 | 0.526 | 0.438 |
| Any lime vs Unexposed | 580.56 | 0.78 | 0.324 | 0.453 |
| Dustline | 409.86 | 1.00 | 0.008 | 0.766 |
| Total Particulate Level | 394.38 | | | |
| Medium versus Low | | 1.57 | 0.463 | 0.331 |
| High versus Low | | 1.95 | 0.378 | 0.077 |
| Sinusitis | 1623.60 | 2.93 | 0.235 | 0.001 |
| Chronic Bronchitis | 1587.14* | 7.90 | 0.228 | 0.001 |
| Asthma | 1623.60** | 2.93 | 0.235 | 0.001 |
| Wheeze | 1602.86** | 2.82 | 0.228 | 0.001 |
| Rhinitis | 1637.92 | 1.68 | 0.389 | 0.184 |
| Cough | 1630.37** | 1.90 | 0.194 | 0.001 |
| Phlegm | 1633.64** | 1.65 | 0.192 | 0.009 |
| Hayfever | 1624.28 | 1.45 | 0.268 | 0.170 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 11 : Multivariate Cox Proportional Hazards Models with Sinusitis as the Dependent Variable.

| Variable | Multivariate Cox Proportional Hazards Models with Sinusitis as the Dependent Variable | | | |
|----------------------------------------|---------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Asthma | 636.38 | 1.17 | 0.524 | 0.736 |
| Age | | 0.997 | 0.014 | 0.800 |
| Asthma | 177.15 | 0.955 | 1.043 | 0.964 |
| Age | | 1.00 | 0.023 | 0.991 |
| Medium particulate exposure versus Low | | 1.51 | 0.708 | 0.561 |
| High particulate exposure versus Low | | 2.20 | 0.558 | 0.158 |
| Asthma | 175.69 | 0.928 | 1.041 | 0.942 |
| Age | | 0.997 | 0.024 | 0.885 |
| Total Particulate Level | | 1.01 | 0.005 | 0.012 |
| Chronic Bronchitis | 176.80 | 1.97 | 1.045 | 1.97 |
| Age | | 1.00 | 0.020 | 1.00 |
| Medium particulate exposure versus Low | | 1.55 | 0.710 | 1.55 |
| High particulate exposure versus Low | | 2.15 | 0.560 | 2.15 |
| Chronic Bronchitis | 175.14 | 2.38 | 1.036 | 0.404 |
| Age | | 0.997 | 0.024 | 0.904 |
| Total Particulate Level | | 1.01 | 0.005 | 0.011 |
| Bronchitis | 175.70 | 2.11 | 0.582 | 0.199 |
| Age | | 0.999 | 0.023 | 0.955 |
| Medium particulate exposure versus Low | | 1.44 | 0.709 | 0.608 |
| High particulate exposure versus Low | | 2.04 | 0.562 | 0.203 |
| Bronchitis | 173.88* | 2.31 | 0.578 | 0.147 |
| Age | | 0.997 | 0.024 | 0.884 |
| Total Particulate Level | | 1.01 | 0.005 | 0.013 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 12a : Multivariate Cox Proportional Hazards Models with Asthma as the Dependent Variable.

| Variable | Multivariate Cox Proportional Hazards Models with Asthma as the Dependent Variable | | | |
|------------------------|------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Sinus | 710.78* | 1.19 | 0.520 | 0.742 |
| Age | | 0.97 | 0.014 | 0.027 |
| Chronic Bronchitis | 707.02** | 3.19 | 0.470 | 0.014 |
| Age | | 0.97 | 0.014 | 0.031 |
| Bronchitis | 690.89** | 3.86 | 0.277 | 0.001 |
| Age | | 0.97 | 0.014 | 0.032 |
| Wheeze | 659.43** | 2.96 | 0.332 | 0.001 |
| Age | | 0.97 | 0.015 | 0.032 |
| Sinus | 245.35** | 0.75 | 1.026 | 0.777 |
| Age | | 0.95 | 0.025 | 0.038 |
| Quicklime Exposure | | 4.67 | 1.039 | 0.138 |
| Hydrated Lime Exposure | | 2.55 | 1.229 | 0.445 |
| Mixture of Exposure | | 6.51 | 1.100 | 0.089 |
| Chronic Bronchitis | 240.64** | 5.44 | 0.627 | 0.007 |
| Age | | 0.95 | 0.025 | 0.040 |
| Quicklime Exposure | | 4.40 | 1.042 | 0.155 |
| Hydrated Lime Exposure | | 2.80 | 1.232 | 0.403 |
| Mixture of Exposure | | 6.48 | 1.102 | 0.090 |
| Bronchitis | 234.92** | 4.69 | 0.436 | 0.001 |
| Age | | 0.95 | 0.025 | 0.036 |
| Quicklime Exposure | | 5.09 | 1.038 | 0.117 |
| Hydrated Lime Exposure | | 3.33 | 1.229 | 0.327 |
| Mixture of Exposure | | 7.40 | 1.099 | 0.069 |
| Wheeze | 229.16** | 3.07 | 0.532 | 0.035 |
| Age | | 0.95 | 0.026 | 0.068 |
| Quicklime Exposure | | 4.49 | 1.042 | 0.149 |
| Hydrated Lime Exposure | | 2.53 | 1.227 | 0.450 |
| Mixture of Exposure | | 5.81 | 1.106 | 0.111 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 12b : Multivariate Cox Proportional Hazards Models with Sinusitis as the Dependent Variable.

| Variable | Multivariate Cox Proportional Hazards Models with Asthma as the Dependent Variable | | | |
|--------------------|------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Sinus | 707.79* | 1.18 | 0.520 | 0.749 |
| Age | | 0.98 | 0.014 | 0.090 |
| Ex-Smokers | | 0.57 | 0.391 | 0.147 |
| Current Smokers | | 0.67 | 0.307 | 0.197 |
| Chronic Bronchitis | 703.87** | 3.28 | 0.473 | 0.012 |
| Age | | 0.98 | 0.014 | 0.098 |
| Ex-Smokers | | 0.58 | 0.392 | 0.158 |
| Current Smokers | | 0.64 | 0.308 | 0.153 |
| Bronchitis | 703.87** | 3.90 | 0.278 | 0.001 |
| Age | | 0.98 | 0.014 | 0.096 |
| Ex-Smokers | | 0.57 | 0.388 | 0.152 |
| Current Smokers | | 0.63 | 0.308 | 0.136 |
| Wheeze | 655.03 | 3.27 | 0.344 | 0.001 |
| Age | | 0.98 | 0.015 | 0.133 |
| Ex-Smokers | | 0.48 | 0.425 | 0.082 |
| Current Smokers | | 0.59 | 0.320 | 0.101 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 13a : Multivariate Cox Proportional Hazards Models with Chronic Bronchitis as the Dependent Variable.

