Pollen and mold exposure impairs the work performance of employees with allergic rhinitis

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Background: Although quality of life studies suggest that allergic rhinitis has a substantial impact on work impairment, national survey estimates of the magnitude of this impairment have varied widely. Retrospective recall bias is likely to be a major cause of this variability.

Objective: This study used a nationally representative daily diary sample to obtain prospective data that improve on previous estimates of the work impairment because of allergic rhinitis.

Methods: The MacArthur Foundation National Survey of Daily Experience is a daily diary survey that included a nationally representative subsample of 739 employed people, each of whom provided daily reports on work performance for 1 randomly assigned week of the calendar year. National Allergy Bureau monitoring station data were merged with the survey data to study the association of time-space variation in pollen/mold exposure with impaired daily work quality and quantity.

Results: National Allergy Bureau pollen/mold counts are significantly related to work impairments only among respondents with self-reported allergic rhinitis. The average estimated monthly salary-equivalent work impairment costs associated with pollen/mold exposure for each allergy sufferer is between $109 and $156, with an annualized national projection of between $5.4 billion and $7.7 billion.

Conclusions: The extent to which these costs can be recovered by increasing the proportion of allergy sufferers who are successfully treated remains unknown and can only be evaluated definitively in effectiveness trials.

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INTRODUCTION

Allergic rhinitis is one of the most common of all chronic conditions.[1–4] Quality of life studies suggest that work impairment plays an important part in the overall impact of allergic rhinitis.[5–8] This is true both because the illness itself is impairing and because many people with allergic rhinitis treat themselves with over-the-counter sedating antihistamines that have been linked to impairments in laboratory cognitive and motor performance tasks[9–11] and to occupational injuries.[12]

It is not known whether increasing the proportion of workers with allergic rhinitis who obtain appropriate treatment would increase work productivity enough to outweigh the increased cost of treatment. A first step in evaluating this possibility is to quantify the magnitude of the work impairment caused by allergic rhinitis. Although several cost of illness studies have attempted to do this,[3,4,13] their results are quite variable. For example, despite agreement that the number of employed people in the United States suffering from allergic rhinitis is in the range of 12.6 to 12.8 million, estimates of the annual number of work loss days because of allergic rhinitis vary by a factor of four in these studies, from a high of 3.4 million days per year[4] based on the 1988 National Health Interview Survey[14] to a low of 800,000 days per year[3] based on the 1987 National Medical Expenditures Survey.[15] Estimates of restricted activity days attributable to allergic rhinitis are also highly variable across studies.

This wide variation in estimates is, at least in part, attributable to the fact that respondents were asked for retrospective reports about number of work days lost because of allergic rhinitis over recall periods that vary across surveys. Retrospective reports of this sort are notoriously unreliable,[16–18] both because of recall failure (forgetting and telescoping) and because of attribution bias (confusion about whether allergic rhinitis is the cause of the work impairment).

The purpose of the current report is to present nationally representative data on the workplace costs of allergic rhinitis that avoid these measurement problems. This is done by working with a unique database, the MacArthur Foundation's National Survey of Daily Experience (NSDE).[19] The NSDE is a nationally representative daily diary survey carried out in 1996 and 1997 that evaluated the prevalences of sickness absence days and restricted activity days contemporaneously, thus avoiding the problem of retrospective

recall bias. As the NSDE was carried out in random subsamples over a full calendar year, it was possible to link individual-level work impairment data with archival data on time-space variation in pollen and mold counts from National Allergy Bureau (NAB) monitoring sites throughout the country. This made it possible to study the association between pollen exposure and daily work impairments separately among respondents with and without allergic rhinitis independent of respondent perceptions about the reasons for their work impairment, thus avoiding the problem of attribution bias.

