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Self-reported work activities, eye, nose, and throat symptoms, and respiratory health outcomes among an industrial hog operation worker cohort, North Carolina, USA

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DJH, DCL, and CDH conceived the work, DJH oversaw data collection, VRC, MFD, and CDH were responsible for data analysis, VRC drafted the work, while VRC, MN, MFD, and CDH were responsible for substantially revising the manuscript, and all authors have reviewed and approved its submission.

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Abstract

Introduction: Respiratory disease among industrial hog operation (IHO) workers is well documented; however, it remains unclear whether specific work activities are more harmful and if personal protective equipment (PPE), as used by workers, can reduce adverse health outcomes.

Methods: IHO workers (*n*=103) completed baseline and up to eight bi-weekly study visits. Workers reported typical (baseline) and transient (bi-weekly) work activities, PPE use, and physical health symptoms. Baseline and longitudinal associations were assessed using generalized logistic and fixed-effects logistic regression models, respectively.

Results: At baseline, reports of ever versus never drawing pig blood, applying pesticides, and increasing years worked at any IHO were positively associated with reports of eye, nose, and/or throat irritation. Over time, transient exposures, associated with dustiness in barns, cleaning of barns, and pig contact were associated with increased odds of sneezing, headache, and eye or nose irritation, particularly in the highest categories of exposure. When PPE was used, workers had decreased odds of symptoms interfering with sleep (odds ratio (OR): 0.1; 95% confidence interval (CI): 0.01, 0.8), and eye or nose irritation (OR: 0.1; 95% CI: 0.02, 0.9). Similarly, when they washed their hands ≥8 times per shift (the median) versus less frequently, workers had decreased odds of any respiratory symptom (OR: 0.3; 95% CI: 0.1, 0.8).

Conclusions: In this healthy volunteer worker population, increasingly unfavorable IHO activities were associated with self-reported eye, nose, throat, and respiratory health symptoms. Strong protective associations were seen between PPE use and handwashing and the odds of symptoms, warranting further investigation.

Keywords

PPE; animal workers; indoor air; respiratory; occupational health practice

INTRODUCTION

Industrial hog operations (IHOs) pose a respiratory health risk to workers[1-6]. Particulates become airborne from the movement of workers and animals to, from, and within animal housing facilities[7, 8], contributing to human exposures to bacteria, endotoxin, fungi[9] viruses, dander, gases, and feed constituents[10]. These airborne contaminants lead to a number of negative respiratory health outcomes including lung inflammation, airway hyper-responsiveness, and irritation of the eye, nose, and throat[2, 11-12]. Even though researchers have been cataloging these harmful exposures for decades[13-14], they have not fully identified the riskiest contemporary work activities, since many of the relevant studies were conducted in the 1970s and 1980s and few detailed exact work tasks. Quantification of the effectiveness of personal protective equipment (PPE) to reduce impacts from these exposures is also lacking in this industry.

These knowledge gaps limit the ability to propose suitable guidance for the estimated 31,000 IHO workers in the U.S.[15]. For example, while we know that respirators can reduce the health effects from IHO contaminants[16-18], a 2010 expert panel was unable to determine whether PPE use for specific tasks is sufficient or whether PPE should be donned as soon as a worker enters an IHO[19]; a potentially onerous and expensive recommendation that may not be feasible given harsh IHO work conditions.

A majority of data regarding health risks to U.S. agricultural workers comes from the Agricultural Health Study, a prospective cohort of over 50,000 North Carolinian and Iowan licensed pesticide applicators. While well-designed to study incident cancer outcomes related to pesticide exposures[20], and a follow-up interview was conducted to capture respiratory symptoms[21], it was not designed to focus on IHO workers and does not capture all farming activities. Further, this cohort consists largely of male managers[20], rather than those who work day-to-day inside IHO barns. Inclusion of both male and female workers in these studies is essential as there are known sex differences in respiratory outcomes among operation workers[12, 22].

Lack of researcher access to IHOs (due to owner’s legal concerns) has impeded data collection and therefore our understanding of IHO work conditions, exposures, and worker health outcomes. In addition, workers, who are often from marginalized communities including minorities, those with low-incomes, and lacking health insurance, may face job termination for participating in research. This makes on-site air monitoring and the collection of health data exceedingly rare. Further, IHOs are often heterogenous in their age, design, animal density, animal life stages, and waste management systems. Therefore, comparing workers to one another from different operations without air sampling presents statistical problems and may lead to residual confounding due to differences in exposures[23], feed type[24], barn construction[25], and activities between operations.