| Variable | Multivariate Cox Proportional Hazards Models with Chronic Bronchitis as the Dependent Variable | | | |
|-----------------|------------------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Sinus | 295.25** | 4.93 | 0.481 | 0.001 |
| Gender-(female) | | 2.12 | 0.749 | 0.316 |
| Asthma | 298.26** | 3.95 | 0.512 | 0.007 |
| Gender-(female) | | 3.41 | 0.750 | 0.102 |
| Bronchitis | 228.25** | 124.54 | 1.02 | 0.001 |
| Gender-(female) | | 2.63 | 0.74 | 0.192 |
| Wheeze | 289.56** | 6.31 | 0.449 | 0.001 |
| Gender-(female) | | 4.03 | 0.760 | 0.066 |
| Sinus | 1458.37* | 1.98 | 0.296 | 0.021 |
| Gender-(female) | | 0.95 | 0.510 | 0.911 |
| Packyears | | 1.01 | 0.005 | 0.120 |
| Bronchitis | 1460.16** | 7.52 | 0.240 | 0.001 |
| Gender-(female) | | 1.17 | 0.512 | 0.755 |
| Packyears | | 1.01 | 0.005 | 0.192 |
| Wheeze | 1455.88** | 2.82 | 0.232 | 0.001 |
| Gender-(female) | | 0.79 | 0.512 | 0.640 |
| Packyears | | 1.01 | 0.005 | 0.164 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 13b : Multivariate Cox Proportional Hazards Models with Chronic Bronchitis as the Dependent Variable.

| Variable | Multivariate Cox Proportional Hazards Models with Chronic Bronchitis as the Dependent Variable | | | |
|----------------------------------------|------------------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Sinus | 96.71** | 1.84 | 1.07 | 0.570 |
| Medium particulate exposure versus Low | | 0.00 | 1659 | 0.993 |
| High particulate exposure versus Low | | 2.33 | 0.676 | 0.210 |
| Sinus | 101.52 | 2.30 | 1.06 | 0.432 |
| Total Particulate Level | | 0.99 | 0.033 | 0.704 |
| Asthma | 94.72* | 4.08 | 0.803 | 0.080 |
| Medium particulate exposure versus Low | | 0.00 | 1820 | 0.993 |
| High particulate exposure versus Low | | 2.34 | 0.672 | 0.207 |
| Asthma | 99.35 | 4.71 | 0.802 | 0.053 |
| Total Particulate Level | | 0.99 | 0.031 | 0.706 |
| Bronchitis | 70.12** | 57.73 | 1.07 | 0.001 |
| Medium particulate exposure versus Low | | 0.00 | 1728 | 0.993 |
| High particulate exposure versus Low | | 1.36 | 0.676 | 0.648 |
| Bronchitis | 73.85** | 60.35 | 1.06 | 0.001 |
| Total Particulate Level | | 0.98 | 0.040 | 0.612 |
| Wheeze | 93.59** | 5.05 | 0.802 | 0.044 |
| Medium particulate exposure versus Low | | 0.00 | 1482 | 0.992 |
| High particulate exposure versus Low | | 2.49 | 0.671 | 0.175 |
| Wheeze | 99.26 | 3.90 | 0.803 | 0.090 |
| Total Particulate Level | | 0.99 | 0.033 | 0.772 |

**Model chi square p-value \leq 0.05

*Model chi square p-value \leq 0.15

Table 14 : Multivariate Cox Proportional Hazards Models with Bronchitis as the Dependent Variable.

| Variable | Multivariate Cox Proportional Hazards Models with Bronchitis as the Dependent Variable | | | |
|----------------------------------------|----------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Sinus | 364.11 | 2.12 | 0.537 | 0.162 |
| Packyears | | 1.01 | 0.010 | 0.168 |
| Medium particulate exposure versus Low | | 1.40 | 0.464 | 0.465 |
| High particulate exposure versus Low | | 1.62 | 0.396 | 0.221 |
| Sinus | 365.30 | 2.40 | 0.536 | 0.103 |
| Packyears | | 1.01 | 0.010 | 0.167 |
| Total Particulate Level | | 0.99 | 0.014 | 0.602 |
| Asthma | 359.88** | 3.62 | 0.454 | 0.005 |
| Packyears | | 1.01 | 0.010 | 0.143 |
| Medium particulate exposure versus Low | | 1.55 | 0.466 | 0.350 |
| High particulate exposure versus Low | | 1.73 | 0.395 | 0.166 |
| Asthma | 361.95 | 3.48 | 0.453 | 0.006 |
| Packyears | | 1.01 | 0.010 | 0.164 |
| Total Particulate Level | | 0.997 | 0.014 | 0.829 |
| Chronic Bronchitis | 349.68** | 8.97 | 0.449 | 0.001 |
| Packyears | | 1.01 | 0.010 | 0.216 |
| Medium particulate exposure versus Low | | 1.74 | 0.474 | 0.241 |
| High particulate exposure versus Low | | 1.44 | 0.399 | 0.359 |
| Chronic Bronchitis | 351.27** | 8.65 | 0.426 | 0.001 |
| Packyears | | 1.01 | 0.010 | 0.186 |
| Total Particulate Level | | 0.996 | 0.015 | 0.797 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 14 b: Multivariate Cox Proportional Hazards Models with Bronchitis as the Dependent Variable.

| Variable | Multivariate Cox Proportional Hazards Models with Bronchitis as the Dependent Variable | | | |
|----------------------------------------|----------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Wheeze | 359.05* | 2.89 | 0.456 | 0.020 |
| Packyears | | 1.01 | 0.010 | 0.161 |
| Medium particulate exposure versus Low | | 1.35 | 0.467 | 0.525 |
| High particulate exposure versus Low | | 1.73 | 0.395 | 0.166 |
| Wheeze | 360.87 | 2.87 | 0.452 | 0.020 |
| Packyears | | 1.01 | 0.010 | 0.186 |
| Total Particulate Level | | 0.996 | 0.014 | 0.783 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

F. LITERATURE CITED

- Axelsson O. Some recent developments in occupational epidemiology. *Scand J Work Environ Health*. 1994; 20 (special issue): 9-18.
- Awad El Karim MA, Gad El Rab MO, Omer AA, El Haimi YAA. Respiratory and allergic disorders in workers exposed to grain and flour dusts. *Archives of Environmental Health*. 1986; 41:297-301.
- Becklake MR, Bourbeau J, Menzies R, Ernst P. The relationship between acute and chronic airway responses to occupational exposures. *Curr Pulmonol* 1986; 9:25-66.
- Breslow NE. Covariance analysis of censored survival data. *Biometrics*. 1974; 30:89-99.
- Hoult B, Sigsgaard T, Tuxford AF. A comparison of micro-organisms, endotoxin levels and respiratory symptoms in wool mills and cotton mills. 1993 Proceedings, Beltwide Cotton Council of America, Memphis, TN, 281-284.
- Lee J. Regression estimate of the adjusted risk ratio [letter]. *Br J Ind Med*. 1986;43:356-7.
- Lee J, Chia KS. Estimation of prevalence rate ratios for cross sectional data: an example in occupational epidemiology. *Br J Ind Med*. 1993; 50:861-2.
- Lee J, Chia KS. Use of the prevalence ratio v the prevalence odds ratio as a measure of risk in cross sectional studies. *Occ & Envir Med*. 1994; 51:841.
- Mastromatteo E. Nickel and Its Compounds. *Occupational Medicine: Principles and Practical Applications*, Second Edition, C. Zenz, Editor; Chicago, Year Book Medical Publishers, Inc. 1988; 597-608.
- Moulin JJ, Wild P, Mur JM, Caillard JF, Massin N, Meyer-Bisch C, Toamain JP, Hanser P, Liet S, DuRoscoat MN, Segala A. Respiratory health assessment by questionnaire of 2024 workers involved in man-made mineral fiber production. *Int Arch Occup Environ Health*. 1988; 61:171-178.
- Tatken RL. Health effects of exposure to wood dust. A summary of the literature. US Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Standards Development and Technology Transfer, 1987.
- Wegman DH, Eisen EA, Smith RG. Draft Final Report: Acute and Chronic Respiratory Effects of Quicklime (CaO) and Hydrated Lime (Ca(OH)₂) Particulate Exposures; 1991.

