

Risk factors associated with allergic sensitization and asthma phenotypes among poultry farm workers

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Background: This study investigated the risk factors for occupational allergic sensitization and various asthma phenotypes in poultry-workers.

Methods: A cross-sectional study of 230 workers used a modified ECRHS questionnaire, spirometry, FeNO, Phadiatop, and sIgE to poultry farming related allergens.

Results: Worker's mean age was 37 ± 9 years, 68% male, 43% current-smokers, 34% atopic, and 5% casual-workers. The prevalence of non-atopic asthma (NAA = 7%) was higher than atopic-asthma (AA = 5%) and probable allergic occupational-asthma (OA = 3%). Sensitization to at least one poultry farming related allergen was 24%. Workers sensitized to chicken-specific-allergens were more likely to be atopic ($OR_{unadj} = 20.9$, 95%CI: 4.7-93.2) or employed as casual-workers ($OR_{unadj} = 6.0$, 95%CI: 1.1-35.9). Work-related chest symptoms were associated the rearing-department ($OR_{adj} = 3.2$, 95%CI: 1.2-8.4) and exposure to high gas/dust/fumes ($OR_{adj} = 4.8$, 95%CI: 2.4-9.5). Airflow reversibility ($OR_{adj} = 10.9$, 95%CI: 2.0-60.3) was significantly associated with casual-work status.

Conclusion: Allergic and non-allergic mechanisms play a role in asthma development among poultry-workers with casual workers demonstrating increased risk.

KEYWORDS

allergic sensitisation, occupational asthma, poultry

1 | INTRODUCTION

Agricultural production is associated with a spectrum of different occupational diseases.¹ Workers involved in animal production,

particularly poultry workers, have been shown to have a greater prevalence of respiratory symptoms than other farmers.² This is due to exposure to diverse and potentially hazardous airborne agents including dust particulate, allergens, endotoxins, micro-organisms, chemical pollutants, and organic gases.³

Both acute and chronic work-related respiratory symptoms have been reported in poultry workers exposed to these pollutants.⁴ The

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extent to which airborne agents cause rhinitis and asthma depends on various environmental risk factors such as the overall design and operation of the poultry facilities, the level of exposures, and concomitant exposure to multiple respiratory sensitizers.^{4,5} Furthermore, other host associated risk factors such as age, atopy, and smoking have been associated with rhinitis and asthma in poultry workers.^{2,4}

Although an association between poultry work and work-related respiratory diseases has been demonstrated, very few studies have reported on the extent to which occupational sensitization to specific allergens present in poultry dust constitutes a risk to the health of poultry workers. This study investigated the prevalence and risk factors associated with occupational allergic sensitization and various asthma phenotypes in poultry workers.

2 | MATERIALS AND METHODS

2.1 | Study design, population, and sampling

A cross-sectional study of currently employed poultry farm workers from a commercial poultry farm, employing 1483 workers, was conducted in the North West Province, South Africa. Workers were categorized into high medium and low exposure groups based on the initial walk through inspections where visual estimation of poultry dust and bioaerosol exposure was conducted. Workers were further categorized into five major exposure groups (rearing, laying, hatchery, broiler, and catching departments) based on the tasks performed in the farm. Proportionate sampling of participants was done from these five exposure groups, with aim of obtaining 20% from each exposure group. Written informed consent was sought from workers before embarking on the project. While the calculated sample size was 296, 230 workers finally agreed to participate in the study giving a response rate of 78%.

2.2 | Poultry farming work process

The poultry farming processes involved five major departments viz rearing, laying, hatchery, broiler, and catching. In rearing farms, chickens are procured and reared until they are 21 weeks old after which they are transferred to laying farms. In the laying farms, hens and cocks are mated and fertile hens lay their eggs until they are 60 weeks old after which they are sold. There are two systems for laying eggs viz automatic and manual systems. The main task of workers is to collect eggs from nests five times per day. Workers spend more than half a day inside poultry houses with manual egg collection system as compared to 3 h in automated egg collection system. In the hatchery, eggs are hatched under controlled temperature and humidity conditions before being transferred to broiler farms. The day old chicks are raised to 32–35 days in the broiler farms before they are transferred to the factory for slaughtering. Broiler farms are categorised in two groups viz small farms that house $\leq 20\,000$ chickens and large farms housing $>20\,000$ chickens. The transfer of chickens between the various processes are done by catchers who are outsourced to a service provider. This task is done at every growth cycle of the chickens.

