

The prevalence of exposure to high molecular weight asthmagens derived from plants among workers in Australia

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Background: Limited information is available on exposure to high molecular weight (HMW) asthmagens derived from plants and on the main occupations and tasks that result in such exposure among workers.

Methods: Data were collected as part of the Australian Work Exposures Study—Asthma. We estimated adjusted prevalence ratios (aPR) using modified Poisson regression models to determine which factors were associated with exposure.

Results: A 12.8% of 4878 workers were exposed to HMW asthmagens derived from plants. The highest prevalence of exposure was found among farmers/animal workers, education workers, and food processing workers. The main circumstances of exposure were through handling flour, freesias, or through raising livestock. Exposure was more common among female workers (aPR = 1.26, 1.10–1.43) than males, while it was lower among workers born overseas (aPR = 0.70, 0.57–0.86) than those born in Australia.

Conclusion: Prevention of exposure to HMW asthmagens derived from plants requires a broad strategy targeting different tasks and occupations.

KEYWORDS

asthma, asthmagens derived from plants, occupation, prevalence, task

1 | INTRODUCTION

In recent years, there has been an increasing recognition of the importance of adult-onset asthma caused by exposures at work.¹ It has been estimated that between 5% and 20% of adult-onset asthma is triggered by occupational exposures.^{1,2} More than 360 workplace “asthmagens” can cause occupational asthma in vulnerable individuals and their number is steadily growing with the development of new industrial processes. The agents responsible for occupational asthma are divided according to their molecular weight. High molecular weight (HMW) asthmagens include proteins and microorganisms of animal and plant origins. HMW asthmagens act as complete antigens and

cause an allergic or immunologic asthma by inducing the production of specific Immunoglobulin E antibodies. Low molecular weight asthmagens include metals, wood dust, and other chemicals and many of these appear to induce occupational asthma by pathways that do not entail IgE-dependent mechanisms.³

Occupational exposure to HMW asthmagens derived from plants is common in various occupations and industries. For example, exposure to flour is common among bakers and millers, while exposure to certain flowers is common among farmers and gardeners, and latex exposure is common among health workers. Some of these agents have been listed as asthmagens by a number of bodies such as the health and safety executive (HSE)⁴ in the United Kingdom and the Association of Occupational and Environmental Clinics (AOEC) in the United States.⁵ Additionally, several studies have demonstrated a clear

relationship between occupational exposure to HMW asthmagens derived from plants and occurrence of occupational asthma.^{6,7}

There has been some outstanding success in reducing occupational asthma incidence from latex in health workers,⁸ while for other asthmagens including flour, specific flowers, and agents derived from other plants, few interventions have been tried. In order to carry out a successful intervention, we first need to recognize and identify the tasks in which the workers are exposed to these asthmagens. Having information regarding which occupations and circumstances result in exposure to HMW asthmagens derived from plants can be used to establish appropriate priorities for occupational interventions.

The aims of this study are to: estimate the current prevalence of exposure to HMW asthmagens derived from plants among Australian workers; identify the circumstances of exposure and identify the occupations with the highest proportion of respondents exposed. However, this study will not estimate the prevalence of exposure to latex which will be addressed in an upcoming publication.

2 | METHODS

This study used data from the Australian Work Exposures Study (AWES)—Asthma. AWES-Asthma was a cross-sectional telephone survey, conducted in 2014, which investigated the prevalence of current occupational exposures to 27 groups of asthmagens, including asthmagens derived from flour, flowers, and other plants, among worker working in Australia. Details regarding the asthamagen groups selected⁹ and the national survey¹⁰ have been described previously.

Briefly, Australian residents aged between 18–64 years old who were currently employed were eligible to participate. In total, 38 051 households were randomly telephoned. No response was obtained from 10 284 households (27%) and 21 453 were ineligible because they were too ill, deaf (1%), unemployed (28%), outside the age range of 18–65 (60%), or did not speak sufficient English (4%). Of 6314 eligible persons who were contacted, 4878 persons completed the interview.

Using a computer-assisted telephone interview, data from respondents were collected by trained interviewers. All participants were queried to provide demographic information including age, gender, highest education level completed, and country of birth. We derived socioeconomic status (according to the Socio-Economic Indexes for Areas disadvantage score)¹¹ and remoteness of residence (according to the Accessibility/Remoteness Index of Australia)¹² from the respondent's residential postcode. We also obtained occupational information about the current job held by the respondent. When the respondent's occupation fell into one of seven predetermined job categories that were not considered exposed to any of the 277 asthmagens the data collection ended at that point ($n = 2255$).