MATERIALS AND METHODS

Sample

The NSDE is a substudy of the MacArthur Foundation Midlife Development in the U.S. Survey (MIDUS), a nationally representative general population survey of 3,032 persons aged 25 to 74 years residing in households with telephones in the 48 coterminous United States.[20,21] MIDUS data collection was carried out between January 1996 and January 1997. All respondents provided verbal informed consent over the telephone and then completed a 30-minute telephone interview (70.0% response rate) and two mail questionnaires estimated to take a total of approximately 90 minutes to complete (86.8% conditional response rate in the subsample of telephone respondents), for an overall response rate of 60.8% (0.700 × 0.868). The data were weighted using nested propensity score adjustments[22] to correct for differential probabilities of selection and nonresponse. More details on the MIDUS design, field procedures, and sampling weights are available elsewhere.[23]

The NSDE substudy was carried out between March 1996 and May 1997 in a representative subsample of 1,031 MIDUS respondents (83.0% response rate from a predesignated subsample of 1,242). All respondents provided verbal informal consent over the telephone before the initiation of data collection. Data collection consisted of daily self-administered diaries filled

out in the course of 8 consecutive days that documented episodes of stress and impairments in role functioning. Telephone debriefing interviews were administered each night during the diary period to inquire about daily stresses, role impairments, and moods during the preceding 24 hours.

NSDE respondents were randomized to start their 8-day diary period in one of 40 "flights" distributed throughout the data collection period. The day of the week on which data collection started was randomized to avoid an association between day of the week and time in the study. The data were then weighted to adjust for the fact that the number of interviews varied by month of the year. This two-part randomization and weighting made the NSDE sample representative of all seasons of the year in all parts of the country. On average, 7 of the 8 nightly interviews were completed, for a total of 7,229 person-days in the sample. A propensity score weight[22] was used to adjust for differences between the distribution of the NSDE sample and the full MIDUS sample on a range of sociodemographic variables evaluated in MIDUS as well as for variation in sample size by season of the year. More details on the NSDE design and field procedures are available elsewhere.[19] The results reported here are based on the 739 employed NSDE respondents (5,104 person-days), 114 of whom reported having allergic rhinitis.

Measures

Allergic rhinitis and other chronic conditions. On the MIDUS chronic conditions checklist, respondents were asked whether they suffered from each of 22 different chronic conditions such as asthma, cancer, diabetes, and hypertension.[23] The category "hay fever or other seasonal allergies" was among these conditions. As described in more detail below, responses were used to subdivide respondents into those with and without allergic rhinitis and to control for the effects of other comorbid conditions on work impairment.

Time-space variation in pollen and mold exposure. The Aerobiology

Committee of the NAB publishes weekly pollen and mold counts for each of 86 NAB monitoring sites throughout the United States. Each of four broad categories of pollen and mold (trees, grasses, weeds, and molds) are classified as being either very high, high, moderate, low, or absent. The NAB data were merged with the NSDE data by selecting the geographically closest NAB monitoring site to each NSDE respondent and assigning NAB scores for the reporting week that contained the start date of the 8-day NSDE data collection. Because of sparse data, very high and high pollen/mold counts were collapsed into a single category described below as "high." In the case of weed pollen, very high, high, and moderate were all collapsed into a single "high-moderate" category because of sparse data. Low and absent were collapsed for each of the four pollen/mold counts into a single "low" category. Missing NAB data, which occurred in the winter, when some stations stop counting, were coded "low."

Daily work impairment. Separate measures of daily work quality and quantity were derived from the nightly NSDE interviews. The *quality* measure was based on responses to a yes/no question about whether respondents cut back on the quality of their work or how carefully they worked because of ill health. Impaired work quality was reported on 5.0% of diary days. The *quantity* measure was based on responses to three questions. The first question was about sickness absence (ie, missing the entire day of work because of ill health) on the day of interview. The second question asked those who did not report sickness absence if they cut back on the amount of work they completed on the day of interview because of ill health. The third asked those who reported cutback to characterize the amount on a 0-to-10 scale in which 0 = not working at all and 10 = working a full, productive work day. The final quantity score was coded 0 for respondents who reported sickness absence, 10 for respondents who reported no cutback, and in the

range 0 to 9 for respondents who reported cutback. As responses were highly skewed, the scale was dichotomized to define scores in the 0 to 5 range as impaired and the rest as not impaired. Using this definition, 3.6% of diary days were classified as impaired.