V. INVESTIGATION OF SINUSITIS IN A BORAX EXPOSED COHORT

A. INTRODUCTION AND BACKGROUND

In 1988 a study of the acute and chronic respiratory effects of sodium borate exposures was undertaken in a large boron plant located in California. There was an earlier survey of this population in 1981, which included 619 participants, 303 of who were successfully re-evaluated in 1988. The study population was predominantly white and male. The two primary objectives of the sodium borate surveys were to look for evidence of chronic pulmonary function abnormalities associated with exposure and to identify any work related acute respiratory irritant symptoms resulting from exposures to borate dust (Wegman, 1991). In the study of chronic health effects, historical exposures to boron and to dust were estimated based on homogeneous exposure groups constructed using current exposure measurements, historical records of exposure and on information regarding implementation of environmental controls. In some cases, duration of employment or baseline lung function were used as surrogates of cumulative exposure. In the acute health effects study, short interval, real time exposures to aerosols were measured using a personal direct reading aerosol monitor (the MINIRAM- MIE Inc., Bedford, MA) in addition to a device that continuously logged the data (the Ranger- Rustrak, E. Greenwich, RI). These dataloggers were outfitted with a button to mark events, so participants could mark the exact time of an incident irritant symptom. A Marple Personal Cascade Impactor with 4 stages (Anderson Samplers, Atlanta, GA) was utilized for the determination of particle size distributions.

Chronic pulmonary function effects were assessed by re-examining the group of 303 workers who had been examined seven years previously in a pulmonary function survey conducted at the same plant. Spirometric measurements were obtained for each person and chronic symptom information was collected via the administration of the American Thoracic Society standard questionnaire and occupational histories were obtained as well. The relationships between chronic respiratory symptoms and exposure had not been completely investigated in these data. Prevalence rates of these symptoms in exposed and unexposed groups had not yet been calculated. These data had not been analyzed for

possible dose response relationships. The same series of questions regarding nose and sinus problems described in the lime data set was included in this version of the ATS questionnaire as well. The relationship between changes in pulmonary function and exposure to estimated levels of dust exposure during the seven year period was assessed, and no observable decrements in pulmonary function that could be related to workplace exposures to sodium borate were identified.

One hundred and seven workers participated in the study of acute effects. Workers were studied over 4 consecutive days in an intensive repeated measures design. Acute health effects were assessed by peak expiratory flow measurement and acute respiratory symptom questionnaires in conjunction with short real time exposures. Because these data are in the form of repeated measures, within person correlations had to be accounted for. Models were fit using a two stage logistic regression analysis developed by Korn and Whittemore (Korn, Whittemore, 1979). To avoid unstable parameter estimates, only subjects who had a minimum of three symptom reports were included in the analyses. Incidence rates were calculated for each symptom using the ratio of the number of symptom episodes to the appropriate period of time at risk. Fifteen minute and six hour time periods were examined and both demonstrated the same trend. The final model for symptom incidence at different exposure indices is presented in Table 1. Exposure was quantitatively associated with more frequent reports of eye, nose, and throat irritation and breathlessness in a dose-related fashion (Table 1). Those reporting multiple symptoms had substantially higher average exposures to dust. The tests for linear trend were significant at $p < 0.05$ for all symptom groups.

Given the significance of the relationships between acute respiratory irritants and exposure to boron dusts, the chronic symptoms also warranted further consideration. Long term exposure and repeated acute assaults are argued to predispose workers to longer term or chronic health effects manifested in reports of chronic symptoms (Becklake, 1986). Although this possibility could not be directly assessed in these data as they are cross-sectional, chronic symptoms in relation to estimates of historical exposures could be examined. Because multiple sinus questions were administered to this cohort, two

additional objectives were met: 1) the relationship between exposure (to boron dust and total dust) and sinus symptoms including chronic sinusitis, sinus surgery were assessed; and 2) relationships between sinus conditions, asthma, atopy, chronic bronchitis and chronic respiratory symptoms such as cough, phlegm, wheeze and breathlessness were also examined.

B. METHODS AND STUDY POPULATION

The methods used for these analyses are the same as those described for the Lime data. There were differences in the analyses relating to exposure. Exposure was measured in years of total borax exposure. This variable was assessed continuously and categorically (unexposed; 1-9 years; ≥ 10 years). Because exposure was not associated with the conditions of interest in the bivariate analysis, it was not included in the modeling.

C. RESULTS

1. Descriptive Analyses

Demographics of the population: The population was predominantly male (92%) and white (94%) and had an mean age of about 41 years (Table 2). Thirty eight percent were current smokers, while 37% had never smoked. The mean number of packyears smoked for current and ex-smokers was 15.2. The average total number of years of borax exposure was 9.5.

Prevalence of Conditions: Sinusitis, asthma, chronic bronchitis and bronchitis were reported by 10%, 8%, 2%, and 28% (respectively) of the cohort. Cough, wheeze and phlegm were reported in proportions comparable to asthma and sinusitis (8.1%, 5.9%, 5.6%, respectively). While rhinitis and hayfever approached the rates observed for bronchitis. Reports of deviated nasal septum and nasal polyps were infrequent (3.6%, 1.7% respectively). Nose or sinus operations were reported by about 6% of the cohort, though no differentiation for surgery type was possible.

Prevalence Ratios for Conditions : Prevalence ratios were calculated for pairs of each of the conditions under study (Tables 4a-4d). Overall the conditions are very highly associated with one another. Sinusitis was most associated with chronic bronchitis (PR=4.3, p=0.003) followed by hayfever (PR=2.7, p=0.001). Those reporting sinusitis

were about twice as likely to also report asthma, bronchitis, wheeze, chest tightness and rhinitis. Cough, phlegm, and shortness of breath did not demonstrate associations with sinusitis. Women reported sinusitis more frequently than did men (PR=1.9 p=0.04) and whites may have been at a slightly greater risk as compared to non-whites (PR=1.1, p=0.09). Sinusitis was more prevalent in Never smokers. The total number of years of Borax exposure was not associated with the chronic sinusitis.

Asthma also demonstrated relatively strong associations with other respiratory conditions including, bronchitis (PR=1.9, p=0.001), wheeze (PR=2.7 p=0.006), Chest Tightness (PR=2.0 p=0.001), Shortness of breath (PR=2.1. p=0.02), Rhinitis (PR=2.4 p=0.001), Cough (PR=1.85 p=0.09), and hayfever (PR=3.3 p=0.001). Race and gender were difficult to evaluate because of the cohort was so predominantly white and male. Asthma was more likely to be reported by never smokers. The total number of years of Borax exposure was not associated with the asthma.

