

ORIGINAL RESEARCH

Exposure to additives or multigrain flour is associated with high risk of work-related allergic symptoms among bakers

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ABSTRACT

Objectives Wheat flour exposure in bakers can elicit respiratory and skin symptoms. Scarce data are available on the prevalence of such conditions in bakers. We investigated the prevalence of work-related rhinitis, asthma-like symptoms and dermatitis in bakers according to job task and type of allergens involved.

Methods Of the 229 traditional bakeries in Verona area who were invited to participate in a cross-sectional survey, 211 (92%) accepted; 727 employees in these bakeries answered a modified version of a questionnaire on job tasks; allergen exposure within the bakery; and work-related nasal, asthma-like and skin symptoms during 2010–2014. Determinants of work-related nasal, asthma-like or skin disorders were separately evaluated using different logistic models.

Results The prevalence of work-related nasal and asthma-like symptoms was, respectively, 15.1% and 4.2% in bakery shop assistants, increasing to 25.7% and 9.5% in bakers using only wheat flour, and further to 31.8% and 13.6% in bakers using flour and additives, and then to 34.1% and 18.2% in bakers using flour with additives and multigrain ($p < 0.001$). The risk of work-related asthma-like symptoms was more than doubled in bakers using additives without or with multigrain than in shop assistants (OR 2.3, 95% CI 1.0 to 5.5 and OR 3.4, 95% CI 1.1 to 10.8, respectively). Making bread with additives alone or with multigrain significantly increased the risk of work-related nasal symptoms in shop assistants, while the risk of skin symptoms was not significantly affected.

Conclusions Bakers using additives alone or with multigrain are at a high risk of experiencing nasal and asthma-like symptoms.

INTRODUCTION

Occupational asthma is the most common occupational lung disease in industrialised countries, where approximately 15% of adult-onset asthma is caused by occupational exposure.¹ Occupational rhinitis is two to four times more prevalent than occupational asthma^{2,3}; moreover, both diseases frequently coexist, especially when high molecular weight (HMW) agents such as flour or enzymes are involved.⁴ Occupational skin diseases are also very common, accounting over 30% of all occupational diseases.^{5,6} In particular, bakers are at an increased risk for hand dermatitis,⁷ especially those working in small bakeries where bread is handmade

Key messages

What is already known about this subject?

- The prevalence of work-related asthma, rhinitis and dermatitis is higher among bakers than among the general population. Although it is well established that flour exposure can elicit these allergic conditions, little is known about the effect of concomitant exposure to enzymes and/or multigrain flour among bakers.

What are the new findings?

- Bakers working in the bread-making section reported more work-related asthma-like and nasal symptoms than the shop assistants. The increase was moderate in bakers using flour only and substantial in bakers using additives alone or with multigrain.
- The risk of work-related skin symptoms was not affected by job task or exposure.

How might this impact on policy or clinical practice in the foreseeable future?

- Better risk assessment and health surveillance processes may be needed in order to reduce the risks of allergic diseases in small bakeries, as these bakers are at a high risk of developing allergic comorbidities, especially when exposed also to enzymes and multigrain.

and, thus, the hands and forearms are extensively exposed to wet dough and flour dust.⁸

Airborne flour exposure is clearly related to specific sensitisation to flour and enzymes and to the related onset of upper and lower respiratory symptoms.⁹ However, in small bakeries, little is known about the relative effect of occupational exposure to wheat flour alone or with enzymes or to multigrain flour—a blend of several cereal flours, seed flours and enzymes.

Furthermore, the relationship between skin and respiratory occupational exposure is a promising area of research interest as suggested in studies on animal models of skin exposure to protein and chemical allergens. In an international study, the prevalence of work-related asthma-like (WRA) symptoms was double in bakers reporting work-related itchy skin, but the association was not statistically significant.¹⁰



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Workplace

Moreover, the coexistence of different work-related allergic comorbidities has not been evaluated as a function of the type of allergens involved in bread-making.

Hence, studies on a full range of bakeries are needed to address the complexity of occupational hazards involving different types of allergens (wheat only, enzymes added to wheat, and multigrain).

