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Respiratory Health Outcomes, Rhinitis, and Eczema in Workers from Grain Storage Facilities in Costa Rica

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Abstract

Objectives: To examine the associations of inhalable grain dust exposure with respiratory health outcomes, rhinitis, and eczema reported by workers from rice, wheat, and maize storage facilities.
Methods: A cross-sectional study of 136 workers (73 operators and 63 administrative staff and other workers) from eight Costa Rican grain storage facilities was conducted in 2014–2015. Full-shift personal inhalable dust samples from all workers were collected. Study participants were administered a short version of the European Community Respiratory Health Survey questionnaire to identify symptoms of asthma, chronic bronchitis, rhinitis, and eczema. Associations between grain dust exposure and health outcomes were assessed using multivariable logistic and negative binomial regression models adjusted for age, smoking history, grain type, and presence of pets or farm animals in the home.
Results: The median inhalable grain dust concentration was 2.0 (25th to 75th percentile: 0.3–7.0) mg m^{-3}. Higher concentrations of inhalable dust were associated with increased odds of (i) asthma symptoms or medication use [adjusted Odds ratio (OR_a) per 10-fold increase in dust concentration 2.7; 95% confidence interval (CI): 1.3–6.7]; (ii) a score of at least two out of five symptoms suggestive of asthma (OR_a 1.2; 95% CI: 1.0–1.3); and (iii) eczema (OR_a 3.6; 95% CI: 1.7–9.6). No associations of inhalable grain dust exposure with chronic bronchitis and rhinitis were observed.

Conclusions: High exposure to inhalable dust in Costa Rican grain storage facilities was associated to asthma symptoms and eczema in workers.

Keywords: Costa Rica; eczema; grain dust exposure; grain storage facilities; grain workers; inhalable grain dust; respiratory health; rhinitis

Introduction

Grain dust contains a variable combination of soil particles, plant fragments, insect body parts, rodent droppings, pesticide residues, microorganisms (e.g. fungal spores, bacteria), and/or their components or secreted products [e.g. endotoxins, β-(1→3)-glucans, and mycotoxins] (Krysińska-Traczyk et al., 2001; Halstensen et al., 2007; Straumfors et al., 2016).

Occupational exposure to grain dust has been associated with an increased prevalence of self-reported asthma symptoms (e.g. shortness of breath, chest tightness, and wheeze) (Chan-Yeung et al., 1980; Ghosh et al., 2014). Several epidemiological studies have also observed associations of grain dust exposure with allergic asthma (Chan-Yeung et al., 1979; Jacobs et al., 1982; Warren et al., 1983), asthma-like syndrome or non-allergic asthma (i.e. acute neutrophilic airway inflammation unrelated to atopic status) (Chan-Yeung et al., 1980; Tabona et al., 1984), and chronic obstructive pulmonary disease (COPD) (Minov et al., 2016) using inhalation challenge tests. In addition, a few studies have found hematological abnormalities and chest opacities on radiological exams among rice mill workers with prolonged exposure to very high levels of dust, suggesting the presence of extrinsic allergic alveolitis (Lim et al., 1984; Ghosh et al., 2014).

Exposure to grain dust has been associated with an increased prevalence of chronic bronchitis (i.e. chronic cough and phlegm) (Ghosh et al., 2014; Minov et al., 2016), rhinitis (Chan-Yeung et al., 1980; Lim et al., 1984; Hogan et al., 1986; Ghosh et al., 2014), and skin-related outcomes (Lim et al., 1984; Hogan et al., 1986). For example, a recent cross-sectional study conducted in Macedonia observed a higher prevalence of chronic cough and phlegm in grain workers than in office workers (Minov et al., 2016). Notably, several studies suggest that microbial agents in grain dust, as opposed to grain components themselves, could be responsible for these health effects (Straumfors et al., 2016).