Chronic Bronchitis demonstrated some associations of larger magnitude than those observed with asthma and other conditions. These associations were observed for chest tightness, cough and phlegm. Race and gender effects were not able to be assessed in this cohort as no women or non-whites reported chronic bronchitis. No effects of smoking were observed. The total number of years of Borax exposure was not associated with the chronic bronchitis.

Bronchitis was also associated with the other conditions under study. It was very strongly associated with chronic bronchitis. Relationships were also observed for bronchitis, chest tightness, rhinitis, cough and hayfever. Shortness of breath and wheeze had associations of borderline significance. There were no observable effects of smoking status. The total number of years of Borax exposure was not associated with the bronchitis.

Exposure: As described above, the exposure measure was not associated with any of the conditions of interest. It was therefore, excluded from further analysis.

Measures of Pulmonary Function: There was no consistent pattern between the conditions investigated and the maximum values of FEV₁, FVC and PEFR.

2. Models

Univariate (Tables 7-10) and multivariate logistic regression (Tables 11-14) and Cox proportional hazards models were constructed for each of four outcome variables: sinusitis, asthma, chronic bronchitis and bronchitis. Comparisons were made to ensure that there were no major differences between the modeling methods. Only the Cox proportional hazards models are included in this report. As with the lime cohort, the borax cohort was predominantly white and male. In general, this limited our ability to evaluate race and gender effects.

Risk of sinusitis increased slightly with age (3% per year) and was greater for whites (RR=4.46, p=0.14) and for women (RR=1.19, p=0.06), though these relationships were of borderline significance (Table 7). The mean age of those reporting sinusitis was significantly greater than those without sinusitis (mean age: 44 versus 41 years, p=0.02). Smoking was not strongly associated with reports of chronic sinusitis—in fact current smokers demonstrated a smaller risk than never smokers though this relationship was not statistically significant. Univariate models with conditions as explanatory variables did not differ much from the bivariate described above and will not be re-summarized in this section. Asthmatics were almost twice as likely to report having sinusitis when compared to non-asthmatics.

Multivariate models with sinusitis as an outcome variable did not add much information (Table 11). The final models generally included each condition (separately) along with age in the continuous version. Smoking status and pack years were included separately in some models, as well. Current smoking and packyears were negatively associated with reports of chronic sinusitis, though these associations were not very strong.

Reports of asthma decreased significantly with age (about 3% per year) and were negatively associated with smoking status (Table 8). The mean age of those reporting asthma was significantly lower than that in non-asthmatics (mean age: 38 versus 41

years, $p=0.03$). Ex-smokers and Current smokers were about half as likely to report asthma when compared to never smokers. Hayfever, rhinitis, wheeze and bronchitis were between two and a half and 4 and a half times more likely to be reported by asthmatics than non-asthmatics.

Final multivariate models included each condition separately, age and smoking status (Table 12). They generally demonstrate that risk of asthma decreases with age and is greater for never smokers and those reporting other respiratory conditions including: sinusitis, bronchitis and wheeze.

Chronic bronchitis did not demonstrate associations with age or smoking (status or packyears) (Table 9). Race and gender effects could not be evaluated as no women or non-whites reported chronic bronchitis. As in the bivariate analysis, this condition demonstrated strong associations with bronchitis, sinusitis, rhinitis, cough, phlegm and hayfever.

Multivariate analysis similar to that run for the other conditions was completed. This was done simply for the purpose comparison, as the terms in these models are not significant when combined.

Reports of bronchitis were more prevalent in females as compared to males ($RR=1.60$, $p=0.03$). Age, race and smoking (status and packyears) were not associated with bronchitis. Again those conditions demonstrating strong associations in the bivariate analysis remained strong in the univariate models. All but phlegm demonstrated some association, though that for wheeze was borderline ($RR=1.5$, $p=0.13$).

As with chronic bronchitis, multivariate analysis similar to those completed for sinusitis and asthma were conducted for bronchitis. These were done for the purpose of comparison. Neither age nor smoking status contributed any predictive value to these models.

D. DISCUSSION

Much of the discussion written in chapter V applies to this section as well. As seen in the lime cohort, reports of chronic sinusitis were lower than expected in this cohort of borax workers. Because the workforce was so predominantly white and male, race and gender effects in relation to conditions and exposure were not able to be investigated in this cohort. These effects were only observable for some conditions, namely sinusitis and bronchitis. Overall, the conditions investigated demonstrated strong associations with one another. Though no strong associations were observed between conditions and measures of pulmonary function.

Exposure was measured using a variable that represented total years of borax exposure. This measure was not associated with any of the conditions investigated in the bivariate analysis, so it was not included in the modeling analysis. This finding is consistent with results observed in the original analysis of these data that demonstrated no chronic effects of exposure to borax on measures of pulmonary function. This, however is a very crude measure of exposure and should not be used to rule out the possibility that chronic respiratory effects may result from long term exposure to borax. Because the original analysis provided evidence of acute respiratory effects from borax exposure, it is possible that chronic outcomes could result from chronic exposures. Poor measures of exposure limit our ability to fully investigate this potential.

Because of the cross-sectional nature of these data, we are not able to determine which of the diseases precedes the others in relation to exposure. We are unable to follow the natural history of this disease(s). This is unfortunate, as this information would enable us to better investigate and describe the disease process relating upper respiratory conditions to lower respiratory conditions. The investigation of this "disease process" as it relates to exposure would be very valuable in trying to determine whether or not this is in fact one disease process or separate processes. It is recommended that questions relating to chronic sinusitis be included in standard respiratory questionnaires (see page 38). As mentioned earlier, longitudinal examination of these processes in relation to exposure would be the optimal means by which to investigate and describe upper and lower respiratory conditions.

E. TABLES

Table 1: Logistic regression analysis for any respiratory irritant symptom at different levels of exposure.

| Exposure (mg/m ³) | $\beta \pm SE^*$ | Odds Ratio | 95% C.I.† |
|-------------------------------|------------------|------------|-----------|
| < 1 | - | 1.0 | - |
| 1-4 | 0.95 ± 0.18 | 2.6 | 1.8-3.7 |
| 5-9 | 1.72 ± 0.22 | 5.6 | 3.6-8.6 |
| 10-14 | 2.45 ± 0.25 | 11.6 | 7.1-18.9 |
| >15 | 2.71 ± 0.20 | 15.1 | 10.2-22.2 |

* β is the coefficient. SE is the standard error of the estimate.
 † is the 95% confidence interval.

