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Asthma and chemical hypersensitivity: prevalence, etiology, and age of onset

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This study investigates asthma's national prevalence and potential overlap with chemical hypersensitivity. It also examines asthma's etiology, age of onset, and demographic characteristics. Data were collected from a geographically weighted random sample of the continental U.S. (1058 cases), in four seasonal cohorts (2005–2006). The study found that 12.9% of the sample report asthma, 11.6% report chemical hypersensitivity, and 31.4% of those with asthma report chemical hypersensitivity. Among asthmatics, 38% report irritation from scented products, 37.2% report health problems from air fresheners, and 13.6% report their asthma was caused by toxic exposure. Asthma cases affected each racial/ethic group in roughly the same proportion, with nearly 50% classified as childhood onset. *Toxicology and Industrial Health* 2009; **25**: 71–78.

Key words: *asthma; chemical hypersensitivity; exposure; MCS; prevalence*

Introduction

An expanding body of evidence indicates that asthma is increasing in the United States and other industrialized nations (Centers for Disease Control and Prevention, 2004). To understand this growth of reported asthma cases, researchers are examining various aspects of asthma's etiology and dynamics. A major focus of this research has been on asthma's potential association with other conditions and with exposure to chemicals.

Complicating this research is that asthma has different ages of onset, frequently classified into childhood onset and adult onset categories. Additional sub-classification distinguishes some adult onset cases as occupational asthma, a result of a workplace exposure to toxic substances. Efforts to analyze the origins of asthma have motivated researchers to investigate its connection with other related conditions. Recent studies have explored the possible association of certain types of asthma with chemical hypersensitivity (Ross, 1997; Meggs, 1995; Overstreet and Djuric, 1999), suggesting that the presence of chemical hypersensitivity in some asthma cases can help elucidate asthma's origin.

Chemical hypersensitivity may be medically diagnosed as multiple chemical sensitivities (MCS), and is also known as toxicant induced loss of tolerance or environmental illness (Miller, *et al.*, 1997). Chemical hypersensitivity is usually considered a condition distinct from asthma. Individuals with MCS react adversely to common chemical substances at levels that are normally considered tolerable. MCS sufferers have difficulty being exposed to common products such as household cleaners, fresh paint, perfume, synthetic

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building materials, new carpets, pesticides, and other petrochemical-based products (Ashford and Miller, 1998). MCS is chronic, and the primary way that sufferers can prevent reactions is to avoid offensive chemicals. Although asthma's symptoms usually include wheezing and breathing difficulties, MCS is characterized by a range of multi-system symptoms such as dizziness, eye burning, headache, numbness, gastritis, fevers, edema, and seizures. MCS reactions range from mild to disabling and can result from exposures to even low levels of irritating substances (Rea, *et al.*, 1978).

MCS is characterized by a two-step process. The first step is initiation. Initiation is when the disorder first develops and can result from a single high-level exposure to a particular toxic agent or after chronic exposure to one or more toxic substances, often at low levels. The second step is triggering, which occurs after MCS has developed. Triggering is characterized by adverse physical reactions that result from exposure to any one of a wide range of offensive substances, even at levels considerably lower than previously tolerated.

Research on a potential linkage between asthma and MCS indicates that they can co-occur with certain types of asthma. Some adult-onset asthma may be the result of exposures to toxic materials in the workplace (deBono and Hudsmith, 1999), and some childhood onset asthma may also be promoted by exposures to toxins (Gustafsson and Andersson, 2004). Occupational asthma originates from workplace exposures to toxic substances (Brooks, 1995), and work-aggravated asthma is preexisting asthma that is aggravated by irritants at work (Chan-Yeung and Malo, 1995). Reactive airways dysfunction syndrome (RADS), also termed irritant-induced asthma (Alberts and Brooks, 1996), is characterized by bronchial malfunction and originates after a massive single exposure to a toxic substance (Chan-Yeung, 1995). RADS is a persistent airways hyperresponsiveness and, once sensitized, afflicted individuals react adversely to much lower levels of the irritating substance.

Evidence from case studies suggests that RADS sufferers can exhibit chemical hypersensitivity (Meggs, 1995). Individuals with RADS experience adverse reactions not only to low levels of the substances that originally caused their condition but also to a wide range of other toxic chemical substances at levels that are typically considered to be tolerable. Although the mechanisms of this combination of symptoms, not typically associated with asthma, are not thoroughly understood, the simultaneous occurrence of bronchial hyperresponsiveness with chemical hypersensitivity has led some researchers to conclude that RADS and MCS have overlapping characteristics.