2.3 | Health outcome assessment

2.3.1 | Questionnaire

The study questionnaire used was a modified version of the European Community Respiratory Health survey (ECRHS II) incorporating work-related aspects (exposures and symptoms) adapted for local conditions.⁶ The interviewer administered questionnaire collected information on important demographic factors, work-related respiratory and skin symptoms, history of previous illnesses, employment history, degree of exposure to bioaerosols, and smoking status.

2.3.2 | Immunological tests

Serum analysis was performed to determine the presence of atopy and specific IgE to commercially available poultry associated allergens viz storage mite (*Lepidoglyphus destructor*), sunflower seed (*Helianthus annuus*), and mould mix (containing *Penicillium chrysogenum*, *C. herbarum*, *A. fumigatus*, *C. Albicans*, *A. alternata*, *S. rostrata*) using the UniCAP Phadia system. The sera were also tested for specific IgE to chicken specific allergens such as meat, feathers, serum protein, and droppings. Allergen extracts from chicken related sources were collected from the farms and were prepared in-house. Allergens extracts were prepared according to LABSOP01v1 (Occupational and Environmental health group, Netherlands) and then labeled with biotin. The biotin protein labeled extracts were loaded onto the streptavidin ImmunoCAP and quantified for chicken specific allergens using the sera of participants. An ImmunoCAP value ≥ 0.35 kUA per litre was considered positive.

2.3.3 | Spirometry

Lung function tests were performed using a computerised portable spirometer (EasyOne™ Diagnostic Spirometer). Spirometers were calibrated at least twice a day with a three-litre syringe under controlled temperature and humidity. The procedure was performed according to the American Thoracic Society (ATS)/European Respiratory Society (ERS) recommendations for spirometry by an experienced technologist who was blinded to the exposure status of each worker.⁷ Reproducibility criteria entailed the two best tracings for both FEV₁ and FVC varying by no more than 150 mL or 5%, whichever was greater. The best FEV₁ and FVC were used regardless of whether they belonged to the same tracing. An increase in FEV₁ $\geq 12\%$ and ≥ 200 mL after inhalation of a short-acting β_2 agonist salbutamol (400 mg) was regarded as a significant airway reversibility suggestive of asthma. Predicted values were calculated using the Global Lung Initiative (GLI) reference equations.

2.3.4 | Fractional exhaled nitric oxide

A hand-held portable sampling device (NIOX MINO) was used to determine FeNO during the work shift according to American Thoracic Society (ATS)/European Respiratory Society (ERS) recommendations.^{8,9} Testing of workers occurred throughout the working week and work

shift, with no particular variation with regard to time of testing in the different departments. Two technically adequate FeNO efforts were performed on each worker and an average was determined. Special instructions were given to workers to refrain from smoking, eating or drinking (at least 1 h) before the test. Those with recent chest infections were tested at a later stage after resolution of their symptoms. A value >50 ppb was considered to be indicative of allergic airway inflammation.⁹

2.3.5 | Definition of main predictor variables

Work related skin symptoms were defined as self-reported history of having skin symptoms that get worse at work and better when off work.

Poultry product ingestion related reactions were defined as self-reported reactions following ingestion of poultry products.

Atopy was defined as sensitization to common aeroallergens signified by a positive Phadiatop test (≥ 0.35 kUA/l)

2.3.6 | Operational definitions of asthma phenotypes

Current asthma was defined as the presence of either an attack of shortness of breath, an attack of asthma or use of asthma medication (ECRHS).¹⁰

Atopic asthma (AA) was defined as either an attack of shortness of breath, an attack of asthma or use of asthma medication; and presence of atopy or FeNO >50 ppb.

Non-atopic asthma (NAA) was defined as either an attack of shortness of breath, an attack of asthma or use of asthma medication; and absence of atopy.

Probable occupational allergic asthma (OA) was defined as either an attack of shortness of breath, an attack of asthma or use of asthma medication; and sensitization to poultry work related allergens viz storage mite, sunflower seed, mould mix, chicken meat, feathers, serum protein, and droppings.