Basic grain production is an important economic activity in Latin American countries (Baumeister, 2010; Cruz Delgado et al., 2012). It has been estimated that about a third of the population in Central America (n ~ 12 million) works handling basic grains (Baumeister, 2010). Despite the relevance of this economic activity in the region, inadequate regulations (Van Egmond and Jonker, 2004), lack of engineering measures to control grain dust exposure, and little to no monitoring of workers' health are common in most of these countries. To date, few studies have assessed respiratory outcomes, rhinitis, and eczema in workers exposed to grain dust in Latin American countries (i.e. Argentina, Venezuela, and Cuba) (González Vara et al., 1992; Corzo and Naveda, 1998; Ochoa and Jacas, 1999; Ardusso et al., 2001), but no study has been conducted in Central America.

This study is part of a cross-sectional investigation that assessed exposure to inhalable dust in workers from grain storage facilities in Costa Rica and found that about 46% of all study participants (80% of operators) exceeded the threshold limit value-time weighted average for grain dust corrected for the median work shift of 57 h/week (corrected-TLV-TWA = 2.4 mg m^{-3}), established by the American Conference of Governmental Industrial Hygienists (ACGIH, 2015). Furthermore, it was found that inhalable dust concentrations were 15.8 (95% CI: 10.0–26.3) times higher in operators that reported cleaning in addition to their regular job category tasks (Rodríguez-Zamora et al., 2017). In the present analyses, associations of occupational exposure to inhalable grain dust with self-reported respiratory health outcomes, rhinitis, and eczema were examined in those workers.

Materials and methods

Study population

A cross-sectional study of 136 workers from eight grain storage facilities (four rice, three maize, and one wheat) was conducted in Costa Rica. Detailed study methods have been described elsewhere (Rodríguez-Zamora et al., 2017). Briefly, eligible workers were male (given that all operators were men) and aged 18 years or older. Participants were recruited at their workplaces between October 2014 and December 2015. Seventy-five operators (i.e. workers who unloaded grains in pits or flat bed sheds, dried, dehulled, or packed) and 63 administrative staff and other workers (i.e. purchasing agents, laboratory technicians, warehouse workers, forklift drivers, plant managers, mechanics, security officers, and weighers) were invited to participate in this study. In total, 99% (n = 136) of them accepted (only two operators refused). Workers who were not directly exposed to grain dust (i.e. not operators), regardless of their measured inhalable dust concentrations, were included *a priori* in the comparison group (i.e. administrative staff and other workers).

Written informed consent was obtained from all workers before participation. The Ethics Committee of the Universidad Nacional approved all study activities and instruments.

Assessment of respiratory health outcomes, rhinitis, and eczema

Study participants were interviewed at enrollment using a structured questionnaire. Data on socio-demographic and occupational information, smoking history, pre-existing medical conditions, medication use, and presence of pets or farm animals (i.e. cats, dogs, cattle, pigs, or poultry) in the home were collected. A short version of the Spanish European Community Respiratory Health Survey (ECRHS) (Burney et al., 1994) questionnaire, which has been previously used in studies of Costa Rican populations (Fieten et al., 2009; Gascon et al., 2012), was also administered to the participants in order to identify symptoms of asthma, chronic bronchitis, rhinitis, and eczema.

Two definitions of asthma were used, based on other studies that have also administered the ECRHS questionnaire (Kogevinas et al., 1999; Sunyer et al., 2007). The first asthma definition (referred to henceforth as asthma symptoms or medication use) consisted of the presence of at least one of the following criteria: (i) having an asthma attack in the last 12 months, (ii) having been woken by an attack of shortness of breath in last 12 months, or (iii) taking any asthma medication at the time of the interview (Kogevinas et al., 1999). The second definition (referred to henceforth as asthma symptom score) consisted of a simple sum of positive answers to five respiratory symptoms (i.e. a score range of 0–5): (i) wheezing with shortness of breath in last 12 months, (ii) woken with a feeling of chest tightness in last 12 months, (iii) attack of shortness of breath at rest in last 12 months, (iv) attack of shortness of breath after exercise in last 12 months, and (v) woken by attack of shortness of breath in last 12 months (Sunyer et al., 2007). Symptoms included in the asthma symptom score were also examined individually.