The present study was aimed to assess the prevalence and coexistence of work-related rhinitis (WRR), WRA and work-related dermatitis (WRD) in a geographically defined population of bakery employees according to job task and type of allergens involved.

METHODS

Study design, population and questionnaire

In total, 229 traditional bakeries in the Verona district were invited to participate in a cross-sectional survey through Bakers Labour Organization, whose members included the owners of contacted bakeries; 211 of them (92%) accepted. The survey was conducted during 2010–2014, and two questionnaires were administered to bakery workers employed in the participating bakeries: (1) a clinical questionnaire, administered to the bakery employees working in either the production (bread making) area or the selling area (shop); and (2) a workplace questionnaire, administered to the employer, on the characteristics of the bakery. Types of flour used to make bread were the following: (1) wheat flour only; (2) wheat flour and additives (enzymes); (3) multigrain flour, that is, a mixture of wheat and other cereal flour, and additives (enzymes). The clinical questionnaire was a modified version of the ECRHS questionnaire (www.ecrhs.org), and it included questions on age, sex, years worked in the bakery, smoking habits, asthma attacks and treatments in the last year, and personal history of allergic diseases. Allergic rhinitis, defined by a positive answer to the question “Do you have any nasal allergies including hay fever?” (www.ecrhs.org), was used as a proxy of atopy. The questionnaire also inquired about nasal symptoms (watery nose, sneezing, itching and nasal congestion), respiratory symptoms (cough, wheezing, chest tightness and shortness of breath) and skin symptoms (itchy skin, rash and skin fissuring/crusts) at work. Symptoms were defined as work-related ones if reported to be triggered by exposure to flour. The questionnaires were sent by mail and were self-completed. To increase the response rate, the participants were reminded through telephone calls. Nearly all employees answered the questionnaire.

Statistical analysis

The significance of differences between the exposure groups was evaluated using Fisher’s exact test or χ^2 test for categorical variables, χ^2 test for trend (Mantel-Haenszel for trend) for ordinal variables, and one-way ANOVA or Kruskal-Wallis test for continuous variables.

The relationship between occupational exposure (working in shop only, making bread with flour only, with flour and additives without multigrain, with flour additives and multigrain) and each of the work-related allergic symptoms (WRR, WRA, WRD) was further assessed using multivariable logistic regression models, adjusted for potential confounders (sex, age, atopy and working <5 years in the bakery).¹¹ The results of the logistic models were synthesised through the ORs. The significance level was set at p value <0.05. All analyses were performed with the statistical SPSS V.20.0 software package (IBM).

Table 1 Workers’ characteristics by job tasks

	Working only in shop n=259	Working in shop and bread-making section n=180	Working only in bread-making section n=288	P value
Gender (male)	27 (10.4)	244 (84.7)	104 (57.8)	<0.001
Age mean (SD)	36.8 (11.6)	39.6 (11.7)	40.7 (11.6)	0.001
Smoking				
Non-smokers	172 (66.4)	100 (55.6)	136 (47.2)	
Ex-smokers	30 (11.6)	30 (16.7)	57 (19.8)	<0.001
Current smoker	57 (22)	50 (27.8)	95 (33)	
Years worked in the bakery mean (SD)	8.2 (9.5)	14.7 (12.4)	12.8 (11.6)	<0.001
Personal history of atopy	46 (17.8)	35 (19.4)	53 (18.4)	NS
Work-related asthma symptoms	11 (4.2)	20 (11.1)	37 (12.8)	0.002
Work-related rhinitis	39 (15.1)	54 (30)	83 (28.8)	<0.001
Any work-related skin symptoms	23 (8.9)	22 (12.2)	36 (12.5)	NS
Itching, flushing skin	14 (5.4)	17 (9.4)	26 (9.0)	NS
Skin crusts, ulcers	11 (4.2)	13 (7.2)	13 (4.5)	NS
No of work-related respiratory/skin disorders				
None	206 (79.5)	118 (65.6)	185 (64.2)	
One	37 (14.3)	36 (20)	63 (21.9)	0.001
Two or three	16 (6.2)	26 (14.4)	40 (13.9)	