2.3.7 | Statistical analysis

Data was analysed using STATA V.12 computer software (StataCorp, College Station, Texas). The main associations of interest were between risk factor variables (host and environmental) and important clinical endpoints viz work-related ocular-nasal and chest symptoms; airway inflammation (FeNO >50 ppb); reversible airway obstruction (FEV₁ increase $\geq 12\%$ and ≥ 200 mL post-bronchodilator); allergic sensitization; and asthma phenotypes (AA, NAA, OA). These were first explored using bivariate analysis demonstrating age and gender to be potential confounders. These variables together with smoking status were then added in the saturated multivariate logistic regression models.

3 | RESULTS

3.1 | Demographic characteristics

The demographic characteristics of the study population are outlined in Table 1. Subjects were predominantly male (68%), the mean age was

37 (range: 21-68) years, 44% were current smokers having an average 5 pack-year smoking history, with a significantly greater proportion of male than female smokers (Pearson chi-square $P < 0.001$). A family history of atopy was reported in 13% of the workers. All workers reported habitual consumption (At least 2-3 times per month) of chicken products with 4% reporting allergic reactions following ingestion of poultry products viz chicken canned food, chicken feet, livers, tripe, skin, eggs, and spice.

3.2 | Occupational history

Most participants worked in the laying department (36%), broiler (30%), and hatchery (23%) (Table 1). The mean duration of employment in the farm was 5.3 years and was similar to the 4.9 years employed in the current job. A high proportion of workers (95%) worked day shift with 5% employed on a casual basis. About 25% workers had less than 2 years of employment. A large proportion (97%) of workers reported their current job to produce dust, with 72% reporting very high levels. The majority of workers (89%) reported wearing respiratory protective equipment for an average duration of 4 years. Other personal protective equipment used by employees included aprons (68%), goggles (80%), and gloves (78%). Only 68% of workers reported receiving safety training on the risks associated with poultry farming with no difference in the training between casual workers and full-time workers.

3.3 | Respiratory symptoms

Chest symptoms (any one of tight chest wakening, wheeze, shortness of breath, shortness of breath wakening) were reported by 7-15% of workers, with 23% having work-related symptoms (Table 1). Based on the ECRHS definition of asthma (presence of either an attack of shortness of breath, an attack of asthma, or use of asthma medication)¹⁰, 12% of workers had symptoms suggestive of asthma. About 5% reported symptoms suggestive of chronic bronchitis and these were more likely to be current smokers (OR = 7.36, 95%CI: 1.21-44.80) (data not shown). The prevalence of work-related ocular-nasal symptoms (46%) was double that of work-related chest symptoms (23%). About 48% of workers reported an episode of high exposure to gas, dust and fumes (GDF) causing tight chest, wheeze or cough. The most commonly reported work-related agents suspected to cause respiratory symptoms by subjects ($n = 53$) included poultry dust (74%), chicken feathers (47%), bedding (9%), and chicken feed (8%). Job change due to work-related chest symptoms was reported by eight workers (3%) all of whom reported GDF causing respiratory symptoms.

3.4 | Patterns of allergic sensitization

The overall prevalence of atopy in this population was 34%, with atopic workers having a higher prevalence of sensitization to poultry work related allergens (Table 2). The prevalence of sensitization to at least one poultry work related allergen was 24%, with sensitization to sunflower seeds (13.0%), and storage mites (13.0%) being the most prevalent. The prevalence of sensitization to at least one chicken

TABLE 1 Demographic, employment characteristics, and respiratory symptom experience of poultry farm workers

Characteristics (n = 230)	
Age (years)	37 ± 9
Gender (%M:F)	68:32
Obesity (BMI >30 kg/m ²)	39 (17)
Smoking status	
Never-smokers	129 (56)
Current smokers	98 (43)
Ex-smokers	3 (1)
Pack-year history of current smokers (pack-years)	4.6 ± 3.8
Department (exposure group)	
Hatchery	52 (23)
Rearing	22 (10)
Laying	83 (36)
Broiler	68 (30)
Catching	5 (2)
Employment status	
Duration of employment in poultry farm (years)	5.3 ± 6.2
Duration of employment in current job (years)	4.9 ± 6.0
Permanent job status	218 (95)
No. <2 years employment	59 (25)
Past history of lung disease (self-reported)	
Previous treatment for tuberculosis	9 (4)
Repeated childhood chest infections	7 (3)
Previous treatment chronic bronchitis	3 (1)
Family history of atopy	30 (13)
Self-reported adverse reactions to	
Chicken products ^a	6 (2.61)
Eggs	2 (0.87)
Chicken spice	1 (0.43)
Upper airway symptoms	
Work-related ocular-nasal symptoms	105 (46)
Asthma history	
Doctor diagnosed asthma	2 (1)
<17 years	1 (0.5)
≥17 years	1 (0.5)
Wheezing or whistling in chest in the past year	35 (15)
Woken up with a tight chest in the past year	17 (7)
Shortness of breath in the past year	26 (11)
Woken up with shortness of breath in the past year	21 (9)
Asthma attack in the past year	2 (1)
Work-related asthma symptoms	
Work-related chest symptoms	54 (23)
Episode of high exposure to GDF causing tight chest, wheeze or cough	110 (48)