For the remaining workers, the interviewer obtained more information on the respondents' current job (including job title, industry type, the number of hours worked per week, and weeks worked per year) and based on this information, the interviewer then

assigned one of 52 job-specific modules (JSMs). The JSMs were part of OccIDEAS, a web-based tool that managed the interviews and the exposure assessment process (<http://www.occideas.org/>). Each JSM contained specific questions relating to occupational tasks which had been developed based on published literature and the expert knowledge.¹³ During the development of the JSMs, exposure rules were defined based on expert judgement. These rules provide an automatic exposure assessment. Where a suitable JSM could not be found ($n = 73$), a Generic JSM was used to collect information about tasks carried out in the job.

Exposure to five asthmagens belonging to the flour group, four asthmagens belonging to the flowers group, and 18 asthmagens belonging to the other plants group were asked through task-based questions in the JSMs. The asthmagens that were included in each group and the JSMs that contained task-based questions related to exposure to these asthmagens groups are presented in Table 1. For instance, if workers declared growing vetch (*Vicia sativa*) they were assigned exposed to asthmagens derived from other plants and if workers declared cooking with flour they were assigned exposed to flour. We refer to the three groups combined as "HMW asthmagens derived from plants" for the remainder of the paper.

The interview process took approximately 15 min. Verbal consent was obtained from each participant before starting the interview process. At the end of the data collection, the respondent's job title was coded according to the Australian and New Zealand Standard Classification of Occupations (ANZSCO).¹⁴ These codes were then categorized into 24 occupational groups, each group containing occupations which were broadly similar with respect to the exposure related tasks undertaken.

The statistical analyses were performed using Stata version 14 (StataCorp, College Station, TX). Modified Poisson regression models with robust error variance were used to estimate the prevalence ratios (PR) and to determine which demographic factors were associated with being exposed to asthmagens derived from flour, flowers, and/or other plants. This model was used, rather than a logistic regression model because PR was considered a better measure of risk than an odds ratio, which might overestimate effect size.^{15,16} We estimated the proportion of respondents within a given occupation who were exposed to asthmagens derived from flour, flowers, or other plants by dividing the number of exposed respondents by the number of respondents within that occupation. The prevalence of exposure to each of these asthamagen groups was extrapolated to the Australian working population with reference to the 2011 Census¹² to provide an estimate of how many workers in Australia are currently exposed.

Our study sample was found to be representative of the Australian working population in terms of gender, country of birth (Australia vs other), education, and socioeconomic status. However, our sample underrepresented younger workers, and those living in major cities as well as manager/administration workers among males only. Therefore, we weighted our sample by age group, remoteness, and manager/other occupation (for men only) when extrapolating our numbers to

TABLE 1 Asthmagen groups and the JSMs that contained task-based questions to identify exposure to these asthmagens

Group	Asthmagens	JSMs
Flowers	Baby's breath, freesia, <i>Limonium tataricum</i> (German statice), sunflower	Farmers, florists, gardeners, health workers, drivers, railway workers and shipping/fishing
Flour	Buckwheat, flour NOS ^a , rye flour, soya flour, wheat flour	Bakers, butchers, cooks, cleaners, drivers, teachers and workers in hospitality, food processing, food retail, laboratories, railways and shipping/fishing
Derived from other plants	Almond dust, <i>Arabidopsis thaliana</i> (thale or mouse-ear cress), chlorella algae, grain dust, gum Arabic, henna, kapok, linseed oilcake, <i>Pinellia ternata</i> , quillaja bark, rice dust, tall oil crude, tall oil-rosin, tobacco leaf, tragacanth, turpentine, <i>Vicia sativa</i> (vetch), weeping fig.	Animal workers, bakers, barbers, hairdressers, cleaners, construction drivers, electricians, farmers, fitters, janitors, machinists, mechanics, plumbers, teachers, welders, and workers in food processing, foundries, laboratories, printing, industrial manufacturing, railways, shipping/fishing, aluminium, ceramics, military, petroleum industry, metal manufacturing, upholstery

^aNot otherwise specified.

better represent the Australian population. These extrapolations were stratified by gender.

3 | RESULTS

Of the 4878 respondents included in this analysis, 12.8% were exposed to HMW asthmagens derived from plants. There were 6.0%, 2.3%, and 5.1% of respondents who were exposed to asthmagens derived from flour, flowers, and other plants, respectively.