RESULTS

The study included 727 subjects, 288 working only in the bread-making section, 180 in the shop and in the bread-making section, and 259 only in the shop. Nearly all the shops had an adjoining bread-making area. People working only in the shop were younger, predominantly female, never smokers and had worked in the bakery for a shorter time, while bread-making bakers were older, predominantly male and ever smokers. Bread-making bakers more frequently reported WRA and nasal symptoms as well as a combination of work-related disorders than shop assistants (table 1). Work-related allergic disorders were strongly interrelated (figure 1). Asthma-like symptoms were common in workers with WRR (53/176=30.1%) but rare in the other subjects (15/551=2.7%; $p<0.001$). A similar pattern was observed for WRD, which was seen in 27.8% (49/176) of the former group and 6.0% (33/551) of the latter ($p<0.001$). WRA symptoms were reported by 36.6% (30/82) of the subjects with WRD but only by 5.9% (38/645) of those without these symptoms ($p<0.001$) (figure 1).

Regarding exposure to the allergens in the bakery, 40% of the bread-making bakers (189/468) were exposed only to wheat

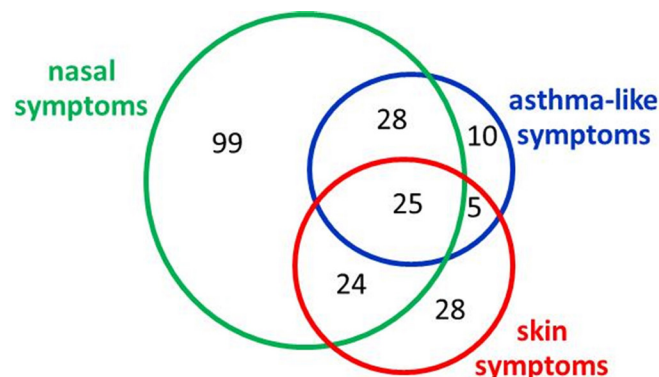


Figure 1 Number of workers as a function of concomitant work-related disorders.

Table 2 Workers' characteristics by the presence of work-related rhinitis, work-related asthma symptoms and work-related skin symptoms

	Work-related rhinitis symptoms*			Work-related asthma symptoms*			Work-related skin symptoms*		
	Yes n=176	No n=551	OR (95% CI) or p†	Yes n=68	No n=659	OR (95% CI) or p†	Yes n=82	No n=645	OR (95% CI) or p†
Gender (male) n (%)	113 (64.2)	262 (47.5)	2.0 (1.4 to 2.8)	48 (70.6)	327 (49.6)	2.4 (1.4 to 4.2)	47 (58)	328 (50.8)	1.3 (0.8 to 2.1)
Age mean (SD)	36.6 (11.4)	39.8 (11.8)	0.001	40.3 (12)	38.9 (11.7)	NS	38.8 (12.1)	39.1 (11.7)	NS
Personal history of atopy (yes) n (%)	75 (42.6)	59 (10.7)	6.2 (4.1 to 9.3)	31 (45.6)	103 (15.6)	4.5 (2.7 to 7.6)	42 (51.9)	92 (14.2)	6.5 (4 to 10.6)
Smoking									
Non-smokers n (%)	93 (52.8)	315 (57.2)	1	30 (44.1)	378 (57.4)	1	38 (46.9)	370 (57.3)	1
Ex-smokers n (%)	37 (21)	80 (14.5)	1.6 (1 to 2.5)	14 (20.6)	103 (15.6)	1.7 (0.9 to 3.4)	17 (21)	100 (15.5)	1.7 (0.9 to 3.1)
Current smoker n (%)	46 (26.1)	156 (28.3)	1 (0.7 to 1.5)	24 (35.3)	178 (27)	1.7 (1 to 3)	26 (32.1)	176 (27.2)	1.4 (0.9 to 2.4)
Years in the bakery mean (SD)	11.5 (10.8)	11.7 (11.6)	NS	13.7 (11.6)	11.4 (11.4)	NS	12 (12.3)	11.6 (11.3)	NS
Working ≥5 years in bakery‡ n (%)	115 (66.1)	332 (60.8)	1.3 (0.9 to 1.8)	51 (75)	396 (60.7)	1.9 (1.1 to 3.4)	49 (60.5)	398 (62.3)	0.9 (0.9 to 1.6)
Job task n (%)									
Working only in shop	39 (22.2)	220 (39.9)	1	11 (16.2)	248 (37.6)	1	23 (28.4)	236 (36.5)	1
Making bread with wheat flour only	48 (27.3)	141 (25.6)	1.9 (1.2 to 3.1)	16 (23.5)	173 (26.3)	2.1 (0.9 to 4.6)	21 (25.9)	168 (26.0)	1.3 (0.7 to 2.4)
Making bread with wheat flour and additives	68 (38.6)	146 (26.5)	2.6 (1.7 to 4.1)	29 (42.6)	185 (28.1)	3.5 (1.7 to 7.3)	25 (30.9)	189 (29.3)	1.4 (0.7 to 2.5)
Making bread with wheat flour, additives and multigrain	21 (11.9)	44 (8.0)	2.7 (1.4 to 5.0)	12 (17.6)	53 (8.0)	5.1 (2.1 to 12.1)	12 (14.8)	53 (8.2)	2.3 (1.0 to 5.0)