Fixed-effects regression, which compares workers to themselves over time, can be used to examine exposure-outcome relationships and mitigate some of the threats to inference from heterogeneity in IHO sites. This technique has been successfully employed by Schinasi *et al.* who found strong associations between increasing IHO odors and decrements in community health[26]. To the best of our knowledge, no prior U.S. study has related work activities and PPE use to health outcomes among IHO workers who perform the day-to-day operations on facilities. Further, no study of IHO worker activities and health outcomes has been analyzed using fixed-effects regression techniques. The purpose of this investigation was to identify factors that are associated with the respiratory and eye, nose, and throat health of the IHO workers we surveyed and to provide insight into factors for future research and interventions using an underemployed biostatistical method.

MATERIALS AND METHODS

Study population

Detailed methods on enrollment have been previously described[27]. In brief, 103 IHO workers were recruited on a rolling basis from October 2013 to February 2014, with the last surveys completed in June 2014. Participants were eligible for inclusion in the sample population if they: (1) were current IHO workers (full- or part-time) and (2) agreed to participate in the study. Eligibility for inclusion in the baseline analysis population required that they provide survey data for the baseline enrollment visit. Workers were eligible for inclusion in the longitudinal analysis population if they: (1) were enrolled in the study and (2) completed at least one follow-up visit. Signed informed consent was obtained from each participant prior to participation. The study protocol was approved by the Johns Hopkins Bloomberg School of Public Health Institutional Review Board.

Study location: SE North Carolina

North Carolina contains 10% of all pig and hog operations in the U.S., employing ~3,300 workers[15]. Located in southeast N.C., Duplin County is the second-greatest pork producing county in the U.S.[28]. It is also home to the Rural Empowerment Association for Community Help (REACH; https://www.ncruralempowerment.org), who performed the recruitment, enrollment, and much of the data collection for this study.

Questionnaires

Baseline—At enrollment, a baseline questionnaire, designed to capture established work routines and health symptoms, was employed. Participants responded to survey questions consisting of how health, job tasks, and their work environment were typically at their current IHO (see Supporting Material, Questionnaires).

Follow-up—The follow-up questionnaire was adapted from the Agricultural Health Study (https://www.aghealth.nih.gov/collaboration/questionnaires.html), the American Thoracic Society (ATS-DLD-78-A), and Kimbell-Dunn *et al.*[29]. It was employed at two-week intervals for up to eight visits. Differing from the baseline questionnaire, it was designed to capture the frequency, magnitude, and duration of transient work activities, exposures, and symptoms (see Supporting Material, Questionnaires). Each question asked participants about the week prior to the study visit.

In both questionnaires, with an attempt to capture a dose-response relationship, some questions asked participants to rate exposures using a Likert-like scale.

Statistical analyses

Baseline—At baseline, generalized logistic models clustered for household were used to assess the relationship between cross-sectional exposures and outcomes. Persons reporting at least one eye, nose, or throat symptom were grouped. Due to collinearity, those who reported ever giving pigs shots and/or antibiotics were likewise grouped together. Analyses on exposures and outcomes with fewer than 5% of respondents were not run.

Covariates explored in baseline analyses included age at enrollment (a continuous variable in years), sex (male/female), race/ethnicity (non-black Hispanic/other), asthma medication use if person reported being an asthmatic (controlled/uncontrolled), current smoking status (smoker/non-smoker), season (summer, fall, winter, spring)[30], and days since last work shift (continuous). Ultimately, based on prior knowledge and model fit, age and sex were included as confounders in baseline sensitivity analyses.

Follow-up—Longitudinal exposures or outcomes with limited variability (≤1% of respondents) were dropped from analyses to reduce any bias associated with small numbers (Tables SI-SII).

Scores were created for exposure activities that were similar in nature and displayed multi-collinearity (assessed via χ^2 tests, with an α cutoff of 0.05). For example, poor *environmental barn conditions* consisted of reports of: vent fans turned off or non-existent at the facility (yes/no), extreme malodor (3 or 4 on a 4-point Likert-like scale), extreme temperature (3 or 4 on a 4-point Likert-like scale), a new herd entering the barns (yes/no), or extreme dust (3 or 4 on a 4-point Likert-like scale) in the past week. In main binary analyses, persons experiencing poor *environmental barn conditions* during that specific week were coded as a 1, whereas persons who reported none of the aforementioned activities were coded as referent 0. For sensitivity dose-response analyses, binary forms of each of the five input variables were summed; 1 being reported and 0 not being reported for that week, with a score of up to 5 for *environmental barn conditions*.