Table 2: Demographics of the Borax Cohort

| Conditions | % (n) |
|-------------------------------------------|---------------|
| Sinusitis | 9.7 (69) |
| Asthma | 8.0 (57) |
| Bronchitis | 28.4 (203) |
| Chronic Bronchitis | 2.2 (16) |
| Wheeze | 5.9 (42) |
| Rhinitis | 27.1 (194) |
| Cough | 8.1 (58) |
| Phlegm | 5.6 (40) |
| Hayfever | 18.6 (130) |
| Deviated Nasal Septum | 3.6 (30) |
| Nasal Polyp | 1.7 (12) |
| Nose/Sinus Operation | 6.4 (46) |
| Demographics | |
| Age (mean, sd) | 40.9 (10.3) |
| Race White | 93.8 (671) |
| Gender-Male | 91.8 (653) |
| Smoking Status | |
| Never Smoke | 36.6 (261) |
| Ex-Smoker | 25.5 (182) |
| Current Smoker | 38.0 (271) |
| Packyears (mean, sd) | 15.2 (20.1) |
| Pulmonary Function | |
| FEV ₁ (mean, sd) | 383.6 (81.2) |
| FVC (mean, sd) | 498.3 (98.3) |
| PEFR (mean, sd) | 576.9 (374.8) |
| Exposure: | |
| Years Total Borax Exposure, (Mean, sd) | 9.5 (8.98) |

Table 3: Correlation Analysis for Mean Age of Onset for Respiratory Conditions.

| | N | Mean Age of Condition Onset | Standard Deviation | Pearson Correlation Coefficient | Spearman Correlation Coefficient |
|----------------------------------|----|-----------------------------|--------------------|---------------------------------|----------------------------------|
| Wheeze Asthma | 35 | 12.7 13.8 | 11.7 12.0 | R=0.90 (p=0.001) | R=0.82 (p=0.001) |
| Wheeze Bronchitis | 46 | 22.3 23.7 | 14.9 14.4 | R=0.6 (p=0.001) | R=0.59 (p=0.001) |
| Wheeze Chronic Bronchitis | 7 | 26.0 24.4 | 11.6 12.4 | R=0.96 (p=0.001) | R=0.64 (p=0.124) |
| Asthma Bronchitis | 31 | 13.1 13.1 | 12.4 12.4 | R=0.30 (p=0.10) | R=0.07 (p=0.69) |
| Asthma Chronic Bronchitis | 2 | 38.5 35.5 | 17.7 21.9 | R=1.0 (p=0.001) | R=1.0 (p=0.001) |
| Bronchitis Chronic Bronchitis | 15 | 19.5 19.7 | 11.6 10.7 | R=0.91 (p=0.001) | R=0.87 (p=0.001) |

Table 4: Relative Risks for Sinusitis and Asthma Versus Other Respiratory Conditions.

| Outcome | Condition | Relative Risk | 95% Confidence Interval. | p-Value |
|-------------------------|-------------------------|-------------------|--------------------------|---------|
| Sinusitis | Asthma Ever | 1.99 | (1.1, 3.8) | 0.036 |
| | Still have Asthma | 4.40 | (1.8, 10.3) | 0.001 |
| | Bronchitis | 2.02 | (1.6, 2.6) | 0.001 |
| | Still have Bronchitis | 6.20 | (1.8, 21.6) | 0.001 |
| | Cough4-6 times/day | 6.20 | (1.1, 36.7) | 0.021 |
| | Usual Cough | 1.29 | (0.61, 2.7) | 0.515 |
| | Chronic Bronchitis | 4.26 | (1.5, 11.9) | 0.003 |
| | Usual Phlegm | 1.04 | (0.38, 2.84) | 0.939 |
| | Phlegm 4 times/day | 5.60 | (1.4, 23.0) | 0.007 |
| | Rhinitis | 2.06 | (1.6, 2.7) | 0.001 |
| | Wheeze | 1.87 | (0.87, 4.1) | 0.113 |
| | Hayfever | 2.69 | (1.9-3.7) | 0.001 |
| | Nose Allergy Symptoms | 1.72 | (1.4, 2.13) | 0.001 |
| | Eye Allergy Symptoms | 1.42 | (1.09,1.86) | 0.026 |
| | Cough from Allergy | 2.71 | (1.81, 4.06) | 0.001 |
| | Throat Allergy Symptoms | 2.3 | (1.70, 3.12) | 0.001 |
| | Asthma | Still have Asthma | + | + |
| Bronchitis | | 1.92 | (1.4, 2.6) | 0.001 |
| Still have Bronchitis | | 2.90 | (0.63, 13.3) | 0.16 |
| Cough4-6 times/day | | 2.9 | (0.33, 25.4) | 0.32 |
| Usual Cough | | 1.80 | (0.92, 3.7) | 0.09 |
| Chronic Bronchitis | | 1.70 | (0.38, 7.08) | 0.50 |
| Usual Phlegm | | 0.30 | (0.04, 2.11) | 0.19 |
| Phlegm 4 times/day | | 1.01 | (1.004, 1.021) | 0.40 |
| Rhinitis | | 2.37 | (1.8, 3.06) | 0.001 |
| Wheeze | | 2.70 | (1.3, 5.6) | 0.006 |
| Nose Allergy Symptoms | | 2.07 | (1.72, 2.50) | 0.001 |
| Eye Allergy Symptoms | 1.94 | (1.55, 2.44) | 0.001 | |
| Cough from Allergy | 2.73 | (1.95, 3.82) | 0.001 | |
| Throat Allergy Symptoms | 3.95 | (2.74, 5.69) | 0.001 | |

+ Those ever reporting asthma still had the condition.

Table 5a: Relative Risks for Sinusitis and conditions, symptoms, demographic and exposure variables of interest.

| Variable | Relative Risk | 95% Confidence Interval | p-value |
|------------------------------------------------------------------|---------------|-------------------------|---------|
| Conditions | | | |
| Asthma* | 1.99 | 1.06-3.76 | 0.036 |
| Bronchitis* | 2.02 | 1.56-2.62 | 0.001 |
| Chronic Bronchitis* | 4.26 | 1.52-11.89 | 0.003 |
| Wheeze** | 1.87 | 0.87-4.06 | 0.113 |
| Chest Tightness | 1.90 | 1.37-2.64 | 0.001 |
| Shortness of Breath on Hurrying | 1.50 | 0.77-2.89 | 0.237 |
| Rhinitis | 2.06 | 1.58-2.70 | 0.001 |
| Cough*** | 1.29 | 0.61-2.72 | 0.515 |
| Phlegm*** | 1.04 | 0.38-2.84 | 0.939 |
| Hayfever* | 2.69 | 1.93-3.74 | 0.001 |
| Demographics | | | |
| Race-White | 1.06 | 1.02-1.09 | 0.087 |
| Gender-Female | 1.94 | 1.03-3.66 | 0.043 |
| Smoking Status | | | |
| Ex- versus Never | 0.09 | 0.65-1.36 | 0.727 |
| Current versus Never | 0.77 | 0.54-1.09 | 0.104 |
| Total Years Borax Exposure (unexposed is reference group) | | | |
| 1-9 years | 0.78 | 0.32-1.93 | 0.59 |
| ≥ 10 years | 0.66 | 0.31-1.39 | 0.276 |

*Diagnosis by physician

**Wheeze in the morning and at night

***Reports of Usual Cough/Phlegm

Table 5b: Relative Risks for Asthma and conditions, symptoms, demographic and exposure variables of interest.