*Work-related rhinitis symptoms=watery nose, sneezing, itching and nasal congestion at work. Work-related asthma symptoms=cough, wheezing, chest tightness and shortness of breath at work. Work-related skin symptoms=itchy skin, rash and skin fissuring/crusts at work.

†P referred to differences in mean.

‡Data available in 720 subjects.

flour, 46% (214/468) to manually added enzymes, and 14% (65/468) to both enzymes and multigrain flour.

Workers' characteristics as a function of work-related symptoms are listed in table 2. Male bakers and bakers working with additives or additives and multigrain more frequently reported work-related nasal and WRA symptoms than female bakers and shop assistants. The majority of subjects reporting work-related nasal and asthma-like symptoms (50.6% and 60.3%, respectively) were bread-making bakers using additives or additives and multigrain, while shop assistants did not report these symptoms as frequently (39.9% and 37.6%, respectively) ($p<0.001$). Work-related skin symptoms were not significantly associated with job task and related exposure. A history of allergic diseases was associated with all the three work-related disorders, reported by 42.6%, 45.6% and 51.9% of the participants with work-related nasal, asthma-like and skin symptoms, respectively. In addition, asthma-like symptoms were less common in people who had worked in the bakery for less than 5 years, and nasal symptoms were more common in younger people. No significant association was observed between smoking habits and work-related disorders (table 2).

In multivariable analysis, the risk of WRA and nasal symptoms progressively increased from shop assistants to bakers using flour only, to bakers using flour and additives, and peaked in bakers using also multigrain. The trend was less pronounced and not significant for work-related skin symptoms (table 3).

The association between job exposure and WRR/WRA symptoms was stronger in bakers who had worked in the bakery for

more than 5 years than in those with a shorter working duration. With respect to counter hands, the OR of WRR symptoms in bakers exposed to flour; flour and enzymes; and flour, enzymes and multigrain were, respectively, 2.01 (95% CI 0.86 to 4.71), 2.37 (95% CI 1.04 to 5.38) and 3.61 (95% CI 1.29 to 10.08), whereas ORs for WRA symptoms were, respectively, 1.29 (95% CI 0.37 to 4.35), 2.66 (95% CI 0.86 to 8.25) and 5.78 (95% CI 1.58 to 21.13) when working duration was ≥5 years. For shorter working duration (<5 years), the ORs of WRR symptoms in bakers exposed to flour; flour and enzymes; and flour, enzymes and multigrain were, respectively, 1.26 (95% CI 0.47 to 3.34), 1.57 (95% CI 0.66 to 3.76) and 1.16 (95% CI 0.34 to 3.92), while for WRA symptoms, the ORs were, respectively, 2.27 (95% CI 0.50 to 10.22), 1.78 (95% CI 0.42 to 7.48) and 0.99 (95% CI 0.10 to 10.21) when the working duration was ≥5 years.