Rhinitis was defined as the occurrence of sneezing or a runny or a blocked nose, without having a cold or the flu, during the last 12 months. Chronic bronchitis was described as having cough and phlegm on most days for at least 3 consecutive months (American Thoracic Society, 2005). Lastly, eczema was defined as the appearance and disappearance of an itchy rash during at least 6 months in the last 12 months, in the folds of the elbows; behind the knees; in front of the ankles; under the buttocks; or around the neck, ears, or eyes (Weiland, 2004; Fieten et al., 2009).

Personal exposure to inhalable dust

Personal inhalable grain dust (particles with an aerodynamic mass median diameter <100 µm) samples were collected from all study participants. Ninety-nine workers were sampled once, 34 were sampled twice, and 3 were sampled three times (total of samples = 176; median time between measurements = 253 days, range = 2–364). All workers were sampled during ≥70% of their workday (median sampling time = 7.4 h, range = 5.6–10.1). Operators who did cleaning work (n = 14) were sampled during days in which they cleaned and also completed their typical job tasks [i.e. those associated with their job category (packing, dehulling, and unloading)].

Detailed methods for inhalable dust samples collection and analyses have been described previously (Rodríguez-Zamora et al., 2017). Briefly, dust samples were collected using sampling heads from the Institute of Occupational Medicine (IOM) with polyvinyl chloride filters (SKC Inc, 25 mm of diameter, 5.0 µm of pore size), cellulose support pads, and personal sampling pumps (Zefon, model ESCORT ELF) calibrated at a flow rate of 2.0 L/min (HSE, 2014). Dust samples were analyzed by gravimetry at the Instituto Tecnológico de Costa Rica (ITCR). The limit of detection (LOD) was defined as the average mass of the field blanks (n = 19) plus three times the standard deviation (SD) and was set at 0.2 mg; therefore, the concentration LOD ranged between 0.2 and 0.3 mg m^{-3} (calculated from the 0.2 mg per filter LOD and sample volume range of 0.67–1.21 m^3). Inhalable grain dust concentrations below the LOD (19%) were imputed using robust regression on order statistics, which is one of best imputation methods for environmental data sets with <50% censoring and single reporting limits (Helsel, 2011). Inhalable dust concentrations of those workers who were sampled more than once were then averaged.

Statistical analyses

Associations of personal inhalable grain dust concentrations with respiratory health outcomes, rhinitis, and eczema were examined using simple logistic regression (for dichotomous outcomes such as asthma symptoms or medication use) and negative binomial models (for the asthma symptom score) (Sunyer et al., 2007). The estimated adjusted Odds ratios (OR_a) represent the change in the odds of an outcome per 10-fold increase in inhalable dust concentrations, after adjusting for potential confounders. The OR_a for asthma symptom score represents the increase factor of the mean score per 10-fold increase in inhalable dust concentrations, after adjusting for confounders.

Age and smoking history were included *a priori* in regression models because they are known predictors of respiratory diseases, rhinitis, and eczema (Deacon and Paddle, 1998; Zock et al., 2001; Lindberg et al., 2005). Other potential confounders (i.e. education level, storage facility, time in current job category, grain type stored in facility, and having pets or farm animals in the home) were assessed using directed acyclic graphs and by adding them, one at a time, to the logistic regression and negative binomial models adjusted by age and smoking. If a confounder was associated with at least one of the outcomes of interest ($P < 0.10$), it was then included in all multivariate models (i.e. for all outcomes of interest).

To assess the robustness of the current findings and compare them with those from previous studies that did not measure and/or model exposure to grain dust as a continuous variable, several sensitivity analyses were conducted by modeling the exposure as a dichotomous variable: (i) operators versus administrative staff and other workers; (ii) exposures above versus below the corrected-TLV-TWA; and (iii) cleaning versus no cleaning tasks in addition to the regular job category tasks. Lastly, additional analyses including time in current job category (continuous variable) in the final adjusted models and stratifying by time in current job category (Ghosh et al., 2014) were conducted.