Analysis procedures. The data were analyzed with random effects logistic regression analysis[24] using the GLIM-MIX procedure in the SAS software package.[25] This procedure evaluates both within-person and between-person covariances and corrects significance tests for non-independence among repeated measures.[24,26] The logits were exponentiated and are reported below in the form of odds ratios (ORs). The initial models investigated the effects of control variables on daily work impairments. Both within-person controls (day of the week, number of days in the study, and month) and between-person controls (demographics, chronic conditions) were included in these models. Subsequent models then estimated the incremental effects of time-space variation in pollen/mold exposure in subsamples of workers with and without allergic rhinitis. Statistical significance was evaluated with 0.05 level two-sided tests. Finally, individual-level wage rate data were combined with the results of the regression analyses to estimate the average salary-equivalent monthly costs of allergic rhinitis on the work productivity of allergy sufferers at both the individual and aggregate levels.

RESULTS

Sociodemographic Correlates of Allergic Rhinitis

The distributions of key sociodemographic variables are reported in Table 1 separately for respondents with (n = 114) and without (n = 625) self-reported allergic rhinitis. Respondents with allergic rhinitis in the NSDE are less likely than others to be in the age range 35 to 49, more likely to have high education, more likely to live in the west, and less likely to have been interviewed in the winter.

Table 1. Sociodemographic Distribution of the Sample

	With allergic rhinitis		Without allergic rhinitis	
	%	SE	%	SE
Age				
25–34	35.5	4.4	28.1	1.8
35–49	34.7	4.3	46.1	2.0
50+	29.7	4.2	25.8	1.7
	$\chi^2_2 = 23.6^*$			
Sex				
Male	39.5	4.5	44.7	1.7
Female	60.5	4.5	55.2	2.0
	$\chi^2_1 = 1.2$			
Education				
0–11	8.2	2.5	6.1	0.1
12	32.1	4.3	40.5	1.9
13–15	28.5	4.1	28.8	1.8
16+	31.2	4.2	24.6	1.8
	$\chi^2_3 = 33.8^*$			
Region				
Northeast	14.5	3.2	19.3	1.6
Midwest	23.6	3.9	27.2	1.8
South	34.2	4.3	36.5	1.9
West	27.3	4.1	16.3	1.5
	$\chi^2_3 = 69.6^*$			
Season				
Summer	38.5	4.4	35.4	1.9
Fall	16.8	3.4	15.0	1.4
Winter	4.1	1.8	13.4	1.3
Spring	40.5	4.5	36.1	1.9
	$\chi^2_3 = 61.3^*$			
(n)	(114)		(625)	

* Significant difference between distributions in the subsamples with and without allergic rhinitis.

The Age-Sex Distribution of Daily Work Impairment

As shown in Table 2, the reported prevalences of impairment in daily work quality and quantity are significantly higher among female than male respondents. Although there is a generally negative monotonic association between age and impairment, this association is not significant either among males or females for either work quality or work quantity.

Sociodemographic Predictors of Daily Work Impairment

Basic sociodemographic predictors of work impairment were controlled to minimize the possibility of biasing the

Table 2. The Prevalences of Daily Work Impairment in the Total Sample by Age and Sex

	Quality		Quantity	
	%	SE	%	SE
Male				
25–34	5.8	0.1	3.0	0.1
35–49	3.9	0.1	2.1	0.0
50+	3.3	0.1	3.5	0.1
Total	4.3	0.4	2.7	0.3
	$\chi^2_3 = 4.8$		$\chi^2_3 = 2.8$	
Female				
25–34	6.2	0.1	4.9	0.1
35–49	5.8	0.1	4.3	0.1
50+	4.4	0.1	3.3	0.1
Total	5.5	0.4	4.2	0.4
	$\chi^2_3 = 3.1$		$\chi^2_3 = 3.1$	
Total				
25–34	6.0	0.1	4.1	0.1
35–49	4.9	0.0	3.3	0.0
50+	4.0	0.0	3.4	0.0
Total	5.0	0.1	3.6	0.1
(n)	(5104)		(5104)	

estimated association between pollen/mold exposure and work performance. For example, if pollen/mold exposure is lower in the winter than in other seasons and work impairment is higher in the winter than in other seasons, failure to control for season of evaluation would artificially reduce the estimated effects of pollen/mold exposure on work impairment. The ORs for the control variables in predicting daily work impairment are presented in Table 3. Impaired work quality is inversely related to age, higher in the west than other regions of the country, and lower in the fall than other seasons. Impaired work quantity is higher among women than men and higher in the west than other regions of the country. There is a trend for impaired work quantity to be higher on Mondays and Saturdays than other days of the week, but this association is not statistically significant in a global test of day-of-the-week variation.