After adjustment for various demographic factors, exposure to HMW asthmagens derived from plants was more common among female workers, workers born in Australia, and among those with a Trade certificate or diploma (Table 2).

The occupational groups with the highest prevalence of exposure to HMW asthmagens derived from plants were farmers/animal workers, followed by food preparation workers and carers (eg, nursing support and personal care workers). Exposure to flour was most prevalent among food preparation workers, followed by education workers, and food processing workers. Exposure to flowers was most prevalent among gardeners, followed by nursing, and medical staff and

TABLE 2 Adjusted prevalence ratio and 95% confidence interval for association between demographic characteristics and exposure to HMW asthmagens derived from plants in the current job

		HMW asthmagens derived from plants	
Demographic characteristics	N	Exposed n (%)	Adjusted prevalence ratio ^a
Age (in years)			
18-34	528	55 (10.4)	1
35-50	2165	256 (11.8)	0.76 (0.54-1.08)
51-64	2185	315 (14.4)	0.72 (0.51-1.03)
Gender			
Men	2441	275 (11.3)	1
Women	2437	351 (14.4)	1.26 (1.10-1.43)
Country of birth			
Australia	3850	554 (14.4)	1
Other	1028	72 (7.0)	0.70 (0.57-0.86)
Education status			
Bachelor degree	528	182 (10.7)	1
Trade certificate or diploma	2165	200 (14.3)	1.26 (1.06-1.50)
High school or less	2185	244 (13.8)	1.15 (0.96-1.38)
Socioeconomic status (SES) ^b			
Fifth quintile (most advantaged)	1079	96 (8.9)	1
Fourth	998	110 (11.0)	0.97 (0.79-1.20)
Third	1042	128 (12.3)	0.96 (0.78-1.18)
Second	1026	170 (16.6)	1.13 (0.92-1.38)
First quintile (least advantaged)	722	116 (16.1)	1.06 (0.85-1.32)
Remoteness ^c			
Major city	2448	206 (8.4)	1
Inner regional	1878	298 (15.9)	0.95 (0.81-1.12)
Outer regional/ Remote/Very remote	552	122 (22.1)	1.05 (0.86-1.28)

^aAdjusted for all variables in the model including occupational groups.^bFrom Socio-Economic Index for Areas Index of Relative Socio-economic Disadvantage (SEIFA IRSD).^cFrom Australian Standard Geographical Classification Accessibility/Remoteness Index of Australia (ARIA+).

Bold denotes statistically significant differences.

carers. Exposure to asthmagens derived from other plants was most prevalent among farmers/animal workers, followed by technical and engineering workers, and hairdressers (Table 3).

Among the 287 workers who were assigned an exposure to flour, the main exposure circumstances were through handling

TABLE 3 Prevalence of exposure to asthmagens derived from flour, flowers, and other plants by occupational group

Occupational groups	N	HMW asthmagens derived from plants n (%)	Flour n (%)	Flowers n (%)	Other plants n (%)
Farming/animal worker	238	178 (74.8)	-	3 (1.3)	178 (74.8)
Food preparation	150	91 (60.7)	91 (60.7)	-	4 (2.7)
Carers	124	42 (33.9)	19 (15.3)	23 (18.5)	-
Education	431	130 (30.2)	130 (30.2)	-	-
Food service	60	18 (30.0)	18 (30.0)	-	1 (1.7)
Gardening	79	23 (29.1)	-	22 (27.8)	1 (1.3)
Technical/engineering	77	18 (23.4)	5 (6.5)	-	14 (18.2)
Nursing and medical staff	272	59 (21.7)	-	59 (21.7)	-
Hairdresser	21	3 (12.5)	-	-	3 (12.5)
Other (NOS)	34	4 (11.8)	-	-	4 (11.8)
Transport	184	15 (8.2)	3 (1.6)	1 (0.5)	12 (6.5)
Manufacturing	86	6 (7.0)	2 (2.3)	-	5 (5.8)
Electric/electronic	75	5 (6.7)	-	-	5 (6.7)
Mechanical workers	65	4 (6.2)	-	-	4 (6.2)
Retail	348	17 (4.9)	15 (4.3)	-	4 (1.1)
Metal workers	84	4 (4.8)	-	-	4 (4.8)
Painting/printing	49	2 (4.1)	-	-	2 (4.1)
Cleaning	107	3 (2.8)	2 (1.9)	-	1 (0.93)
Allied health	45	1 (2.2)	-	-	1 (2.2)
Manager/Administration	2000	3 (0.2)	2 (0.1)	-	2 (0.1)

flour (97.9%), sweeping the bakery floor (5.2%), and processing dough (3.3%). Handling flour was mainly reported by education workers who stated that they teach cooking ($n = 129$), followed by food preparation workers ($n = 89$), and carers ($n = 19$). Sweeping flour was only reported by food preparation workers (bakers) (Table 4).