Results

Workers had a median (P25–P75) age of 31.0 (27.0–40.0) years and approximately half of them had completed high school (45%). Most workers had never smoked (69%), had a pet or farm animal in the home (62%), worked in a facility that stored rice (57%), and worked >50 h/week (64%; Table 1). Median (P25–P75) time working in the current storage facility and current job category were 4.2 (1.3–8.6) years and 3.4 (1.1–7.3) years, respectively. Operators and administrative staff and other workers differed in their education level, work shifts, and type of grain handled in the storage facility (chi-square P-values <0.01), but not in other sociodemographic and occupational characteristics (Table 1). Median (P25–P75) and range of averaged personal concentrations of inhalable dust in all workers were 2.0 (0.3–7.0) and <0.2–141.2 mg m^{-3}. Concentrations were higher in operators than in administrative staff and other workers [median (P25–P75) = 6.6 (4.0–15.9) versus 0.3 (<0.2–0.6) mg m^{-3}, respectively; Wilcoxon Mann–Whitney test P-value <0.01; Table 2].

The most prevalent individual asthma symptoms reported by the study participants were waking up with a feeling of chest tightness (25%) and shortness of breath after exercise in last 12 months (18%; Table 3). Twelve workers (9%) reported having had asthma symptoms or medication use in last 12 months, but only three (2%) had physician-confirmed asthma diagnosed during childhood (i.e. work-exacerbated asthma). Notably, 43% of workers reported having had at least one of the five respiratory symptoms of the continuous asthma symptom score and 9% had a score ≥3 (Table 3).

Higher inhalable grain dust concentrations were associated with increased odds of being woken by an attack of shortness of breath in last 12 months, having asthma symptoms or medication use, having an increased asthma symptom score, and presenting eczema, after adjusting for age, smoking history, grain type, and presence of pets or farm animals in the home (Table 3). When the exposure was modeled as a dichotomous variable based on job categories (i.e. operators versus administrative staff and other workers), instead of using personal inhalable dust concentrations, it was observed that operators had increased odds of shortness of breath after exercise in last 12 months, an increased asthma symptom score, and eczema, compared with administrative staff and other workers (Supplementary Table S1, available at *Annals of Occupational Hygiene* online). Furthermore, workers with grain dust exposures above the corrected-TLV-TWA of 2.4 mg m^{-3} had increased odds of being woken up with a feeling of chest tightness (OR_a = 2.5; 95% CI: 1.1–5.8), being woken by an attack of shortness of breath (OR_a = 2.2; 95% CI: 1.2–4.6), having asthma symptoms or medication use (OR_a = 2.2; 95% CI: 1.2–4.6), having an increased asthma symptom score (OR_a = 1.3; 95% CI: 1.1–1.6), and presenting eczema (OR_a = 8.4; 95% CI: 2.1–56.7), compared with workers exposed to dust levels below the corrected-TLV-TWA (Supplementary Table S2, available at *Annals of Occupational Hygiene* online). Similar findings were observed when exposure was modeled as cleaning versus not cleaning tasks (Supplementary Table S3, available at *Annals of Occupational Hygiene* online). Number of years in the current job category was moderately correlated with age (r = 0.51, P < 0.01) and its inclusion in the adjusted regression models did not change the observed effect estimates. Lastly, the variable years in current job category did not modify the exposure-outcome associations (<2 years, 2–6 years, and >6 years; data not shown).

Discussion

In this study of workers from grain storage facilities in Costa Rica, higher inhalable dust concentrations were associated with asthma and eczema. Working as an operator, having dust concentrations above the established occupational exposure limit, and cleaning in addition

Table 1. Socio-demographic and occupational characteristics of operators (n = 73) and administrative staff and other workers (n = 63) from grain storage facilities in Costa Rica, 2014–2015.