(Continues)

TABLE 1 (Continued)

Characteristics (n = 230)	
Job change due to work-related chest symptoms	8 (3)

GDF, gas dust and fumes; Never-smoker, lifelong abstinence; Ex-smoker, quit completely more than one month prior to survey. Continuous variables, mean ± SD; categorical variables, number (%).

^aChicken canned food, chicken feet, livers, tripe, and skin.

specific allergen was lower (8%), with chicken droppings being the most common sensitizer (6%). A statistically significant correlation was found between sensitization to chicken droppings and serum protein (Spearman's-rho 0.65, $P < 0.001$).

3.5 | Pulmonary function tests

Although 19% of the workers had FEV₁ less than 80% of predicted, only 7% of the workers showed evidence of probable chronic obstructive lung disease (FEV₁/FVC % predicted less than the 5th centile) (Table 3). Significantly more males than females showed evidence of airway obstruction (FEV₁/FVC <70%). Overall, the prevalence of non-atopic asthma (NAA = 7%) was slightly higher than atopic (AA = 5%) and probable occupational allergic asthma (OA = 3%).

3.6 | Host risk factors associated with clinical endpoints

Simple logistic regression analysis revealed a significant association between increasing age and features suggestive of probable obstructive lung disease (OR = 1.10, 95%CI: 1.03-1.16) and AA (OR = 1.06, 95%CI: 1.01-1.13) (Table 4). Atopy was associated with presence of airway inflammation (FeNO >50 ppb; OR = 3.04, 95%CI: 1.11-8.34), sensitization to chicken specific allergens (OR = 20.90, 95%CI: 4.69-93.21) and sensitization to at least one poultry work related allergen (OR = 43.45, 95%CI: 17.00-111.05). Workers sensitized to chicken specific allergens (OR = 5.46, 95%CI: 1.28-23.18) and those with AA (OR = 5.86, 95%CI: 1.08-31.67) were more likely to report adverse reactions following ingestion of poultry products. Sensitization to at least one poultry work related allergen was more likely to occur in males (OR = 2.03, 95%CI: 1.00-4.13). Subjects with work-related ocular nasal symptoms were more likely to be obese (OR = 2.17, 95%CI: 1.07-4.40) and report work-related skin symptoms (OR = 3.05, 95%CI: 1.13-8.25).

3.7 | Environmental risk factors associated with allergic respiratory disease and asthma

The adjusted (OR_{adj}) and unadjusted (OR_{unadj}) odds ratios for association between environmental risk factors and health outcome measures of interest were essentially similar. Table 5 presents these analyses adjusted for age, gender, and smoking. Workers with work-related ocular nasal symptoms (OR_{unadj} = 2.89, 95%CI: 1.69-4.94; OR_{adj} = 2.73, 95%CI: 1.58-4.73), chest symptoms (OR_{unadj} = 4.89, 95%CI: 2.44-9.78; OR_{adj} = 4.73, 95%CI: 2.35-9.54) and NAA (OR_{unadj} = 3.89, 95%CI: 1.23-12.31; OR_{adj} = 3.65, 95%CI: 1.13-11.76) were more likely to