Effects of Pollen/Mold Exposure on Daily Work Impairment

The effects of NAB published weekly pollen/mold counts are presented in Table 4, separately for respondents with and without allergic rhinitis. All models controlled for the effects of the variables presented in Table 3 as well as for the effects of the other 21 chronic conditions evaluated in MI-DUS. The ORs for the control variables are not reported to simplify presentation of key results. As shown in the first two columns of the table, the ORs associated with high or moderate pollen/mold exposure (in comparison to the contrast category of low exposure) in the allergic rhinitis subsample are generally >1.0 (12 of 14 ORs associated with high or moderate exposure in either the quality or quantity columns) and statistically significant (10 of 14). Most of the associations are monotonic, with the impairment because of high exposure greater than that because of moderate exposure (5 of 6 comparisons); the impairment because of moderate exposure generally greater than that because of low exposure (8 of 8 comparisons). High grass pollen has the largest OR in predicting impaired work quality (9.9, with a 95% confidence interval [CI] of 3.3 to 29.8), whereas high mold has the highest OR in predicting impaired work quantity (18.1 with 95% CI, 4.1 to 72.9). A categorical variable for number of types of pollen/mold with high or moderate exposure also has a significant monotonic relationship with both quality and quantity of work in the allergic rhinitis subsample.

The situation is dramatically different in the subsample of respondents without self-reported allergic rhinitis. There is no consistent sign pattern in this subsample, with 50% of the ORs in Table 4 >1.0 and 50% <1.0. Although three of the ORs are significant at the 0.05 level, not one is part of a monotonic pattern. Further, all three of the significant ORs show pollen exposure to be associated with comparatively low, rather than high, levels of work impairment.

Table 3. The Effects of Control Variables on Daily Work Impairments

	Quality		Quantity	
	OR	95% CI	OR	95% CI
Age				
25–34	1.5*	1.1, 2.2	1.3	0.9, 1.9
35–49	1.3	0.9, 1.8	1.0	0.7, 1.6
50+	1.0		1.0	
		$\chi^2_2 = 6.1$*		$\chi^2_2 = 1.8$
Sex				
Male	1.0		1.0	
Female	1.3	1.0, 1.7	1.5*	1.1, 2.8
		$\chi^2_1 = 3.2$		$\chi^2_1 = 6.7$*
Region				
Northeast	0.5*	0.4, 0.8	0.5*	0.3, 0.8
Midwest	0.6*	0.4, 0.8	0.6*	0.4, 1.0
South	0.8	0.6, 1.0	0.6*	0.4, 0.9
West	1.0		1.0	
		$\chi^2_3 = 13.3$*		$\chi^2_3 = 8.7$*
Day of the week				
Monday	1.0		1.0	
Tuesday	1.2	0.8, 1.8	0.6	0.4, 1.0
Wednesday	1.5	1.0, 2.2	0.6	0.4, 1.0
Thursday	1.2	0.7, 1.8	0.5*	0.3, 0.9
Friday	1.0	0.6, 1.6	0.6	0.4, 1.1
Saturday	0.9	0.5, 1.5	1.0	0.6, 1.7
Sunday	0.7	0.4, 1.1	0.6	0.4, 1.1
		$\chi^2_6 = 11.7$*		$\chi^2_6 = 11.5$*
Season				
Summer	1.0		1.0	
Fall	0.6*	0.4, 1.0	0.7	0.4, 1.1
Winter	1.0	0.4, 1.5	1.2	0.7, 2.0
Spring	1.2	0.9, 1.5	1.2	0.8, 1.7
		$\chi^2_3 = 13.3$*		$\chi^2_3 = 5.9$*
(n)		(5104)		(5104)

* Significant at the 0.05 level, two-sided test.