Characteristics	All workers, *n* (%)	Operators,[a] *n* (%)	Administrative staff and others,[b] *n* (%)	P^c
Age (years)				
18–25	26 (19)	16 (22)	10 (16)	0.68
26–32	48 (35)	25 (34)	23 (36)	
33–44	38 (28)	18 (25)	20 (32)	
45–65	24 (18)	14 (19)	10 (16)	
Education[d]				
≤6 grade	39 (33)	34 (55)	5 (9)	<0.01
7–11 grade	25 (21)	19 (31)	6 (11)	
Completed high school	54 (45)	9 (14)	45 (80)	
Smoking history				
Never smoked	93 (69)	47 (75)	46 (63)	0.26
Former smokers	29 (21)	12 (19)	17 (23)	
Current smokers	14 (10)	4 (6)	10 (14)	
Pets or farm animals in the home				
No	52 (38)	27 (37)	25 (40)	0.75
Yes	84 (62)	46 (63)	38 (60)	
Grain type stored in facility				
Rice	78 (57)	51 (70)	27 (43)	<0.01
Maize	42 (31)	18 (25)	24 (38)	
Wheat	16 (12)	4 (5)	12 (19)	
Work shift (h/week)				
<50	49 (36)	14 (19)	35 (56)	<0.01
50–60	39 (29)	17 (23)	22 (35)	
>60	48 (35)	42 (58)	6 (9)	
Time in current storage facility (years)				
<2	41 (30)	25 (34)	16 (25)	0.51
2–6	47 (35)	23 (32)	24 (38)	
>6	48 (35)	25 (34)	23 (37)	
Time in current job category (years)				
<2	49 (36)	28 (38)	21 (33)	0.51
2–6	47 (35)	22 (30)	25 (40)	
>6	40 (29)	23 (32)	17 (27)	

n, number of workers.
[a]Includes workers in unloading in pits, unloading in flat bed sheds, drying, dehulling, and packing.
[b]Includes administrative staff and other workers (purchasing agents, laboratory technicians, warehouse workers, forklift drivers, plant managers, mechanics, security officers, and weighers).
[c]Pearson's chi-squared test for count data *P*-values.
[d]Data missing for 18 workers (11 operators and 7 administrative staff and other workers).

to regular job tasks were also associated with increased odds of these respiratory and dermal health outcomes.

Consistent with studies of grain elevator workers in Canada (n = 610) (Chan-Yeung et al., 1980) and rice mill workers in India (n = 120) (Ghosh et al., 2014), grain dust exposure was associated with shortness of breath in this study. Importantly, shortness of breath is not only an asthma symptom, but also a COPD symptom (i.e. airflow limitation in the subjects with chronic cough or sputum production) (Perez-Padilla et al., 2013; Minov et al., 2016). Both asthma and COPD may occur simultaneously and the most common diagnostic criteria (e.g. acute responsiveness to inhaled bronchodilators) do not completely differentiate between them (Chhabra, 2005).

Table 2. Distribution of inhalable dust concentrations (mg m^{-3}) in workers from grain storage facilities in Costa Rica, 2014–2015.

	n	*K*	GM (GSD)	Min	Percentile			Max
					25th	50th	75th	
All workers	176	136	1.6 (8.1)	<0.2	0.3	2.0	7.0	141.2
Operators[a]	110	73	7.6 (3.7)	<0.2	4.0	6.6	15.9	141.2
Administrative staff and others[b]	66	63	0.3 (3.4)	<0.2	<0.2	0.3	0.6	4.5

n, number of samples; *k*, number of workers; GM, geometric mean; GSD, geometric standard deviation.
[a]Includes workers in unloading in pits, unloading in flat bed sheds, drying, dehulling, and packing.
[b]Includes administrative staff and other workers (purchasing agents, laboratory technicians, warehouse workers, forklift drivers, plant managers, mechanics, security officers, and weighers).

Table 3. Distribution of personal concentrations of inhalable grain dust (mg m^{-3}) and adjusted ORs for respiratory health outcomes, rhinitis, and eczema in workers from grain storage facilities in Costa Rica, 2014–2015 (*n* = 136).