Using the same methodology, a *cleaning activity* score was created, consisting of on-IHO use of chemicals (yes/no), pressure washing the inside of barns (yes/no), application of pesticides (yes/no), and using a torch to clean the barns (yes/no) in the past week. In binary analyses, a person could have conducted a *cleaning activity* (coded as 1), or not (coded as 0), and in sensitivity trend analyses they could have a score of up to 4 reported activities.

In both the main binary *environmental barn conditions* and main binary *cleaning activity* analyses, summations of scores ≥2 were aggregated due to small numbers (1 of 711 for barn conditions and 12 of 738 for cleaning activities).

Intense *pig contact* activities (giving pigs medicine or shots) were also grouped using the same process, with main binary scores of 0 or 1 for each activity and sensitivity trend scores of 0 to 2.

Individual unweighted exposures and activities were also summed (1 as have been reported, and 0 if not reported in the past week). Up to six activities were reported in a single week by an individual, so scores of ≥4 were aggregated due to small numbers.

The use of PPE, including facemasks, eyewear, and full body suit/coveralls, was also grouped due to multi-collinearity. Participants were coded as a 1 in each category if they reported use of the specific PPE at least 80% of the time while at work in the past week and 0 if they reported using it less often. These scores were then summed, giving possible values from 0 to 3. Mask, eye protection, and coveralls were chosen for this analysis because we believed them to: (1) be *a priori* related to the outcomes of interest and (2) have variability in their use over time and thus would not be dropped from fixed-effects regression models.

Reports of the number of times a person washed his/her hands was assessed in tertiles due to non-linearity.

Groupings were also created for adverse health outcomes *a priori* based on biological understanding and number of cases. These included reports of at least one respiratory symptom (excessive coughing, runny nose, difficulty breathing, or sore throat), at least one symptom that interfered with sleep (any symptoms reported or waking from sleep due to coughing, wheezing, or phlegm), sneezing, headache, and any reported eye or nose irritation.

Fixed-effects logistic regression was used to assess the relationship between exposures and outcomes in the past week and to control for time-invariant confounding variables[31], including physical and operational structures. Confounders of interest and relevant to the longitudinal analyses included only month of follow-up visit[7].

All data were analyzed using Stata (StataCorp. 2017. *Stata* Statistical Software: Release 15. College Station, TX: *StataCorp* LP).

RESULTS

In this study of IHO workers, elevated risk of self-reported symptoms by those who ever performed work activities and those who performed increasingly hazardous transient work activities were found. Due to small case numbers, confidence intervals are often wide, but effect estimates are large and demonstrate a consistency in magnitude and direction across main and sensitivity analyses.

At baseline, 103 IHO workers entered the cohort. As reported in previous studies, these employees were primarily 16-62 years old, male (54%), and non-black Hispanic (88%)[27]. Most did not live on the same property as an IHO (92%) (Table I).

An average of 8 years working on any IHO was reported, with an average of 6.4 days worked per week and a majority of time spent in direct contact with pigs (82%) (Table SIII). The most prevalent work activities employees reported *ever* performing included handling dead pigs (79%), giving pigs shots or injections (69%), having direct contact with pig manure (67%), administering antibiotics (62%), and applying pesticides in or around barns (49%). One-third (38%) of participants reported that they always wore a mask at work (Table SIII).

Participants were asked whether they *ever* experienced a variety of symptoms, outside of having a cold or the flu. Respondents most frequently reported having eye irritation (19%), nose irritation (16%), throat irritation (15%), allergies (13%), and doctor-diagnosed asthma (9%; Table SIV).

Those who reported *ever* drawing pig blood had an increased likelihood of reporting eye, nose, and throat symptoms (PR: 3.7; 95% confidence interval (CI): 1.9, 7.0) and any allergies (PR: 4.4; 95% CI: 1.7, 12) (Table II).

Increased prevalence of eye, nose, or throat symptoms were also reported by those who ever applied pesticides (PR: 2.2; 95% CI: 1.0, 4.8) and those who washed work clothes with household laundry (PR: 2.3; 95% CI: 1.0, 5.3). Across tertiles of years worked on any IHO, increasing eye, nose, and throat symptoms were reported (p-for-trend: 0.01), and in the uppermost tertile of exposure (PR: 4.3; 95% CI: 1.5, 12) (Table II).

Reports of always wearing all three PPE types (full body suit/coveralls, mask, and eye protection) on the job were associated with higher prevalence of allergies (PR: 3.8; 95% CI: 1.4, 9.9), while working seven days per week compared to those working less often was associated with a lower prevalence of allergies (PR: 0.1; 95% CI: 0.01, 0.6) (Table II). In models that converged, these associations were consistent after adjustment for age and sex (Table SV).