The apparent association between MCS and RADS provided the impetus for a study using animal models, which found that some forms of asthma and MCS have some common etiologies and characteristics (Overstreet and Djuric, 1999). An additional case study, which focused primarily on symptomatology, indicated that some forms of asthma and MCS have similar overlapping dynamics (Meggs, 1995).

Asthma's and MCS' etiology

Research on asthma's etiology indicates different potential methods of initiation. Occupational asthma is typically the result of an exposure to a toxic substance in a work environment, but the circumstances surrounding the exposure event can differ (Chan-Yeung and Malo, 1995). RADS is considered to be non-immunologic, while some other forms of asthma have immunologic mechanisms, even though there has been speculation that the dynamics of the origins may have similarities (Brooks, *et al.*, 1985). Additional research has examined the effects of exposure to toxic agents, exposure times, and exposure levels on asthma (Piirilae, *et al.*, 1996).

While research also shows that MCS results from exposure to toxic substances, its connection to other disorders has received considerable attention even though no definitive relationship has been shown. Studies on MCS initiation have been based on one or more of the following systems: neurological, immunological, endocrine, and psychological (Mitchell, 1995). It has been suggested that neurological disorders are connected to MCS (Fiedler, *et al.*, 1992), while other studies indicate that MCS is associated with immunological dysfunctions (Levin and Byer, 1987). Some researchers contend that MCS does not follow the same pattern as immunological disorders, which has led others to

Table 1. Frequencies: entire sample ($n = 1058$)

	Yes, %	No, %	Don't know	Decline/missing
Have asthma	12.9 ($n = 137$)	86.3 ($n = 913$)	0.2 ($n = 2$)	0.6 ($n = 6$)
Have chemical hypersensitivity	11.6 ($n = 123$)	85.7 ($n = 907$)	1.8 ($n = 19$)	0.9 ($n = 9$)
Diagnosed with MCS	3.9 ($n = 41$)	95 ($n = 1005$)	0.4 ($n = 4$)	0.7 ($n = 8$)
Have allergies to natural substances	38.1 ($n = 403$)	59.7 ($n = 632$)	1.8 ($n = 19$)	0.4 ($n = 4$)
Find scented products irritating	29.9 ($n = 316$)	59 ($n = 624$)	10.7 ($n = 113$)	0.5 ($n = 5$)
Air fresheners cause breathing problems	20.5 ($n = 217$)	76.7 ($n = 812$)	2.4 ($n = 25$)	0.4 ($n = 4$)

examine the connection between MCS and immune dysfunction linked to the neuroendocrine system (Meggs, 1992). It also has been suggested that inflammation of the respiratory tract (Meggs, 1995) and disorders such as porphyria are potential causation factors (Ellefson and Ford, 1996). Additional studies have explored the role of the limbic system in chemical hypersensitivity (Bell, *et al.*, 1995). Some studies focus on the role of psychological factors. These psychologically based studies speculate that hypersensitivity to low levels of chemicals may be a somatization disorder (Gots, 1995) or a conditioned response (Siegel and Kreutzer, 1997). Psychogenic studies, however, have been criticized for methodological weaknesses, such as biased patient selection and the lack of pre-symptom data (Davidoff and Fogarty, 1994). Ultimately, the preponderance of research indicates that MCS is a multi-system, multi-symptom condition that is initiated by some form of exposure to toxic substances.

Antecedent population studies

An earlier population study, which examined the potential association of asthma with chemical hypersensitivity, found considerable overlap (Caress and Steinemann, 2005). This previous study, which used a random sample of 1054 geographically weighted cases from the continental United States collected in 2003–2004, found that 14.1% of the respondents reported being diagnosed with asthma and 11.2% reported a hypersensitivity to chemicals. Of those with asthma, 27.2% reported also being hypersensitive to chemicals and 7.4% reported also being diagnosed with MCS. Of those diagnosed with MCS, 42% reported also being diagnosed with asthma.

This earlier population study also inquired about the effects of air fresheners and scented products on individuals with asthma. It found that 29.7% of those with asthma said air fresheners caused breathing difficulties, headaches, or other health problems and that 37.2% of asthmatics said scented products were irritating. Because reactions to both these types of products are typical symptoms of MCS, these results provided additional evidence of a possible association between asthma and MCS. These results also support the findings of other research that indicated that air fresheners could create difficulties for sensitive individuals (Liu, *et al.*, 2004).