TABLE 2 Allergic sensitization profiles among poultry farm workers

Allergic sensitization profile			
Allergen	Overall prevalence (%) (n = 230)	Atopic prevalence (%) (n = 78)	Non-atopic prevalence (%) (n = 152)
IgE to house dust mites			
<i>D. pteronyssinus</i>	57 (25)	53 (68)***	4 (3)
<i>D. farinae</i>	54 (23)	54 (69)***	0 (0)
IgE to poultry associated allergens			
Storage mite (<i>L. destructor</i>)	29 (13)	26 (33)***	3 (2)
Sunflower seed (<i>Helianthus annuus</i>)	29 (13)	27 (35)***	2 (1)
Mould mix (<i>Penicillium chrysogenum</i> , <i>C. herbarum</i> , <i>A. fumigatus</i> , <i>C. albicans</i> , <i>A. alternata</i> , <i>S. rostrata</i>)	18 (8)	16 (21)***	2 (1)
IgE to chicken-specific allergens			
Droppings	14 (6)	12 (15)***	2 (1)
Feathers	5 (2)	5 (6)**	0 (0)
Meat	2 (0.87)	2 (3)*	0 (0)
Serum protein	1 (0.43)	1 (1)	0 (0)
Sensitization to at least one chicken specific allergen	19 (8)	17 (22)***	2 (1)
Sensitization to at least one poultry work related allergen	56 (24)	50 (64)***	6 (4)

* $P < 0.05$.** $P < 0.01$.*** $P < 0.001$.

report an episode of exposure to high gas, dust, and fumes (GDF) causing asthma like symptoms.

Workers with work-related chest symptoms were more likely to work in the rearing department ($OR_{unadj} = 2.51$, 95%CI: 1.01-6.24; $OR_{adj} = 3.18$, 95%CI: 1.20-8.81). Presence of reversible airway obstruction was positively associated with the casual work status ($OR_{unadj} = 6.35$, 95%CI: 1.44-28.00; $OR_{adj} = 10.85$, 95%CI: 1.95-60.26) as well as employment in small broiler farms ($OR_{unadj} = 10.07$, 95%CI: 1.01-104.61; $OR_{adj} = 10.21$, 95%CI: 1.02-124.44). Workers sensitized to at least one poultry work related allergen were more likely to have

<2 years compared to >6 years of employment ($OR_{unadj} = 2.91$, 95%CI: 1.15-7.34; $OR_{adj} = 2.60$, 95%CI: 1.01-7.34).

In further analysis of sensitization trends, the proportion of workers sensitized to at least one poultry work related allergen declined with increasing years of employment (chi-square trend $P = 0.023$).

4 | DISCUSSION

The findings of this study are consistent with other studies that show poultry workers are at increased risk of allergic sensitization and asthma

TABLE 3 Pulmonary function indices among poultry farm workers

Pulmonary function indices			
	Overall (n = 185)	Males (n = 131)	Females (n = 54)
FEV ₁ (litres)	3.13 ± 0.70	3.36 ± 0.66	2.55 ± 0.44**
FVC (litres)	3.77 ± 0.80	4.07 ± 0.69	3.03 ± 0.48**
FEV ₁ % predicted	92.58 ± 13.03	92.45 ± 13.77	92.90 ± 11.15
FEV ₁ /FVC	0.83 ± 0.06	0.83 ± 0.07	0.84 ± 0.04
FEV ₁ /FVC <70%	9 (5)	9 (7)	0 (0)*
FEV ₁ /FVC <lower limit of normal	13 (7)	12 (9)	1 (2)
FEV ₁ <80% predicted	25 (14)	19 (15)	6 (11)
FEV ₁ increase ≥12% and ≥200 mL post-bronchodilator	14 (8)	11 (8)	3 (6)
FeNO >50 ppb	17 (7)	11 (7)	6 (8)
FEV ₁ /FVC ratio post-bronchodilator (<5th percentile)	12 (7)	11 (8)	1 (2)

Reference values for lung indices are from the Global Lung Initiative (GLI) equations. Continuous variables, mean ± SD; categorical variables, number (%).

* $P < 0.05$.** $P < 0.01$.

TABLE 4 Host risk factors associated with allergic respiratory disease and asthma in poultry farm workers using unadjusted logistic regression models