Outcomes	Yes		No		OR_a (95% CI)[a]
	n (%)	Median (P25–P75)	*n* (%)	Median (P25–P75)	
Individual asthma symptoms in the last 12 months					
Breathless while wheezing	9 (7)	1.0 (0.3–6.2)	127 (93)	2.0 (0.3–7.3)	0.9 (0.4–1.8)
Woken up with a feeling of chest tightness	34 (25)	6.3 (0.3–9.3)	102 (75)	1.4 (0.3–6.3)	1.4 (0.9–2.2)
Attack of shortness of breath at rest	19 (14)	6.8 (0.3–15.0)	117 (86)	1.6 (0.3–6.5)	1.7 (0.9–3.2)
Attack of shortness of breath after exercise	25 (18)	6.2 (0.3–16.6)	111 (82)	1.9 (0.3–6.5)	1.6 (0.9–2.6)
Woken by attack of shortness of breath	12 (9)	7.8 (2.8–27.9)	124 (91)	1.5 (0.3–6.5)	2.7 (1.3–6.7)
Asthma symptoms or medication use	12 (9)	7.8 (2.8–27.9)	124 (91)	1.5 (0.3–6.5)	2.7 (1.3–6.7)
Continuous asthma symptom score[b]	*n* (%)		Median (P25–P75)		
0	78 (57)		1.3 (0.3–5.5)		Reference
1	33 (24)		1.3 (0.2–11.0)		1.2 (1.0–1.3)
2	13 (10)		6.5 (3.4–6.9)		
≥3	12 (9)		7.8 (0.9–53.4)		
Rhinitis	59 (43)	1.3 (0.3–7.5)	77 (57)	2.3 (0.4–6.5)	0.8 (0.6–1.2)
Chronic bronchitis	5 (4)	9.3 (0.8–64.2)	131 (96)	2.0 (0.3–6.7)	2.5 (0.8–11.2)
Eczema	14 (10)	7.8 (3.4–22.2)	122 (90)	1.2 (0.3–6.5)	3.6 (1.7–9.6)

n, number of workers.
[a]OR_a represents the change in the odds of presenting an adverse outcome per 10-fold increase in personal inhalable dust concentrations, adjusting for age, smoking history, grain type, and presence of pets or farm animals in the home.
[b]OR_a represents the increase factor of the mean asthma symptom score per 10-fold increase in personal inhalable dust concentrations, adjusting for age, smoking history, grain type, and presence of pets or farm animals in the home.

Data on asthma prevalence in adults in Latin American countries are limited (Vázquez-García et al., 2014). In this study, the prevalence of physician-diagnosed asthma (2%) was lower than the prevalence of asthma in populations aged >40 years from three Latin American cities (~5%; i.e. Montevideo, São Paulo, and Santiago) (Perez-Padilla et al., 2013). However, the prevalence of asthma symptoms or medication use (9%) in this study was higher than the physician-confirmed asthma prevalence reported in the study of three Latin American cities. The relatively low prevalence of physician-confirmed asthma found in this study may reflect under-diagnosis and poor disease control (Neffen et al., 2005; Vázquez-García et al., 2014).

The pathophysiology of grain dust-induced asthma is not well understood (Chan-Yeung et al., 1979; Tabona et al., 1984; Enarson et al., 1985; Blaski et al., 1996; Eduard, 2004). Based on some studies that have observed associations of grain dust exposure with clinical signs of atopy [e.g. altered allergic skin tests with microbial antigens, increased total serum immunoglobulin E (IgE) levels, and increased eosinophil blood counts (Lim et al., 1984; Ghosh et al., 2014)] and certain allergens that have been identified in grain dust [e.g. storage mite, durum wheat dust, beetles, cockroaches, mold (Frankland and Lunn, 1965; Jacobs et al., 1982; Warren et al., 1983; Jeebhay et al., 2005)], it has been suggested that atopy may be a significant determinant of respiratory symptoms in grain workers (Chan-Yeung et al., 1979; Enarson et al., 1985). However, several studies have found that grain dust-induced asthma and other airway diseases are not influenced by atopic status in exposed workers (Tabona et al., 1984; Blaski et al., 1996; Eduard, 2004) and have suggested that mechanisms other than an allergic reaction [e.g. endotoxins of Gram-negative bacteria in organic dust (Nightingale et al., 1998; Douwes et al., 2002; Eduard, 2004)] are likely responsible for respiratory diseases. Unfortunately, this study did not include allergy tests for atopy or sensitivity determinations to grain dust allergens in workers and no information on family history of atopy was collected, so it was not possible to differentiate between allergic and irritant asthma.