| Variable | Relative Risk | 95% Confidence Interval | p-value |
|---------------------------------|---------------|-------------------------|---------|
| Conditions | | | |
| Bronchitis* | 1.92 | 1.45-2.56 | 0.001 |
| Chronic Bronchitis* | 1.65 | 0.38-7.08 | 0.499 |
| Wheeze** | 2.72 | 1.32-5.59 | 0.006 |
| Chest Tightness | 2.00 | 1.43-2.81 | 0.001 |
| Shortness of Breath on Hurrying | 2.09 | 1.13-3.89 | 0.022 |
| Rhinitis | 2.37 | 1.83-3.07 | 0.001 |
| Cough*** | 1.85 | 0.921-3.70 | 0.088 |
| Phlegm*** | 0.30 | 0.04-2.12 | 0.189 |
| Hayfever* | 3.32 | 2.43-4.53 | 0.001 |
| Demographics | | | |
| Race-White | 0.97 | 0.89-1.05 | 0.392 |
| Gender-Female | 0.87 | 0.33-2.31 | 0.773 |
| Smoking Status | | | |
| Ex- versus Never | 0.52 | 0.29-0.94 | 0.012 |
| Current versus Never | 0.67 | 0.46-1.00 | 0.024 |
| Total Exposure Years | | | |
| 1-9 years | 0.91 | 0.33-2.54 | 0.863 |
| ≥ 10 years | 0.42 | 0.16-1.09 | 0.070 |

*Diagnosis by physician

**Wheeze in the morning and at night

***Reports of Usual Cough/Phlegm

Table 5c: Relative Risks for Chronic Bronchitis and conditions, symptoms, demographic and exposure variables of interest.

| Variable | Relative Risk | 95% Confidence Interval | p-value |
|---------------------------------|---------------|-------------------------|---------|
| Conditions | | | |
| Wheeze** | 2.18 | 0.58-8.27 | 0.255 |
| Chest Tightness | 3.80 | 2.89-5.00 | 0.001 |
| Shortness of Breath on Hurrying | 2.10 | 0.74-5.99 | 0.178 |
| Rhinitis | 1.88 | 1.13-3.11 | 0.038 |
| Cough*** | 5.04 | 2.54-10.00 | 0.001 |
| Phlegm*** | 4.85 | 1.96-12.01 | 0.001 |
| Hayfever* | 2.11 | 1.10-4.06 | 0.043 |
| Demographics | | | |
| Race-White | + | + | + |
| Gender-Female | + | + | + |
| Smoking Status | | | |
| Ex- versus- Never | 0.91 | 0.37-2.25 | 0.835 |
| Current versus Never | 1.21 | 0.78-1.88 | 0.439 |
| Total Exposure Years | | | |
| 1-9 years | 3.13 | 0.36-27.11 | 0.272 |
| ≥ 10 years | 1.23 | 0.15-10.28 | 0.848 |

*Diagnosis by physician

**Wheeze in the morning and at night

***Reports of Usual Cough/Phlegm

+ No non-whites or females reported chronic bronchitis

Table 5d: Relative Risks for Bronchitis and conditions, symptoms, demographic and exposure variables of interest.

| Variable | Relative Risk | 95% Confidence Interval | p-value |
|---------------------------------|---------------|-------------------------|---------|
| Conditions | | | |
| Chronic Bronchitis* | 37.83 | 5.03-284.54 | 0.001 |
| Wheeze** | 1.72 | 0.95-3.11 | 0.074 |
| Chest Tightness | 1.64 | 1.25-2.15 | 0.001 |
| Shortness of Breath on Hurrying | 1.47 | 0.91-2.36 | 0.117 |
| Rhinitis | 1.93 | 1.53-2.43 | 0.001 |
| Cough*** | 2.05 | 1.25-3.35 | 0.004 |
| Phlegm*** | 1.36 | 0.72-2.55 | 0.340 |
| Hayfever* | 2.03 | 1.50-2.76 | 0.001 |
| Demographics | | | |
| Race-White | 1.03 | 0.996-1.07 | 0.121 |
| Gender-Female | 1.91 | 1.17-3.13 | 0.010 |
| Smoking Status | | | |
| Ex- versus Never | 0.95 | 0.74-1.23 | 0.706 |
| Current versus Never | 0.98 | 0.82-1.18 | 0.858 |
| Total Exposure Years | | | |
| 1-9 years | 1.45 | 0.86-2.46 | 0.152 |
| ≥ 10 years | 1.09 | 0.67-1.77 | 0.727 |

*Diagnosis by physician

**Wheeze in the morning and at night

***Reports of Usual Cough/Phlegm

Table 6: Sinusitis, Asthma and Chronic Bronchitis by various descriptor, exposure and pulmonary function measures.

| | Mean Yes | Mean No | T-Statistic | p-Value |
|------------------------------------|-------------|------------|-------------|---------|
| SINUSITIS | | | | |
| Age | 43.64 | 40.62 | 2.291 | 0.022 |
| Packyears of Cigarettes | 13.56 | 15.32 | 0.677 | 0.499 |
| Exposure | | | | |
| Total Years of Borax Exposure | 8.97 | 9.01 | -0.038 | 0.971 |
| Pulmonary Function Measures | | | | |
| FEV ₁ | 390.78 | 382.81 | 0.774 | 0.439 |
| FVC | 504.39 | 497.68 | 0.538 | 0.591 |
| PEFR | 631.91 | 570.91 | 1.285 | 0.199 |
| ASTHMA | | | | |
| Age | 38.09 | 41.15 | 2.140 | 0.033 |
| Packyears of Cigarettes | 11.78 | 15.44 | 1.295 | 0.196 |
| Exposure | | | | |
| Total Years of Borax Exposure | 7.24 | 9.15 | -1.53 | 0.126 |
| Pulmonary Function Measures | | | | |
| FEV ₁ | 392.88 | 382.78 | 0.900 | 0.368 |
| FVC | 510.91 | 497.23 | 1.007 | 0.314 |
| PEFR | 582.14 | 576.44 | 0.110 | 0.912 |
| CHRONIC BRONCHITIS | | | | |
| Age | 39.56 | 40.94 | 0.529 | 0.597 |
| Packyears of Cigarettes | 17.45 | 15.10 | 0.447 | 0.655 |
| Exposure | | | | |
| Total Years of Borax Exposure | 8.34 | 9.03 | -0.373 | 0.709 |
| Pulmonary Function Measures | | | | |
| FEV ₁ | 415.81 | 382.85 | 1.607 | 0.109 |
| FVC | 531.69 | 497.57 | 1.373 | 0.170 |
| PEFR | 550.06 | 577.53 | 0.290 | 0.772 |

Table 6 (Continued): Bronchitis by various descriptor, exposure and pulmonary function measures.

| | Mean Yes | Mean No | T-Statistic | p-Value |
|------------------------------------|-------------|------------|-------------|---------|
| BRONCHITIS | | | | |
| Age | 40.97 | 40.88 | 0.109 | 0.913 |
| Packyears of Cigarettes | 13.83 | 15.67 | 1.086 | 0.278 |
| Exposure | | | | |
| Total Years of Borax Exposure | 9.12 | 8.93 | 0.2615 | 0.794 |
| Pulmonary Function Measures | | | | |
| FEV ₁ | 389.07 | 381.40 | 1.132 | 0.258 |
| FVC | 502.27 | 496.77 | 0.671 | 0.503 |
| PEFR | 609.24 | 563.95 | 1.449 | 0.148 |
| COUGH | | | | |
| Age | 41.33 | 40.87 | 0.324 | 0.746 |
| Packyears of Cigarettes | 26.29 | 14.17 | 4.379 | 0.001 |
| Exposure | | | | |
| Total Years of Borax Exposure | 9.44 | 8.94 | 0.483 | 0.630 |
| Pulmonary Function Measures | | | | |
| FEV ₁ | 398.58 | 382.27 | 1.454 | 0.146 |
| FVC | 517.49 | 496.65 | 1.536 | 0.125 |
| PEFR | 506.47 | 583.11 | 1.481 | 0.139 |