Although there have been earlier efforts to determine the national prevalence of asthma (Centers for Disease Control and Prevention, 2004), there has been little systematic epidemiological research that investigates the percentage of asthma cases that are a result of toxic exposures. There is also a paucity of etiological research that accumulates data on potential initiating events of asthma. Additionally, there has been only preliminary research into the demographic characteristics of individuals with asthma, and while there has been speculation that certain population groups are more likely to develop asthma (McLean, *et al.*, 2004), this connection has not been definitively substantiated.

Table 2. Frequencies: asthma with other symptoms

	Yes, %	No, %	Don't know, %	Decline/missing, %
Asked only respondents with asthma				
Have allergies to natural substances	73 ($n = 100$)	26.3 ($n = 36$)	0.7 ($n = 1$)	0 ($n = 0$)
Find scented products irritating	38 ($n = 52$)	51.1 ($n = 70$)	10.9 ($n = 15$)	0 ($n = 0$)
Air fresheners cause breathing problems	37.2 ($n = 51$)	58.4 ($n = 80$)	4.4 ($n = 6$)	0 ($n = 0$)

Table 3. Asthma etiology

Asked only of respondents with asthma				
	<11 years	11–20 years	>20	Don't know/refuse
Age asthma onset	48.9% (n = 66)	15.6% (n = 21)	32.6% (n = 44)	2.9% (n = 4)
	Yes	No	Don't know	Decline/missing
Know cause of asthma	36.1% (n = 48)	55.6% (n = 74)	7.5% (n = 10)	0.8% (n = 1)
Only asked respondents who knew or suspected cause of asthma (n = 59)				
	Yes	No	Don't know/decline	
Asthma from toxic exposure	13.6% (n = 8)	72.9% (n = 43)	13.6% (n = 8)	

Further, because prior studies and anecdotal evidence suggest that specific types of asthma produce symptoms that include chemical hypersensitivity in addition to bronchial hyperresponsiveness, this potential association needs further investigation. These antecedent studies also suggest that occupational asthma and MCS may have potential etiological commonalities. The initiating and triggering process of MCS results from exposures to toxic agents and has apparent similarities to occupational and work-aggravated asthma. There have been, however, no comprehensive population studies of these symptomatic and etiological overlaps.

The increased concern about the growing occurrence of asthma has also provided the impetus for researchers to examine asthma's potentially disproportionate impact on certain racial/ethnic and gender groups (Centers for Disease Control and Prevention, 2004). Although cases studies have been conducted, there has been no comprehensive population study that has explored the etiology and degree that asthma affects different ethnic/racial and gender groups.

Methods

This population study uses a random national sample of the continental United States. The sample size is 1058 cases, which were gathered in four seasonal cohorts (summer 2005, fall 2005, winter 2006, and spring 2006). This sample size produces a confidence interval of ±3.0% and a confidence level of 95%. The research implement used in this study was a 34-item questionnaire administered by phone. The sample population was constructed with random digitally dialed numbers, which were geographically weighted to insure a valid national sampling.

The questionnaire investigated the prevalence of both asthma and chemical hypersensitivity and their potential co-occurrence. It probed etiological and phenotype factors by collecting information on age of onset and potential initiating and triggering sources. It made inquiries to categorize reported asthma cases into age-of-onset groupings and to determine if either childhood or adult asthma were more likely to be associated with chemical hypersensitivity. The questionnaire also asked about allergies to natural substances and the medical diagnosis of MCS. Demographic data were collected on age, race/ethnicity, and educational level of the respondents. The demographic characteristics of those with asthma were contrasted with those of the entire sample to determine whether there is a propensity for specific types of asthma linked with chemical hypersensitivity to affect certain population groups.

This study seeks to provide new data and fill the research gaps described earlier by using a national sample representative of the American population. This sample will be used to achieve the following four research objectives:

Table 4. Frequencies: chemical hypersensitivity

Asked only respondents with chemical hypersensitivity					
	Yes	No	Don't know	Decline/missing	
Also diagnosed with asthma	34.9% (n = 43)	65% (n = 80)	0% (n = 0)	0% (n = 0)	
Also allergic to natural substances	63.5% (n = 78)	34.1% (n = 42)	2.4% (n = 3)	0% (n = 0)	
At what age did you get your sensitivities to common chemicals? (n = 116) (7 missing)					
	<20 years	20–35 years	36–50 years	>50	Don't know/decline
Age of onset	28.5% (n = 33)	30.2% (n = 35)	28.5% (n = 33)	9.5% (n = 11)	3.5% (n = 4)