A few studies have found a lower prevalence of atopy in workers with higher exposures to grain dust (Chan-Yeung et al., 1980; Dimich-Ward et al., 2011), possibly due to a healthy worker effect associated to survivor bias [i.e. atopic workers develop symptoms immediately upon entry to the workplace and will consequently resign or be assigned to other job categories when their symptoms become serious (Broder et al., 1985; Chan-Yeung, 1989)] and/or hire effects [i.e. rejecting new workers depending on atopic status, by for instance pre-employment examinations (Heederik, 2006)].

The rhinitis prevalence found in this study was about six times higher than the prevalence of physician-diagnosed allergic rhinitis estimated for the general Latin American population (~7%) (Meltzer et al., 2012), but this outcome was not associated with grain dust exposure. It is important to point out that atopy is a risk factor of rhinitis (Siracusa et al., 2000) that was not taken into consideration in the adjusted models and could have biased the dust exposure-rhinitis association toward the null. Additionally, the possibility that workers who were less exposed to inhalable grain dust might have also been exposed to other allergens or irritant agents that could have caused rhinitis-like symptoms cannot be ruled out. For example, in this study, administrative staff and other workers could be suffering cold-induced rhinorrhea (Silvers, 1991) because they were exposed to air conditioning in their offices with temperatures ~20°C, up to 10°C lower than the temperature outside their offices.

Previous studies that have examined the association between grain dust exposure and rhinitis have reported inconsistent findings (Chan-Yeung et al., 1980; Lim et al., 1984; Hogan et al., 1986; Deacon and Paddle, 1998; Ghosh et al., 2014; Straumfors et al., 2016). For instance, studies of rice mill workers from India (Ghosh et al., 2014) and Malaysia (Lim et al., 1984) and grain elevator workers from Canada (Hogan et al., 1986) observed positive associations of grain dust exposure with rhinitis. In contrast, in a study of workers from a maize, wheat, and rice cereal manufacturing plant in England (n = 570) (Deacon and Paddle, 1998) rhinitis was not associated with grain dust exposure. Similarly, a study of workers from grain and animal feed production facilities in Norway (n = 92) found that higher dust levels of fungal spores, but not personal inhalable dust concentrations, were associated with self-reported rhinitis (Straumfors et al., 2016). Inconsistent results between studies could be attributable to differences in socio-demographic characteristics of the study populations, grain dust composition (Burch et al., 2010; Poole et al., 2010), exposure assessment methods [e.g. quantitative (Straumfors et al., 2016) versus qualitative (Deacon and Paddle, 1998; Ghosh et al., 2014)], or outcome definitions [e.g. sneezing or a runny or a blocked nose, without having a cold or the flu (this study) versus nose irritation (Deacon and Paddle, 1998; Ghosh et al., 2014)].

A low prevalence of chronic bronchitis was observed in this study population, which was consistent with the one found in a study of Norwegian farmers responsible for harvesting (n = 4735) and a study of Australian workers exposed to organic dust (n = 1213) (4% in both studies) (Matheson, 2005; Eduard et al., 2009). Notably, these two studies observed significant exposure-outcome associations (OR for chronic bronchitis = 1.3; 95% CI: 1.1–1.6 and 1.7; 95% CI: 1.0–3.1, respectively), whereas no association was observed in this study. Studies of grain workers from Macedonia (n = 37) (Minov et al., 2016) and rice mill workers from India (n = 120) (Ghosh et al., 2014) also found significant associations of dust exposure with chronic bronchitis. Workers' relatively young age, short-term exposures to grain dust (median <5 years working in current storage facility), and mostly non-smoking habits (Zock et al., 2001; Lindberg et al., 2005; Minov et al., 2016) could explain the relatively low prevalence of chronic bronchitis in this study population and its lack of association with dust exposure; its small study sample size could also explain this null association. Furthermore, this cross-sectional study could have been biased due to a healthy worker effect, which would have underestimated the health effects of grain dust exposure and biased the effect estimates towards the null (Pearce et al., 2007). To address the potential impact of the healthy worker effect due to survivor bias in this study, workers were asked if they had switched job categories because their job was affecting their breathing or causing them some allergy. They all confirmed that this had not happened since they had started their job in the current storage facility. It was not possible to determine if survivor bias due to resign the facility or hire effects had occurred before this survey because the corresponding data were not collected.