Table 7 : Univariate Cox Proportional Hazards Models with Sinusitis as the Dependent Variable.

| Variable | Univariate Cox Proportional Hazards Models with Sinusitis as the Dependent Variable | | | |
|-----------------------|-------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Age | 874.75** | 1.03 | 0.115 | 0.030 |
| Race-(White) | 903.22** | 4.46 | 1.007 | 0.138 |
| Gender-(Female) | 903.14** | 1.91 | 0.342 | 0.059 |
| Smoking Status | 904.78 | | | |
| Ex-smoker | | 0.91 | 0.293 | 0.743 |
| Current smoker | | 0.64 | 0.289 | 0.125 |
| Packyears | 863.36 | 0.996 | 0.0067 | 0.519 |
| Conditions | | | | |
| Asthma | 903.69* | 1.96 | 0.342 | 0.050 |
| Bronchitis | 889.80** | 2.75 | 0.241 | 0.001 |
| Chronic Bronchitis | 901.96** | 3.41 | 0.464 | 0.008 |
| Wheeze | 905.08 | 1.81 | 0.593 | 0.137 |
| Rhinitis | 889.78** | 2.77 | 0.241 | 0.001 |
| Cough | 906.62 | 1.28 | 0.399 | 0.537 |
| Phlegm | 906.97 | 1.04 | 0.515 | 0.942 |
| Hayfever | 885.94** | 3.26 | 0.244 | 0.001 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 8 : Univariate Cox Proportional Hazards Models with Asthma as the Dependent Variable.

| Variable | Univariate Cox Proportional Hazards Models with Asthma as the Dependent Variable | | | |
|-----------------------|----------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Age | 730.68** | 0.97 | 0.013 | 0.040 |
| Race-(White) | 748.64 | 0.87 | 0.468 | 0.414 |
| Gender-(Female) | 735.39 | 0.87 | 0.519 | 0.782 |
| Smoking Status | 741.27** | | | |
| Ex-smoker | | 0.42 | 0.379 | 0.021 |
| Current smoker | | 0.53 | 0.302 | 0.034 |
| Packyears | 718.08 | 0.99 | 0.008 | 0.214 |
| Conditions | | | | |
| Sinusitis | 745.88* | 1.99 | 0.348 | 0.048 |
| Bronchitis | 736.51** | 2.61 | 0.265 | 0.003 |
| Chronic Bronchitis | 748.88 | 1.59 | 0.720 | 0.520 |
| Wheeze | 744.19** | 2.62 | 0.381 | 0.012 |
| Rhinitis | 725.55** | 3.69 | 0.268 | 0.001 |
| Cough | 747.00* | 1.85 | 0.381 | 0.107 |
| Phlegm | 747.09* | 0.30 | 1.009 | 0.235 |
| Hayfever | 718.13** | 4.66 | 0.265 | 0.001 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 9: Univariate Cox Proportional Hazards Models with Chronic Bronchitis as the Dependent Variable.

| Variable | Univariate Cox Proportional Hazards Models with Chronic Bronchitis as the Dependent Variable | | | |
|-----------------------|----------------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Age | 209.72 | 0.99 | 0.025 | 0.601 |
| Race-(White) | + | + | + | + |
| Gender-(Female) | + | + | + | + |
| Smoking Status | | | | |
| Ex-smoker | 209.27 | 0.86 | 0.730 | 0.837 |
| Current smoker | | 1.54 | 0.570 | 0.448 |
| Packyears | 196.14 | 1.01 | 0.011 | 0.658 |
| Conditions | | | | |
| Sinusitis | 204.57** | 4.26 | 0.539 | 0.007 |
| Asthma | 209.93 | 1.65 | 0.756 | 0.508 |
| Bronchitis | 179.35** | 37.83 | 1.033 | 0.001 |
| Wheeze | 209.34 | 2.29 | 0.756 | 0.273 |
| Rhinitis | 206.56** | 2.69 | 0.500 | 0.048 |
| Cough | 199.65** | 6.80 | 0.516 | 0.001 |
| Phlegm | 203.86** | 5.63 | 0.577 | 0.003 |
| Hayfever | 207.01* | 2.70 | 0.516 | 0.054 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

+No non-whites or females report Chronic Bronchitis

Table 10: Univariate Cox Proportional Hazards Models with Bronchitis as the Dependent Variable.

| Variable | Univariate Cox Proportional Hazards Models with Bronchitis as the Dependent Variable | | | |
|-----------------------|--------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Age | 2638.09 | 1.001 | 0.007 | 0.927 |
| Race-(White) | 2666.39 | 1.60 | 0.361 | 0.194 |
| Gender-(Female) | 2648.74 | 1.59 | 0.214 | 0.030 |
| Smoking Status | 2667.68 | | | |
| Ex-smoker | | 0.94 | 0.182 | 0.749 |
| Current smoker | | 0.98 | 0.162 | 0.879 |
| Packyears | 2564.33 | 0.996 | 0.004 | 0.357 |
| Conditions | | | | |
| Sinusitis | 2655.84** | 2.02 | 0.184 | 0.001 |
| Chronic Bronchitis | 2652.86** | 3.49 | 0.268 | 0.001 |
| Asthma | 2659.25** | 1.92 | 0.201 | 0.001 |
| Wheeze | 2666.31* | 1.47 | 0.253 | 0.132 |
| Rhinitis | 2649.22** | 1.90 | 0.143 | 0.001 |
| Cough | 2663.17** | 1.66 | 0.210 | 0.015 |
| Phlegm | 2667.74 | 1.25 | 0.277 | 0.421 |
| Hayfever | 2655.30** | 1.80 | 0.155 | 0.001 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 11 : Multivariate Cox Proportional Hazards Models with Sinusitis as the Dependent Variable.

| Variable | Multivariate Cox Proportional Hazards Models with Sinusitis as the Dependent Variable | | | |
|--------------------|---------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Asthma | 870.13** | 2.26 | 0.346 | 0.019 |
| Age | | 1.03 | 0.012 | 0.017 |
| Chronic Bronchitis | 869.28** | 3.65 | 0.466 | 0.005 |
| Age | | 1.03 | 0.012 | 0.025 |
| Chronic Bronchitis | 866.79** | 3.80 | 0.466 | 0.004 |
| Age | | 1.03 | 0.012 | 0.024 |
| Ex-Smoker | | 0.85 | 0.303 | 0.602 |
| Current Smoker | | 0.64 | 0.294 | 0.132 |
| Bronchitis | 855.74** | 2.94 | 0.245 | 0.001 |
| Age | | 1.03 | 0.118 | 0.028 |
| Bronchitis | 853.83** | 2.92 | 0.245 | 0.001 |
| Age | | 1.03 | 0.012 | 0.028 |
| Ex-Smoker | | 0.89 | 0.301 | 0.695 |
| Current Smoker | | 0.68 | 0.293 | 0.188 |
| Wheeze | 873.07** | 1.74 | 0.400 | 0.165 |
| Age | | 1.02 | 0.012 | 0.037 |
| Wheeze | 869.99* | 2.05 | 0.413 | 0.082 |
| Age | | 1.03 | 0.012 | 0.038 |
| Ex-Smoker | | 0.84 | 0.304 | 0.556 |
| Current Smoker | | 0.60 | 0.301 | 0.092 |
| Wheeze | 825.418** | 2.20 | 0.408 | 0.054 |
| Age | | 1.03 | 0.013 | 0.023 |
| Gender-female | | 1.75 | 0.361 | 0.114 |
| Packyears | | 0.99 | 0.007 | 0.145 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 12 : Multivariate Cox Proportional Hazards Models with Asthma as the Dependent Variable.