Outcome	OR (95%CI)						
	Age	Gender (male)	Atopy	Work-related skin symptoms	Obesity (BMI >30 kg/m ² vs BMI <30 kg/m ²)	Smoking (current vs never)	Poultry product ingestion related reactions ^a
Work-related ocular-nasal symptoms	1.01 (0.98-1.04)	0.61 (0.35-1.06)	1.03 (0.60-1.78)	3.05 (1.13-8.25)	2.17 (1.07-4.40)	0.93 (0.55-1.57)	2.90 (0.73-11.53)
Work-related chest symptoms	0.98 (0.96-1.02)	0.68 (0.36-1.28)	0.97 (0.51-1.84)	1.45 (0.53-3.97)	1.58 (0.74-3.38)	0.29 (0.49-1.71)	2.26 (0.62 to 8.35)
Sensitization to chicken specific allergens	0.95 (0.90-1.01)	2.70 (0.76-9.59)	20.90 (4.69-93.21)	1.26 (0.27-5.90)	0.55 (0.12-2.50)	1.52 (0.59-3.89)	5.46 (1.28-23.18)
Sensitization to at least one poultry work related allergen	0.98 (0.95-1.02)	2.03 (1.00-4.13)	43.45 (17.00-111.05)	1.37 (0.50-3.76)	0.92 (0.41-2.08)	1.31 (0.72-2.40)	2.15 (0.59-7.93)
FEV ₁ increase ≥12% and ≥200 mL post-bronchodilator	1.00 (0.94-1.06)	1.57 (0.42-5.87)	0.31 (0.67-1.41)	0.79 (0.10-6.50)	0.39 (0.05-3.10)	2.21 (0.71-6.87)	1.55 (0.18 to 13.43)
FEV ₁ /FVC ratio post bronchodilator (<5th percentile)	1.10 (1.03-1.16)	4.90 (0.62-38.92)	0.64 (0.17-2.45)	0.95 (0.11-7.88)	0.47 (0.06-3.77)	2.45 (0.71-8.84)	*
FeNO >50 ppb	0.96 (0.90-1.01)	0.86 (0.31-2.42)	3.04 (1.11-8.34)	*	1.05 (0.29-3.86)	0.41 (0.13-1.33)	*
Atopic asthma	1.06 (1.01-1.13)	1.28 (0.33-4.97)	*	1.05 (0.13-8.67)	1.09 (0.23-5.27)	2.4 (0.68-8.46)	5.86 (1.08-31.67)
Non-atopic asthma	0.99 (0.94-1.05)	0.86 (0.31-2.42)	*	0.64 (0.08-5.08)	1.56 (0.48-5.08)	1.76 (0.63-4.91)	3.42 (0.67-17.54)
Probable occupational allergic asthma	1.04 (0.97-1.12)	0.78 (0.18-3.37)	*	1.53 (0.18-13.07)	1.67 (0.32-8.56)	1.33 (0.32-5.45)	3.38 (0.38-30.48)

OR, each OR is a separate unadjusted regression model.

^aSelf-reported adverse reactions to poultry products following ingestion.

*OR not calculable.

TABLE 5 Multivariate logistic regression models of environmental risk factors associated with allergic respiratory disease and asthma of in poultry farm workers using adjusted models

Outcome	OR (95%CI)						
	Casual vs permanent work	Years of employment <2 years vs >6 years	Rearing (vs other areas of work)	Automated vs manual egg laying activities (n = 83)	Employment in small vs large broilers ^a (n = 68)	Episode of high GDF exposures causing asthma symptoms	
Work-related ocular-nasal symptoms	0.15 (0.02-1.24)	1.05 (0.45-2.46)	2.12 (0.83-5.42)	0.49 (0.19-1.25)	0.58 (0.17-1.98)	2.73 (1.58-4.73)	
Work-related chest symptoms	*	0.95 (0.32-2.82)	3.18 (1.20-8.41)	1.80 (0.62-5.21)	0.37 (0.06-2.15)	4.73 (2.35-9.54)	
Sensitization to chicken specific allergens	3.68 (0.83-16.41)	1.36 (0.22-8.41)	0.90 (0.19-4.35)	0.89 (0.19-4.08)	*	0.68 (0.25-1.84)	
Sensitization to at least one poultry work related allergen	0.99 (0.24-4.06)	2.60 (1.01-7.34)	1.00 (0.36-2.80)	0.77 (0.26-2.31)	0.42 (0.10-1.77)	1.04 (0.56-1.93)	
FEV ₁ increase ≥12% and ≥200mL post- bronchodilator	10.85 (1.95-60.26)	2.60 (0.41-16.49)	1.28 (0.25-6.53)	*	10.21 (1.02-124.44)	0.90 (0.29-2.78)	
FEV ₁ /FVC ratio post bronchodilator (<5th percentile)	*	0.79 (0.15-4.15)	1.32 (0.24-7.31)	*	0.73 (0.05-9.75)	1.96 (0.56-6.89)	
FeNO >50 ppb	1.76 (0.26-11.94)	0.22 (0.04-1.35)	1.67 (0.31-8.89)	0.74 (0.09-6.27)	0.73 (0.05-10.19)	0.49 (0.17-1.47)	
Atopic asthma	*	0.61 (0.09-4.17)	0.74 (0.08-6.60)	0.27 (0.02-3.18)	*	1.98 (0.55-7.13)	
Non-atopic asthma	*	0.38 (0.08-1.82)	0.44 (0.05-3.92)	0.85 (0.14-5.17)	*	3.65 (1.13-11.76)	
Probable occupational allergic asthma	*	0.96 (0.12-7.96)	1.46 (0.15-14.22)	0.35 (0.03-4.52)	*	1.82 (0.42-7.89)	