Among 108 workers who were considered exposed to flower asthmagens, the main exposure circumstances were handling freesias (73.1%), sunflowers (67.6%), and baby breath (53.7%). Freesias were handled by three occupational groups—nurses/medical workers ($n = 45$), carers ($n = 18$), and gardeners ($n = 16$). Similarly, sunflowers were mainly handled by nurses/medical workers ($n = 39$), followed by gardeners ($n = 15$), and carers ($n = 16$) (Table 4).

Contact with livestock (64.4%), harvesting or processing wheat (27.4%), and loading silos (24.9%) were among the main circumstances reported by the 245 workers who were assigned exposure to agents derived from other plants. Contact with livestock was mainly reported by farmers and animal workers ($n = 150$), followed by transport works ($n = 3$), and technical/engineering ($n = 2$). On the other hand, growing wheat was mostly done by farmers and animal workers ($n = 65$) (Table 4).

When we extrapolated to the Australian working population, it was estimated that 6.5% ($n = 607\,000$), 2.0% ($n = 185\,000$), and 3.4% ($n = 336\,000$) of the workforce were exposed to asthmagens derived from flour, flowers, and other plants, respectively (Table 5).

4 | DISCUSSION

We estimated that 11.7% of the Australian workers in 2011 were exposed to HMW asthmagens derived from plants. Exposure to HMW asthmagens derived from plants was more common among female compared to male workers and among workers born in Australian compared to workers born overseas. More specifically, exposure to flowers and flour was mostly among females, and exposure to other plants was more common among males. The occupational groups with the highest proportion of exposure to HMW asthmagens derived from plants included farmer/animal workers, food preparation workers, and carers. The main exposure circumstance for flour asthmagens was through handling flour (NOS). While exposure to asthmagens derived from flowers occurred mainly through coming into contact with Freesias and exposure to asthmagens derived from other plants occurred largely while working with livestock.

In our sample, we found that 6.0% of workers were exposed to flour in their jobs. Very few previous studies have estimated the prevalence of occupational exposure to flour. A population cross-sectional study conducted in New Zealand, between the years 2004–2006, reported that 0.62% of workers reported the use of flour during the last 12 months, with females being less commonly exposed.¹⁷ This prevalence was much lower than what we observed in our study. In the New Zealand survey, respondents were asked if they ever worked in an environment where dust was present and only if they answered yes,

TABLE 4 Main activities associated with exposure asthmagens derived from flour or flowers or other plants

Flours (n = 287)		Flowers (n = 108)		Other plants (n = 245)	
Exposure circumstance	N (%)		N (%)		N (%)
Handling or coming into contact with flour	280 (97.9)	Handling or coming into contact with Freesias	79 (73.1)	Contact with livestock	158(64.4)
Sweeping the bakery floor or other people do around them	15 (5.2)	Handling or coming into contact with sunflowers	73 (67.6)	Harvesting or processing wheat	67 (27.4)
Processing dough	9 (3.3)	Handling or coming into contact with Baby breath	58(53.7)	Loading silos	61 (24.9)
Working with pastry	7 (2.4)	Handling or coming into contact with Statice (<i>Limonium tataricum</i>)	42 (38.9)	Handling or coming into contact with grain	42 (17.1)
Other tasks	4 (1.4)			Handling or coming into contact with resin flux	12 (4.9)
				Harvesting or processing rice	6 (2.4)
				Other tasks	12 (4.9)

were they asked to name the type of dust. Hence, respondents might have failed to recall if they were exposed to flour in the workplace, in particular, if they did not use flour frequently in their jobs. In the current study, workers were asked task-based questions to determine exposure to flour which made it less likely that exposure would be missed.¹⁸

There is an extensive body of evidence, particularly among workers in the baking industry that exposure to flour is a common cause of occupational asthma.¹⁹ In France and Korea, exposure to flour is the second commonest reported cause of occupational asthma.^{20,21} Flour, and its additives and contaminants contain

many potential allergens, including cereal components, mites, weevils, molds, and a variety of enzymes such as amylase.¹⁹ Flour extracted from wheat, barley, rye, and oats has high allergenic potency compared to flour extracted from corn or maize.²²