Table 5. Cross tabulations

Asthma with chemical sensitivity					
		Have asthma			
	Yes	No	Don't know	Decline/missing	
Also chemically hypersensitive	31.4% (n = 43)	64.9% (n = 89)	2.9% (n = 4)	0.7% (n = 1)	
Also diagnosed with MCS	11.7% (n = 16)	87.6% (n = 120)	0.7% (n = 1)	0% (n = 0)	
Age of asthma onset with chemical hypersensitivity					
		Have chemical hypersensitivity			
	Yes	No	Don't know	Decline/missing	Total
Asthma onset					
<11 years	25.8% (n = 17)	71.2% (n = 47)	1.5% (n = 1)	1.5% (n = 1)	100% (n = 66)
11–20 years	52.4% (n = 11)	47.6% (n = 10)	0% (n = 0)	0% (n = 0)	100% (n = 21)
>20 years	29.6% (n = 13)	63.6% (n = 28)	6.8% (n = 3)	0% (n = 0)	100% (n = 44)
Age of asthma onset with age of onset of chemical hypersensitivity					
		Age of chemical hypersensitivity onset			
	<20	>20			
Asthma onset					
<20	86.6% (n = 13)	55.6% (n = 15)			
>20	6.7% (n = 1)	44.4% (n = 12)			
Don't know/refuse	6.7% (n = 1)	0% (n = 0)			
Total	100% (n = 15)	100% (n = 27)			

- The first objective is to determine the prevalence of both asthma and chemical hypersensitivity in the general population and examine their co-occurrence. Additionally, this study will measure the extent that respondents with asthma report breathing difficulties from air fresheners and deodorizers and irritation from scented products such as perfume and aftershave lotion.
- The second objective is to investigate asthma's etiology. Initially, the percentage of respondents with asthma who can identify its origin will be recorded. A further analysis will determine what percentage of asthma cases can be linked to exposure to toxic substances.
- The third objective is to determine the age of onset of asthma and to elucidate asthma's etiology by delineating the circumstances when it initially develops and when it reoccurs (triggers). The age of onset of chemical hypersensitivity in individuals who report both asthma and chemical hypersensitivity will also be explored and compared.
- The fourth objective is to examine whether asthma and chemical hypersensitivity afflict certain population groups more than others and whether specific types of asthma are more commonly found in particular groups. This involves the analysis of demographic data from the entire sample and contrasting it with the demographic characteristics of individuals who report asthma, chemical hypersensitivity, and a combination of both conditions.

Results

The study found that 12.9% (n = 137) of the sample reported being diagnosed with asthma, and 31.4% (n = 43) of this group also reported chemical hypersensitivity. This was higher than the 11.6% (n = 123) of the entire sample that reported chemical hypersensitivity. Of those with chemical hypersensitivity, 34.9% (n = 43) also had been diagnosed with asthma. Also, while 11.7% (n = 16) of those

Table 6. Demographics of entire sample (n = 1058)

Gender					
Male	Female	Missing			
35.4% (n = 374)	63.3% (n = 670)	1.3% (n = 14)			
Education level					
<HS	HS Grad	Some Coll.	Coll. Grad>	Decline	Missing
12.5% (n = 132)	24% (n = 254)	29.5% (n = 312)	32% (n = 339)	1.2% (n = 13)	0.8% (n = 8)
Race/ethnicity					
Asian	Hispanic	Black	White	Other/decline	
3.6% (n = 38)	7.5% (n = 79)	14.2% (n = 150)	69.5% (n = 735)	5.3% (n = 56)	

Table 7. Demographics of respondents with asthma ($n = 137$)

Gender					
Male	Female				
30.7% ($n = 42$)	69.3% ($n = 95$)				
Education level					
<HS	HS Grad	Some Coll.	Coll. Grad>	Decline	Missing
18.9% ($n = 26$)	18.3% ($n = 25$)	29.2% ($n = 40$)	31.4% ($n = 43$)	1.5% ($n = 2$)	0.7% ($n = 1$)
Race/ethnicity					
Asian	Hispanic	Black	White	Other/decline	
1.5% ($n = 2$)	11.7% ($n = 16$)	19.7% ($n = 27$)	65.7% ($n = 90$)	1.5% ($n = 2$)	

with asthma also report being diagnosed with MCS, 3.9% ($n = 41$) of the entire sample was diagnosed with MCS.

While 29.9% ($n = 316$) of the entire sample ($n = 1058$) found scented products irritating and 20.5% ($n = 217$) get headaches or breathing difficulties from air fresheners and deodorizers, this is more common for asthmatics ($n = 137$), with 38% ($n = 52$) being irritated by scented products and 37.2% ($n = 51$) having problems from air fresheners. Asthmatics are also far more likely to have allergies to natural substances (dust, mold, grass, pollen, or animal dander) with 73% ($n = 100$) reporting it compared to the 38.1% ($n = 403$) of the entire sample. Allergies to natural substances were also more common among respondents with chemical hypersensitivity (63.5%) ($n = 78$) than with the entire sample.