Few published studies have examined the association between grain dust exposure and skin-related outcomes (Lim et al., 1984; Hogan et al., 1986; Straumfors et al., 2016), and none of them has focused on eczema. Studies of rice mill workers in Malaysia (n = 122) (Lim et al., 1984) and grain elevator workers in Canada (n = 1954) (Hogan et al., 1986) found that workers exposed to grain dust complained of pruritus. On the other hand, a small study of workers from grain and animal feed manufacturing facilities in Norway (n = 92) observed no association between dust exposure and skin rash (Straumfors et al., 2016). In this study, exposure to inhalable dust was associated with increased odds of eczema (based on self-reported signs and symptoms). Some occupational and non-occupational factors such as individual genetic predisposition, exposure to common environmental allergens (e.g. house dust mite and pollen grains), air chemical pollutants (e.g. exhaust fumes of cars, volatile organic compounds, nitrogen dioxide), ingredients in personal care products, and food additives have also been identified as risk factors for eczema in adults (Montnemery et al., 2003; Tanei, 2009; Worth and Sheikh, 2010); nevertheless, these factors were not assessed in this study. Prospective cohort studies of grain workers that take into account the influence of these factors on the incidence of eczema are warranted.

This study has several limitations. First, its small sample size and possible lack of representativeness limited its statistical power, which nonetheless was sufficient to detect significant associations. Second, the possibility that some associations in this cross-sectional analysis were biased due to a healthy worker effect cannot be ruled out. Third, the cross-sectional nature of this study prevents from establishing a causal relationship or estimating incidence rates of asthma, chronic bronchitis, rhinitis, and eczema due to occupational exposure to grain dust. Fourth, because symptoms and signs were self-reported, the possibility that there might have been reporting or information bias in the responses provided by exposed (i.e. operators) and unexposed (i.e. administrative staff and others) workers (Hernández and Velasco-Mondragón, 2000) cannot be discarded. Finally, this study did not include clinical assessments of the workers' allergic status. Future studies would benefit from using objective measures of respiratory and allergic health outcomes such as lung function tests, chest X-rays, and allergy tests with microbial antigens.

This study contributes to the existing literature by examining the respiratory health outcomes, rhinitis, and eczema associated with grain dust exposure in Costa Rican workers, an occupational health research topic that, to date, has not been assessed in the Central American region. Additional strengths of this study include the use of a validated questionnaire to collect information on health outcomes and the replication of a continuous asthma symptom score that allowed to reduce disease misclassification errors and increase statistical power to examine the associations of interest (Sunyer et al., 2007). It was also possible to examine and/or adjust regression models for several confounders, such as presence of pets and farm animals in the home. Although no objective information on atopy or specific sensitization to grain dust allergens was collected in this study, evidence indicates that rhinitis and eczema may be indicators of atopy (Siracusa et al., 2000; Tanei, 2009; Meltzer et al., 2012).

Findings from this study indicate that workers are highly exposed to inhalable dust in grain storage facilities, particularly operators, and that higher grain dust exposures are associated with respiratory and dermal health outcomes. Therefore, implementing measures to reduce grain dust exposure (e.g. installation of local extraction systems near sources of emission, preventive maintenance of machinery, use of personal protective equipment) and establishing adequate health surveillance systems to reduce the risk of respiratory and allergic diseases are recommended.

Supplementary data

Supplementary data are available at *Annals of Work Exposures and Health* online.

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Contributions

M.G.R. participated in the study design, fieldwork supervision, data analyses, and preparation and editing of the manuscript.

J.P.Z. and B.W.J. collaborated in the study design and editing of the manuscript. A.M.M. participated in the study design, supervision of data analyses, and preparation and editing of the manuscript.

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Conflicts of interest

The authors declare no conflict of interest relating to the material presented in this article. Its contents, including any opinions and/or conclusions expressed, are solely those of the authors.

Participant consent

Obtained.

Ethical approval

The activities and instruments of the study were approved by the Scientific Ethics Committee of the Universidad Nacional, Costa Rica.

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