Salary-Equivalent Effects

An average salary-equivalent transformation of the total effects among people with allergic rhinitis in Table 4 was computed, excluding impairments reported to have occurred on Saturdays or Sundays. The calculation was based on the assumptions that the lost value of work quality is equal to 25% of the respondent's daily wage and that the lost value of work quantity is equal to 75% of the respondent's daily wage. The first of these two assumptions is arbitrary, whereas the second is based on the fact that roughly 50% of the respondents who reported impaired work quantity missed the entire day of work whereas the others rated their impairment as equal to approximately half of a full day's work on the 0 to 10 rating scale. Based on these assumptions, the average salary-equivalent monthly cost of high pollen/mold exposure on the work impairment of respondents with self-reported allergic rhinitis is estimated to be $156.27, with a standard error of $20.04. An annualized population projection of this estimate to the approximately 12.6 million workers in the United States who have self-reported allergic rhinitis based on the time-space distribution of high pollen/mold exposure in the NAB monitoring centers equals $7.7 billion. This estimate decreases to $5.4 billion ($108.83 per worker per month of high pollen/mold exposure) if we set the lost value of work quality impairment to zero and focus entirely on quantity of work.

Table 4. The Effects of Pollen and Mold Exposure on Daily Work Impairment Separately among Respondents with and without Allergic Rhinitis

	With allergic rhinitis				Without allergic rhinitis			
	Quality		Quantity		Quality		Quantity	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Tree†								
High	5.4*	2.4, 12.3	3.8*	1.5, 9.8	0.6	0.3, 1.1	0.4*	0.2, 0.9
Moderate	1.7	0.7, 4.1	1.0	0.4, 2.9	0.7	0.4, 1.3	0.8	0.4, 1.4
Low	1.0		1.0		1.0		1.0	
χ^2_2	16.7*		7.4		3.7		6.4*	
Grass†								
High	9.9*	3.3, 29.8	13.5*	4.8, 37.9	1.7	0.8, 3.9	1.8	0.8, 4.1
Moderate	5.1*	1.9, 13.9	2.7	1.0, 7.4	1.5	0.9, 2.5	0.7	0.3, 1.3
Low	1.0		1.0		1.0		1.0	
χ^2_2	26.9*		22.1*		4.1		2.5	
Weed†								
High-Moderate	0.9	0.2, 3.8	4.0*	1.3, 12.1	1.1	0.6, 2.0	1.9	1.0, 3.7
Low	1.0		1.0		1.0		1.0	
χ^2_1	0.1		4.9*		0.1		3.6	
Mold†								
High	5.0*	1.7, 14.7	18.1*	4.1, 72.9	1.4	0.8, 2.3	0.6	0.3, 1.2
Moderate	5.8*	12.2, 15.3	16.4*	3.4, 80.0	1.1	0.7, 1.8	0.5*	0.3, 1.0
Low	1.0		1.0		1.0		1.0	
χ^2_2	17.0*		34.2*		1.3		5.6	
Number of high-moderate types†								
Two or more pollens	12.2*	4.4, 34.3	11.8*	3.8, 35.8	1.1	0.6, 1.9	0.9	0.5, 1.8
One pollen	4.5*	2.0, 10.3	3.0	0.8, 11.8	1.2	0.8, 1.7	0.6*	0.4, 1.0
None	1.0		1.0		1.0		1.0	
χ^2_2	33.3*		27.0*		1.8		9.4*	
(n)	(828)				(4276)			

* Significant at the 0.05 level, two-sided test.
† Controls are sex, region, day of the week, season, and chronic physical conditions.