When those with asthma were asked if they knew or strongly suspected the cause of their asthma, 36.1% ($n = 48$) said "yes," 55.6% ($n = 74$) said "no," and 7.5% ($n = 10$) said "not sure," with 0.8% ($n = 1$) declining to answer. Additional inquiries were made of the respondents who said either that they knew or strongly suspected the cause of their asthma ($n = 48$) or who said that they had a suspicion but were not sure of the cause ($n = 10$). When asked if their asthma was the result of an exposure to a toxic substance, 13.6% ($n = 8$) said "yes," 72.9% ($n = 43$) said "no," and 13.6% ($n = 8$) said they were not sure if it was from a toxic exposure or not. Those who said their asthma was not a result of a toxic exposure listed a wide variety of causes ranging from accidents, to heredity, to a byproduct of surgery.

The age of original onset of those with asthma was classified as the following categories: 48.9% ($n = 66$) acquired asthma under age 11, 15.6% ($n = 21$) between the ages 11–20, and 32.6% ($n = 44$) after age 20, with 2.9% ($n = 4$) of not sure. This indicates that nearly 50% of the asthma cases can be classified as childhood asthma. Of the cases of asthma that developed under age 11, 25.8% ($n = 17$) reported chemical hypersensitivity, 52.4% of the adolescent onset group (age 11–20 years) ($n = 11$) reported it, as did 29.6% of the over age 20 group ($n = 13$).

The age of onset of asthma was compared with the age of onset of chemical hypersensitivity in respondents who had both conditions. Of the respondents who reported that their chemical hypersensitivity began under age 20, 86.6% said that their asthma also began under age 20. However, 55.6% of those who said that their hypersensitivity began after age 20 also reported that their asthma first developed before age 20.

The racial/ethnic characteristics of those in the sample with asthma were Asian 1.5% ($n = 2$), Hispanic 11.7% ($n = 16$), Black 19.7% ($n = 27$), White 65.7% ($n = 90$), and other/decline 1.5% ($n = 2$). This is in contrast to the racial/ethnic characteristics for the entire sample: Asian 3.6% ($n = 38$), Hispanics 7.5% ($n = 79$), Black 14.2% ($n = 150$), White 69.5% ($n = 735$), and other/decline 5.3% ($n = 56$).

The gender of those with asthma was male 30.7% ($n = 42$) and female 69.3% ($n = 95$), compared with male 35.4% ($n = 374$), female 63.3% ($n = 670$), with missing 1.3% ($n = 14$) for the entire sample.

Discussion

The prevalence of asthma (12.9%) and of chemical hypersensitivity (11.6%) is congruent with findings of previous studies (e.g., Caress and Steinemann, 2005). The percentage of asthmatics that report chemical hypersensitivity (31.4%) also suggests a potential overlap between the two conditions.

Age-of-onset data indicate that nearly half (48.9%) of all asthma cases can be classified as

childhood onset (before age 11), with nearly one-third (32.6%) as adult onset (after age 20) and 15.6% as adolescent onset (between age 11 and 20). Adolescent onset could also be interpreted as childhood asthma, thus expanding the childhood onset asthma group to nearly two-thirds of all asthma cases.

Chemical hypersensitivity with asthma is found in similar proportions in both the childhood (under age 11) onset group (25.8%) and adult (over age 20) onset group (29.6%), with more than 50% in the adolescent (age 11–20) onset group (52.4%).

Respondents with asthma were far more likely to report adverse effects from scented products and air fresheners than other respondents in the sample. Asthmatics exhibit symptoms of MCS, and in greater proportions than the general population, are also consistent with earlier studies (Meggs, 1995).

Demographic data indicate that asthma affects a broad cross section of the American population and apparently does not disproportionately affect any racial or ethnic group in this sample. While a higher proportion of females report asthma, and also report chemical hypersensitivity, these results reflect the gender bias in the sample.

Notably, 13.6% of asthmatics report that their asthma resulted from an exposure to a toxic substance. Definitive conclusions about asthma's etiology and classification, however, are limited by the large percentage of asthmatics that could not identify the cause of their condition. Because chronic exposure to toxic substances is difficult to document and can escape attention of respondents, asthma cases that resulted from chemical exposures may have been obscured. This study provides evidence supporting an association between asthma and chemical hypersensitivity and emphasizes the need for additional research on the links between asthma and chemical exposures.

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