DISCUSSION

This study confirmed that WRR is the most common work-related disease in bakers, and WRA symptoms are frequent in this category. This pattern, as already observed in epidemiological studies,^{12 13} was confirmed in a large sample of bakers working in traditional small bakeries, representing more than 80% of the bakeries of the Verona area.¹⁴ Moreover, our results showed that WRA and WRR symptoms often coexist in bakers, as already observed in a small cohort of people working in traditional bakeries, where WRR symptoms were reported by 14.3%

Table 3 Influence of occupational risk factors on work-related symptoms*

	Work-related rhinitis symptoms		Work-related asthma symptoms		Work-related skin symptoms	
	OR	95% CI	OR	95% CI	OR	95% CI
Working only in shops	1		1		1	
Making bread with wheat flour only	1.49	0.80 to 2.76	1.41	0.55 to 3.63	1.22	0.59 to 2.68
Making bread with wheat flour and additives without multigrain	1.80	1.01 to 3.22	2.25	0.94 to 5.38	1.15	0.54 to 2.43
Making bread with wheat flour, additives and multigrain	2.19	1.03 to 4.65	3.77	1.35 to 10.54	2.38	0.95 to 5.93

*ORs and p values were computed by a logistic regression model, adjusting for sex, age, atopy and working duration in the bakery (< or ≥5 years).

of bakers, WRA symptoms by 3.6% and both symptoms by 3.2%.¹⁵ Coexistence of nasal and respiratory work-related symptoms was found in a substantial proportion of workers employed in supermarket bakeries, where baking processes are performed in larger environments than in small traditional bakeries; hence, airborne flour exposure is lower.¹⁶ Accordingly, the French National Health Surveillance Program on Occupational Diseases found a significant association between occupational asthma and occupational rhinitis in workers exposed to HMW allergens.⁴

In the present study, the prevalence of WRR and WRA symptoms was higher in bakers working in the production area than in those working in the shop. This might be explained by the fact that all the bakers in the present study were employed in traditional bakeries, where inhalable flour dust levels are higher than those in industrial bakeries.^{9 12 17}

Studies^{7 8} have reported an increased risk of work-related skin disorders in bakers. Different pathophysiological mechanisms are involved in the onset of dermatitis in bakers. Irritant contact dermatitis seems to be the most frequent, affecting up to 70% of the bakers¹⁸ who frequently clean dust and dough off their hands. Occupational dermatitis is often due to immunological mechanisms; indeed, IgE-mediated sensitisation to flour¹⁸ and positive skin prick test to enzymes^{19 20} have been observed in 20%–30% of bakers with occupational skin diseases. On the other hand, delayed-type hypersensitivity seems to be more rare, with only few bakers presenting a positive patch test to flour or α -amylase powder.¹⁸ In contrast with the findings reported in literature,^{7 8} in the present study, the bakers working with additives presented a higher prevalence of occupational skin disorders than shop assistants, but with an insignificant difference.

In the present study, work-related allergic disorders were strongly associated, in agreement with a Finnish outpatient series with occupational contact urticaria or protein contact dermatitis, wherein it was mostly Ig-E mediated²¹; 21% of patients in the Finnish series also had occupational asthma and 38% had occupational rhinitis.²¹ In the present study, WRA and nasal symptoms were reported, respectively, by 37% and 60% of the bakers with occupational skin symptoms, confirming the association between IgE-mediated occupational disorders.

As an important contribution, the present study highlighted that handling enzymes and/or multigrain flour largely increased the risk of WRA or nasal symptoms as compared with handling only wheat flour. Accordingly, in a recent work from the UK, sensitisation to enzymes other than alpha-amylase was detected in 25% of supermarket bakers; of these, 86% were also sensitised to either flour or alpha-amylase.²²

The associations became weaker and insignificant when considering only bakers with a work history of <5 years. A logical explanation could be that the onset of allergic symptoms when exposed to additives/multigrain requires more than 5 years of exposure. In fact, sensitisation to other HMW agents such as animal allergens was reported to increase from 11% to 18.4% before and after 5 years of exposure in laboratory workers.²³

Atopic individuals are at a higher risk of allergic rhinitis and asthma. In our population, there were no differences in the prevalence of a personal history of atopy by workplace. This finding is rather surprising because traditional bakeries are often familiar enterprises and we would have expected atopic subjects have moved to a safer job (eg, in shops) in the same bakery, as it was shown previously with a healthy hire effect.²⁴ It should be considered, however, that the prevalence of self-reported atopy was much lower in bakers recruited in the present study (18.4% = 134/727) than in the general population from the same area (37.6%)²⁵ (data not shown).