Exposure to asthmagens derived from other plants was mainly reported by farmers and animal workers and it was primarily through handling livestock. Studies have shown that individuals who work with livestock are likely to handle animal feed (eg, grain).^{23,24} Grain dust has been classified as an occupational asthmagen by HSH⁴ and the AOEC.⁵ An association between occupational asthma and handling animal feeds by farmers and animal workers have been reported in a number of studies.^{23,25}

The prevalence of exposure to flower asthmagens in our study was 2.3%, which was mainly reported by gardeners and healthcare workers. Several case studies of occupational asthma have been reported among workers handling specific flowers: a florist who handled baby's breath²⁶; a farmer who was in regular contact with sunflower plants, seeds, and pollens²⁷; and a farmer who handled fresh *Limonium tatarium* flowers.²⁸

In many instances, it is not possible to completely avoid exposure to the HMW asthmagens derived from plants, since the removal of exposure may have consequences in terms of income and employment. However, interventions to reduce exposure could be an option to decrease the rates of sensitization and clinical expression of asthma. For instance, a study reported that using a vacuum cleaner instead of broom decreases exposure to flour dust.²⁹ A recent study showed that providing feedback on measured organic dust concentrations to livestock farmers reduced their exposure concentrations by 30%.³⁰ Training workers on occupational health and safety have been found to promote safe work practices, which results in a reduction in exposure to hazardous agents.³¹

There are clearly a wide range of tasks in many different jobs which result in exposure to HMW asthmagens derived from plants. These have

TABLE 5 The prevalence of exposure to asthmagens derived from flour, flowers, and other plants among the Australian working population

	Proportion (95%CI)	N
Total		
Flours	6.5 (5.6-7.6)	607 000
Flowers	2.0 (1.5-2.7)	185 000
Other plants	3.4 (2.9 -4.1)	336 000
Any of the above	11.7 (10.4-13.0)	1 099 000
Males		
Flours	4.8 (3.6-6.3)	239 000
Flowers	0.7 (0.4-1.2)	37 000
Other plants	5.4 (4.4-6.6)	272 000
Any of the above	10.6 (9.0-12.3)	532 000
Females		
Flours	8.3 (6.8-10.0)	368 000
Flowers	3.3 (2.4-4.7)	148 000
Other plants	1.4 (1.0-2.1)	64 000
Any of the above	12.8 (11.0-14.8)	567 000

implications for workplace interventions in the sense that it can be difficult to get a common approach that can be effective at raising the profile of HMW asthmagens derived from plants and reducing workers' exposure across these occupations. Our study suggests that workplace interventions and policy development should focus on workers with farming/animal work, food preparation, nursing/medical, gardening, and education occupations as these occupations represented the majority of exposed workers within the occupational groups.

Our study has some strengths and limitations, which are explained elsewhere in more detail.¹⁰ In brief, exposure assessment was considered less prone to error because of the use of task-based questions and our sample was similar to the Australian population in the distribution of many demographic characteristics. The limitations of our study were that we were not able to obtain data from non-responders, which may have introduced selection bias, and we did not collect information on the level of exposure. We may have slightly underestimated exposure as those who did not speak English were excluded from participation. Other work found that workers who chose to be interviewed in a language other than English had a greater prevalence of exposure to workplace hazards than workers interviewed in English.³²

In conclusion, this is the first study that has identified the occupational groups which have potential occupational exposure to HMW asthmagens derived from plants based on reported tasks rather than self-reported exposure to specific agents. Additionally, our study has found that exposure to HMW asthmagens derived from plants is common in a range of occupations and via a variety of different occupational tasks and that the prevalence of exposure differs between male and female workers. The information on the circumstances of exposure can be used to support decisions on appropriate priorities for intervention and control of occupational exposures to HMW asthmagens derived from plants, and provide clinicians further insight into the occupations and tasks that may involve exposure to plant-based asthmagens.

AUTHORS' CONTRIBUTIONS

SE performed the analysis and wrote the article. SE, RNC, ED, LF, TrD, DCG, AR, GB, SS, and MJA were each involved in the design of the study. All authors provided feedback on the draft of this manuscript. All authors read and approved the final manuscript.

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ETHICS APPROVAL AND INFORMED CONSENT

This study was approved by the Curtin University Human Research Ethics Committee.

DISCLOSURE (AUTHORS)

The authors disclose no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

Steven B. Markowitz declares that he has no conflict of interest in the review and publication decision regarding this article.

DISCLAIMER

None.

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