DISCUSSION

Limitations

The results should be interpreted with four limitations in mind: 1) the pollen and mold data are fairly coarse; weekly rather than daily; only 86 region monitoring sites (which, in some cases, are several hundred miles or more away from the homes of respondents); and only for broad categories of absence through very high exposure. In addition, they ignore perennial indoor allergens. These several levels of coarseness presumably cause attenuation in the associations of pollen/mold exposure with work impairment, making the results conservative. 2) The measures of allergic rhinitis and daily work impairment are based on self-reports rather than objective assessments. It is not clear whether this introduces only random error or bias. 3) The compar-

atively low MIDUS response rate (60.8%) combined with the conditional NSDE response rate of 83.0% yields a sample that represents only about 50% of the employed population of the United States. This raises the possibility that the results are not representative of the entire population. The NSDE estimates that 15% of the population has allergic rhinitis is very close to the estimates found in previous government surveys. This fact suggests that any sample biases are likely to be small. Nonetheless, caution is needed in generalizing from the results because of the low response rate. 4) The NSDE sample may underrepresent sickness absence days. Concern about this possibility is raised by the fact that the 3.6% of work quantity limitation days found here is below the low end of the range found in previous studies

that have looked at sickness absence.[24, 27] It is likely that this is because of unwillingness of ill people to agree to participate in the daily diary task. Therefore, the impact of allergy could be greater than presented here.

The Prevalence and Correlates of Allergic Rhinitis

Within the context of these limitations, the NSDE 15% estimated prevalence of allergic rhinitis is very similar to the prevalences found in previous epidemiologic studies.[3,28,29] The positive association with educational attainment and the lack of an association with sex have both been documented consistently in previous epidemiologic studies.[1,30,31] The statistically significant associations of prevalence with age and region have not previously been examined. The association with season of

evaluation must be considered a methodologic artifact either because of incomplete randomization of respondents to month of evaluation or to an association between season of administration and response.

The Effects of Pollen and Mold Exposure on Daily Work Limitations
The NSDE data suggest that the work impairments of the typical allergic rhinitis sufferer during allergy season are 109 to $156 greater, in salary-equivalent terms, than at other times of the year. These are lower bound estimates of the annual salary-equivalent costs of allergic rhinitis because they ignore the effects of indoor allergens. This is an especially important omission in light of the fact that most patients with allergic rhinitis have perennial disease associated with indoor allergens. Although they are a lower bound, these cost estimates are greater than the costs of treatment associated with current seasonal allergy therapy, which suggests that it might be rational for employers to encourage their employees with allergic rhinitis to be treated. This suggestion becomes all the more persuasive when we recognize that the 109 to $156 estimate excludes the fringe benefits and employer profits typically associated with direct salaries as well as the costs associated with increased risk of industrial accidents and inefficiencies in the activities of coworkers whose job performance is negatively affected by the performance of the allergy sufferer.

CONCLUSION
It is unclear whether universal treatment would reduce the work impairments of seasonal allergy sufferers by an amount meaningfully greater than the costs of treatment. The NSDE did not collect data on treatment, so we are unable to study how much of the work impairment associated with seasonal allergies is because of the allergies themselves rather than the side effects of sedating antihistamines. Nor did we account for the reduction in work loss resulting from treatment in the analysis. As noted in the introduction, available evidence is consistent in showing that sedating antihistamines have significant detrimental effects on cognitive and motor performance in laboratory situations. However, the evidence is inconsistent regarding the effects of untreated seasonal allergies on these same performance outcomes. In particular, although self-report studies consistently find that people with untreated seasonal allergies report work impairments because of their allergies,[5,7,32] the one laboratory study that attempted to confirm these reports failed to find decrements.[9]

Nor are we able to determine from the NSDE data whether the impairments associated with untreated allergic rhinitis are reduced by such guideline-based treatments[33] as nonsedating antihistamines, decongestants, nasal corticosteroids, or a combination. Controlled trials have documented significant positive effects of second-generation antihistamines on self-reported role functioning,[32,34] and have documented that the effects of these medications on laboratory measures of cognitive and motor performance are significantly greater than the effects of placebos.[8,11,35,36] However, no published studies have compared the effects of active treatment versus placebo on objective measures of work performance. To resolve this uncertainty definitively, effectiveness trials are needed that evaluate the comparative effects of treatment with first- and second-generation antihistamines versus placebo on objective measures of work performance in representative samples of workers with allergic rhinitis who are followed in and out of allergy season.

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