Self-administered questionnaire and the medical history of bakers referred for clinical evaluation can be useful to predict both occupational asthma and rhinitis using separate models evaluating the exposure to wheat flour.⁶ The relevance of asthma and rhinitis comorbidity has been confirmed in a French National Health Surveillance Program on Occupational Diseases, where it was shown that occupational rhinitis coexisted in more than half of the cases of occupational asthma, frequently in bakers, and that flour was the main causal agent.⁴

Limitations

The main limitation of this study is the absence of an objective assessment of occupational allergen sensitisation, as performed in similar studies.²⁶ It is known that the diagnostic accuracy of questionnaires in detecting allergic sensitisation is generally rather low²⁷; however, diagnostic accuracy has been reported to increase when considering specific occupational allergens in bakers.²⁸ Of note, in bakers, WRR, WRA and dermatitis symptoms are often non-allergic but are symptoms of irritation, as flour dust exposure is higher in traditional bakeries than in industrial bakeries.²⁹

Second, an objective assessment of workplace exposure was lacking. Third, controls were mostly shop assistants working in shops adjoining the bread-making sections; hence, bystander exposure cannot be ruled out. Moreover, bakers who developed rhinitis/asthma/skin disorders within family-run bakeries are often moved to job tasks with lower exposure, such as the shop.

Fourth, the possibility of a 'healthy hire effect' cannot be excluded, considering the cross-sectional design of our study. Indeed, the prevalence of self-reported atopy was much lower in bakers (18.4%, 134/727) than in coevals from the same area (37.6%)²⁵ (data not shown).

Finally, 92% of bakeries took part in the survey, yielding a high participation rate. However, we do not exactly know participation rate at individual level.

CONCLUSIONS

This study has shown that bakers who use enzymes and/or multi-grain flour in their work have a higher risk of WRA symptoms and, to a lower extent, WRR than shop assistants. On the other hand, no significant difference was recorded for work-related dermatitis. Larger studies involving specific IgE assessment are necessary to verify whether enzymes exert a direct sensitising effect in bakers with allergic symptoms not sensitised to wheat flour exposure.

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Patient consent for publication Not required.