FeNO, fractional exhaled nitric oxide; OA, occupational allergic asthma; GDF, Gas, dusts and fumes (GDF). Each OR represents a separate model adjusted for age, gender and smoking status.

^aBroiler houses with ≤ 20 000 chickens = small broilers, >20 000 chickens = large broilers.

*OR not calculable.

with non-atopic asthma being the most prevalent asthma phenotype in this group of workers. Moreover, it demonstrates that sensitization to poultry work related allergens develops early during employment within the first 2 years. The study also suggests that casual workers have an increased risk of respiratory disease compared to permanent workers.

The findings of this study demonstrated that one third of workers (34%) were atopic with sunflower seed and storage mites being the most common sensitizers (13%), on the other hand chicken droppings were the most common chicken specific allergen (6%). The prevalence of atopy reported in this study is similar to previous studies conducted among poultry workers.^{5,11} The specific sensitization to sunflower seeds is probably due to inhalation of sunflower seed husk used as bedding in poultry houses. Occupational exposure to sunflower seed with subsequent sensitization has been reported in animal food processing and in bakery workers.^{12,13} Chicken droppings have also been previously reported as the most common sensitizers in other poultry farms in South Africa.⁵ Chicken droppings are known to contain excreted serum protein antigens, which may explain a strong correlation (Spearman's rho 0.65, $P < 0.001$) between chicken droppings and serum protein sensitization in this study.

The prevalence of NAA (7%) was slightly higher than AA (5%) and OA (3%) phenotypes, suggesting that asthma symptoms associated with poultry dust exposure are mediated by both allergic and non-allergenic mechanisms. This study has also demonstrated the prevalence of work-related ocular-nasal and chest symptoms that is similar to previous studies.^{11,14} The prevalence of asthma reported in our study (12%) is comparable to Spanish (14%)¹⁵ poultry farmers but higher than Portuguese (6.4%)¹⁴ farmers. The latter prevalence may have been due to different epidemiological definitions of asthma used. In the current study 7% of workers had probable allergic airway inflammation (FeNO >50 ppb) with overall mean FeNO value of 19 ppb. This is slightly higher compared to findings of a recent study done in North Carolina reporting mean FeNO levels of 16.8 ppb¹⁶ with few workers having levels >50 ppb (Kearney et al personal communication, April 2016). These differences may be due to higher poultry dust exposures found in our study (geometric mean (GM) = 11.04 mg/m³). Although no environmental measurements were reported in the North Carolina study, only 19% poultry workers reported heavy dusty work compared to 72% of the workers in our study.

Host factors such as atopy, male gender, obesity, work-related skin symptoms, and poultry product ingestion related reactions were positively associated with allergic sensitization and respiratory outcomes. Atopy was associated with airway inflammation, sensitization to at least one chicken or poultry work related allergen as well as OA. Atopy has been consistently reported as a strong risk modifier for sensitization to work-related high molecular weight agents.¹⁷ The association between male gender and sensitization to poultry work related allergens may be attributable to the gendered distribution of work, as has been reported in other work settings.¹⁸ Our findings also show that individuals with work-related ocular nasal symptoms were more likely to have work-related skin symptoms (OR = 3.05, 95%CI: 1.13-8.25) or be obese (OR = 2.17, 95%CI: 1.07-4.40). Recent studies have suggested an association between skin exposure to allergens and subsequent