| Variable | Multivariate Cox Proportional Hazards Models with Asthma as the Dependent Variable | | | |
|--------------------|------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Sinus | 696.26* | 2.40 | 0.354 | 0.013 |
| Age | | 0.97 | 0.016 | 0.090 |
| Sinus | 720.04** | 2.14 | 0.352 | 0.030 |
| Age | | 0.98 | 0.014 | 0.081 |
| Ex-Smoker | | 0.48 | 0.387 | 0.059 |
| Current Smoker | | 0.54 | 0.310 | 0.048 |
| Chronic Bronchitis | 730.35* | 1.56 | 0.720 | 0.538 |
| Age | | 0.97 | 0.013 | 0.041 |
| Chronic Bronchitis | 723.63** | 1.62 | 0.721 | 0.504 |
| Age | | 0.98 | 0.014 | 0.118 |
| Ex-Smoker | | 0.47 | 0.386 | 0.052 |
| Current Smoker | | 0.52 | 0.309 | 0.033 |
| Bronchitis | 718.83** | 2.55 | 0.267 | 0.001 |
| Age | | 0.97 | 0.014 | 0.035 |
| Bronchitis | 712.39** | 2.53 | 0.268 | 0.001 |
| Age | | 0.97 | 0.014 | 0.090 |
| Ex-Smoker | | 0.48 | 0.384 | 0.053 |
| Current Smoker | | 0.53 | 0.309 | 0.038 |
| Wheeze | 724.69** | 2.91 | 0.385 | 0.006 |
| Age | | 0.97 | 0.014 | 0.025 |
| Wheeze | 715.13** | 4.07 | 0.415 | 0.001 |
| Age | | 0.97 | 0.014 | 0.065 |
| Ex-Smoker | | 0.45 | 0.387 | 0.039 |
| Current Smoker | | 0.41 | 0.330 | 0.006 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 13 : Multivariate Cox Proportional Hazards Models with Chronic Bronchitis as the Dependent Variable.

| Variable | Multivariate Cox Proportional Hazards Models with Chronic Bronchitis as the Dependent Variable | | | |
|----------------|------------------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Sinus | 203.48** | 4.62 | 0.545 | 0.005 |
| Age | | 0.98 | 0.025 | 0.433 |
| Sinus | 202.15* | 4.85 | 0.547 | 0.004 |
| Age | | 0.98 | 0.026 | 0.455 |
| Ex-Smoker | | 0.98 | 0.749 | 0.981 |
| Current Smoker | | 1.77 | 0.575 | 0.323 |
| Asthma | 209.37 | 1.61 | 0.759 | 0.531 |
| Age | | 0.99 | 0.025 | 0.635 |
| Asthma | 208.28 | 1.70 | 0.764 | 0.486 |
| Age | | 0.99 | 0.026 | 0.648 |
| Ex-Smoker | | 0.96 | 0.747 | 0.961 |
| Current Smoker | | 1.65 | 0.577 | 0.386 |
| Bronchitis | 178.69** | 37.99 | 1.033 | 0.001 |
| Age | | 0.98 | 0.027 | 0.559 |
| Bronchitis | 177.63** | 38.09 | 1.032 | 0.001 |
| Age | | 0.98 | 0.027 | 0.569 |
| Ex-Smoker | | 0.95 | 0.735 | 0.947 |
| Current Smoker | | 1.64 | 0.571 | 0.385 |
| Wheeze | 208.68 | 2.37 | 0.760 | 0.257 |
| Age | | 0.99 | 0.025 | 0.550 |
| Wheeze | 208.01 | 2.02 | 0.784 | 0.368 |
| Age | | 0.99 | 0.026 | 0.589 |
| Ex-Smoker | | 0.91 | 0.744 | 0.900 |
| Current Smoker | | 1.44 | 0.588 | 0.533 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

Table 14 : Multivariate Cox Proportional Hazards Models with Bronchitis as the Dependent Variable.

| Variable | Multivariate Cox Proportional Hazards Models with Bronchitis as the Dependent Variable | | | |
|--------------------|----------------------------------------------------------------------------------------|------------|----------------|---------|
| | -2 Log Likelihood | Risk Ratio | Standard Error | p-value |
| Sinus | 2624.42** | 2.10 | 0.185 | 0.001 |
| Age | | 0.998 | 0.007 | 0.795 |
| Sinus | 2623.84** | 2.09 | 0.186 | 0.001 |
| Age | | 0.998 | 0.007 | 0.830 |
| Ex-Smoker | | 0.96 | 0.187 | 0.816 |
| Current Smoker | | 0.99 | 0.164 | 0.945 |
| Asthma | 2629.68** | 1.90 | 0.205 | 0.002 |
| Age | | 1.002 | 0.006 | 0.725 |
| Asthma | 2629.15* | 1.89 | 0.207 | 0.002 |
| Age | | 1.002 | 0.007 | 0.733 |
| Ex-Smoker | | 0.99 | 0.187 | 0.957 |
| Current Smoker | | 0.997 | 0.165 | 0.986 |
| Chronic Bronchitis | 2622.58** | 3.49 | 0.269 | 0.001 |
| Age | | 1.001 | 0.007 | 0.848 |
| Chronic Bronchitis | 2621.82** | 3.51 | 0.269 | 0.001 |
| Age | | 1.002 | 0.007 | 0.816 |
| Ex-Smoker | | 0.944 | 0.186 | 0.757 |
| Current Smoker | | 0.927 | 0.164 | 0.645 |
| Wheeze | 2636.06 | 1.47 | 0.254 | 0.133 |
| Age | | 1.00 | 0.007 | 0.999 |
| Wheeze | 2635.15 | 1.51 | 0.261 | 0.116 |
| Age | | 1.00 | 0.007 | 0.966 |
| Ex-Smoker | | 0.93 | 0.186 | 0.714 |
| Current Smoker | | 0.91 | 0.167 | 0.561 |

**Model chi square p-value ≤ 0.05

*Model chi square p-value ≤ 0.15

F. LITERATURE SITED

Korn EL, Whittemore AS. Methods for analyzing panel studies of acute health effects of air pollution. *Biometrics* 1979; 35: 795-802.

Wegman DH, Eisen EA, Smith RG. Final Report: Acute and Chronic Respiratory Effects of Sodium Borate Particulate Exposures; 1991.

Becklake MR, Bourbeau J, Menzies R, Ernst P. The relationship between acute and chronic airway responses to occupational exposures. *Curr Pulmonol* 1986; 9:25-66.