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REFERENCES

- 1 Kogevinas M, Zock J-P, Jarvis D, *et al.* Exposure to substances in the workplace and new-onset asthma: an international prospective population-based study (ECRHS-II). *The Lancet* 2007;370:336–41.
- 2 Siracusa A, Desrosiers M, Marabini A. Epidemiology of occupational rhinitis: prevalence, aetiology and determinants. *Clin Exp Allergy* 2000;30:1519–34.
- 3 Ruoppi P, Koistinen T, Susitaival P, *et al.* Frequency of allergic rhinitis to laboratory animals in university employees as confirmed by chamber challenges. *Allergy* 2004;59:295–301.
- 4 Ameille J, Hamelin K, Andujar P, *et al.* Occupational asthma and occupational rhinitis: the united airways disease model revisited. *Occup Environ Med* 2013;70:471–5.
- 5 HSE. *Self-reported work-related illness and workplace injuries in 2007/08: results from the labour force survey*, 2009.
- 6 Pesonen M, Jolanki R, Larese Filon F, *et al.* Patch test results of the European baseline series among patients with occupational contact dermatitis across Europe—analyses of the European Surveillance System on Contact Allergy network, 2002–2010. *Contact Dermatitis* 2015;72:154–63.
- 7 Brisman J, Meding B, Järholm B. Occurrence of self reported hand eczema in Swedish bakers. *Occup Environ Med* 1998;55:750–4.
- 8 Steiner MFC, Dick FD, Scaife AR, *et al.* High prevalence of skin symptoms among bakery workers. *Occup Med* 2011;61:280–2.
- 9 Cullinan P, Cook A, Nieuwenhuijsen MJ, *et al.* Allergen and dust exposure as determinants of work-related symptoms and sensitization in a cohort of flour-exposed workers; a case–control analysis. *Ann Occup Hyg* 2001;45:97–103.
- 10 Arrandale V, Meijster T, Pronk A, *et al.* Skin symptoms in bakery and auto body shop workers: associations with exposure and respiratory symptoms. *Int Arch Occup Environ Health* 2013;86:167–75.
- 11 Agresti A. *Categorical data analysis*. New York, NY: John Wiley & Sons, 1990.
- 12 Houba R, Heederik D, Doekes G. Wheat sensitization and work-related symptoms in the baking industry are preventable. An epidemiologic study. *Am J Respir Crit Care Med* 1998;158:1499–503.
- 13 Baatjes R, Meijster T, Heederik D, *et al.* Exposure–response relationships for inhalant wheat allergen exposure and asthma. *Occup Environ Med* 2015;72:200–7.
- 14 Olivieri M, Biscardo CA, Delli T, *et al.* [Prevalence of occupational allergic symptoms among bakers of Verona]. *G Ital Med Lav Ergon* 2007;29:610–1.
- 15 Leghissa P, Santini M, Bancone C, *et al.* [The Bergamo experience of health surveillance in the bakery sector]. *G Ital Med Lav Ergon* 2011;33:12–17.
- 16 Brant A, Berriman J, Sharp C, *et al.* The changing distribution of occupational asthma: a survey of supermarket bakery workers. *Eur Respir J* 2005;25:303–8.
- 17 Brisman J, Järholm B, Lillienberg L. Exposure–response relations for self reported asthma and rhinitis in bakers. *Occup Environ Med* 2000;57:335–40.
- 18 Tacke J, Schmidt A, Fartasch M, *et al.* Occupational contact dermatitis in bakers, confectioners and cooks. A population-based study. *Contact Dermatitis* 1995;33:112–7.
- 19 Morren MA, Janssens V, Doooms-Gossens A, *et al.* Alpha-amylase, a flour additive: an important cause of protein contact dermatitis in bakers. *J Am Acad Dermatol* 1993;29:723–8.
- 20 Vanhanen M, Tuomi T, Hokkanen H, *et al.* Enzyme exposure and enzyme sensitisation in the baking industry. *Occup Environ Med* 1996;53:670–6.
- 21 Helaskoski E, Suojalehto H, Kuuliala O, *et al.* Occupational contact urticaria and protein contact dermatitis: causes and concomitant airway diseases. *Contact Dermatitis* 2017;77:390–6.
- 22 Jones M, Welch J, Turvey J, *et al.* Prevalence of sensitization to ‘improver’ enzymes in UK supermarket bakers. *Allergy* 2016;71:997–1000.
- 23 Jones M, Schofield S, Jeal H, *et al.* Respiratory protective equipment reduces occurrence of sensitization to laboratory animals. *Occup Med* 2014;64:104–8.
- 24 Olivieri M, Mirabelli MC, Plana E, *et al.* Healthy hire effect, job selection and inhalation exposure among young adults with asthma. *Eur Respir J* 2010;36:517–23.
- 25 de Marco R, Accordini S, Antonicelli L, *et al.* The gene–environment interactions in respiratory diseases (GEIRD) project. *Int Arch Allergy Immunol* 2010;152:255–63.
- 26 Jonaid BS, Rooyackers J, Stigter E, *et al.* Predicting occupational asthma and rhinitis in bakery workers referred for clinical evaluation. *Occup Environ Med* 2017;74:564–72.
- 27 Hoppin JA, Jaramillo R, Salo P, *et al.* Questionnaire predictors of atopy in a US population sample: findings from the National Health and Nutrition Examination Survey, 2005–2006. *Am J Epidemiol* 2011;173:544–52.
- 28 Meijer E, Suarathana E, Rooijackers J, *et al.* Application of a prediction model for work-related sensitisation in bakery workers. *Eur Respir J* 2010;36:735–42.
- 29 Bulat P, Myny K, Braeckman L, *et al.* Exposure to inhalable dust, wheat flour and alpha-amylase allergens in industrial and traditional bakeries. *Ann Occup Hyg* 2004;48:57–63.