development of sensitisation and respiratory outcomes.¹⁹⁻²¹ However, the evidence for such an association is limited and the immune mechanisms are not well understood. A better understanding of this association is required, more so for agents with a high molecular weight (protein), so as to identify important risk factors that may contribute to existing preventive efforts in reducing the incidence of allergy and asthma in occupational settings.²² On the other hand, overweight or obesity has been shown to increase the risk of non-allergic rhinitis in adults, especially in males.²³ Another interesting finding of this study was that workers sensitized to chicken specific allergen (OR = 5.46, 95%CI: 1.28-23.18) and those with AA (OR = 5.86, 95%CI: 1.08-31.67) were more likely to have poultry ingestion related allergic reaction. This is consistent with other studies demonstrating an association between sensitization to chicken antigens (feathers, droppings, serum) and food allergy with de-novo sensitization due to ingestion or inhalation.²⁴

The findings of this study also showed that workers with ocular-nasal symptoms, chest symptoms or NAA were more likely to report an episode of high GDF exposure. This is similar to other studies reported in previous literature.^{25,26} Notably GDF exposure was described as an independent risk factor for job change due to respiratory symptoms in a Swedish study.²⁷ This may explain the finding that all workers who reported job change due to respiratory symptoms reported an episode of high exposure to GDF causing respiratory symptoms in the current study. This study also showed that workers with work-related chest symptoms were more likely to be from the rearing department (OR = 2.51, 95%CI: 1.01-6.24). This is probably due to high particulate mass concentration levels found in this department (GM = 54.04 mg/m³).

This study also demonstrated that reversible obstructive airway pattern was more likely in workers from small broiler farms (OR = 10.07, 95%CI: 1.01-104.61) compared to large broiler farms. This is contrary to findings from a previous study in which a significant dose-response relationship was demonstrated between wheeze and large farms housing >500 birds (OR = 1.39, 95%CI: 1.10-1.75)². This discrepancy could be attributed to the probable healthy workers effect (HWE) present in the current study, and also previously documented.¹⁴ The HWE may also explain the declining pattern of sensitization observed with increasing years of service. Moreover, an increased risk of sensitization in the first 2 years of employment as shown in this study (OR = 2.91, 95%CI: 1.15-7.34), confirms that sensitization to occupational allergens occurs mainly during the first 2 years of exposure to an agent.²⁸ This finding has important implications for prevention since it provides a window of opportunity for appropriate timing of medical surveillance which should be done more frequently in the first 2 years of employment.

This study reports an increased risk of reversible airway obstruction in casual workers. This finding is consistent with previous studies which demonstrated casual workers to have an increased likelihood of exposure to occupational hazards and poorer occupational health and safety outcomes compared to permanent workers.^{29,30} This is due to a number of factors including casual workers using poor quality personal protective equipment; subjected to constant changes in their tasks; pressurized to take on manual and more hazardous work with limited

supervision or training; and are usually not confident to raise safety issues for fear of having their jobs terminated.³⁰

Although this study demonstrated statistically significant positive associations between several risk factors and some health outcomes of interest, it was unable to do so for other outcomes. This could be due to insufficient statistical power as a result of small sample size, which resulted in some effect estimates having wide confidence intervals. Moreover, the study may have been affected by selection bias as a result of the HWE. Finally, due to the cross-sectional nature of this study, it was difficult to demonstrate temporal relationships between exposure and health outcome variables of interest. Future studies should explore in more detail the dose-response relationships using the various exposure metrics that are identifiable for poultry dust.

In conclusion, this study show that both allergic and non-allergic mechanisms play a role in asthma development among poultry-workers with casual workers having an increased risk of respiratory disease compared to permanent workers. Preventive measures, including appropriate training, are recommended to reduce respiratory health risks, particularly in novice workers.

AUTHORS' CONTRIBUTIONS

MJ and TS were responsible for the overall study design and overseeing the analysis and write up. TS, PD, and OM were responsible for the fieldwork. TS supervised the laboratory analysis of the environmental samples conducted by PD and the analysis of the serum samples done by ER. DN analyzed the data under the supervision of RB and was responsible for preparation and submission of the manuscript. MJ was responsible for final approval of the version to be published and agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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ETHICS APPROVAL AND INFORMED CONSENT

Ethics approval was obtained from the Research Ethics Committee of the Universities of Cape Town and Witwatersrand, prior to the study being conducted. All participants in the study provided written informed consent.

DISCLOSURE (AUTHORS)

The authors declare 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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