Of the 101 persons eligible for longitudinal data analyses, 95% of their study visits were completed (Figure 1). Multiple imputation was not conducted as very few data points were missing (~5-10% per analysis) and the missingness was determined to not be at random.

During the previous week, persons reported working an average of 6 days per week, 42 hours per week, with 38 hours in direct contact with pigs. High-frequency work activities included administering shots (49%) and using cleaning chemical(s) (56%) (Table III).

Outcomes of high prevalence reported in the bi-weekly surveys included any respiratory health symptom (6%), symptoms interfering with sleep (3%), sneezing (2%), headache (2%), and eye or nose irritation (2%) (Table SVI). Due to concerns about false reporting of work conditions or symptoms, researchers included ten symptoms without any known association with exposure to IHOs on the questionnaires. None of these dummy symptoms were reported more than six times within the 752 person-records.

Consistency was seen between an increased odds of reported symptoms during weeks when workers engaged in activities that produced or retained dust within barns, conducted cleaning activities, and had close contact with pigs (13 of 14). Administering pigs medicine or shots was the riskiest activity category for all symptoms examined. Higher odds of respiratory symptoms, symptoms interfering with sleep, sneezing, headache, and eye or nose irritation were observed during weeks when workers conducted two or more categories of activities compared to fewer. Also, as hypothesized, a protective effect was estimated for any PPE use (compared to when none was used) in all five outcomes. Handwashing was also protective in 4 of 5 outcomes during weeks when done at least eight times per shift (the median) versus fewer times (Table IV).

In sensitivity analyses, exposures were modeled via scores to assess dose-response (Tables SVII and SVIII). Higher odds of reporting health impacts were observed with worsening work conditions as demonstrated by a p-for-trend <0.05 for 11 of 25 associations. The use of PPE showed a protective effect (13 of 15 sub-groups) with a no-threshold effect. Sensitivity analyses that included the addition of month were also performed. In those models which converged, estimates of similar magnitude and direction were observed (data not shown).

DISCUSSION

In this study of self-reported IHO work activities and health outcomes, we found that during the weeks when workers performed the most unfavorable job tasks, they also experienced increased odds of eye, nose, and throat irritation and respiratory symptoms. In addition, they reported reduced odds of symptoms when they wore PPE or washed their hands more frequently. To the best of our knowledge, our study is the first to apply fixed-effects regression as a tool to estimate associations between self-reported IHO exposures and health outcomes in a worker cohort. In addition, our study is more generalizable to day-to-day IHO workers than prior work, where most cohort participants have been white male farm supervisors, not in direct contact with swine[20]. For example, of the 207 IHO workers Donham *et al.* enrolled from 40 IHOs in Iowa, 100% were white, 88% male, and 20% smokers[32], limiting generalizability to a workforce who, in practice, is often made of non-white immigrants and, in our cohort, 46% female.

As in our study, Donham *et al.* found that participants who worked in IHOs (compared to those working at non-confinement operations) had more chronic and acute respiratory health symptoms[32]. Unlike our study, Donham *et al.* benefitted from on-operation collection of ambient air samples and samples from inside employees' masks while working; however, they failed to collect data regarding specific work activities.

In congruence with the Agricultural Health Study[20], our cohort consisted primarily of non-smokers; however, our participants had a higher prevalence of self-reported asthma (8.7% versus 5.1%)[33]. The prevalence of asthma in our predominantly non-black Hispanic population was also higher than national average for non-black Hispanic adults (6.4%)[34]. While capturing incident asthma was not possible in our study, there have been prior reports of increased development of asthma among farmers[35].

As hypothesized, reports of ever drawing pig blood, applying pesticides, and increasing years worked at any IHO were consistently associated with increased reports of eye, nose, or throat symptoms. Acute exposures, including those associated with dustiness and cleaning of barns and close contact with pigs were associated with increased odds of symptoms, particularly in the highest categories of exposure. Completing more of these tasks showed an increase in symptoms as well, evidence for a need to rotate job tasks and to create work environments that are inherently less dusty.

Unexpectedly, working an average of seven days per week was associated with decreased symptoms. This association is a potential indication of healthy worker effect bias, where only the healthiest employees and most tolerant of symptoms report for work every day. It may also be due to the fact that when workers are away from IHO exposures their respiratory system rebounds, leading to inflammatory reactions[36]. Another unexpected finding was that at baseline, workers who reported "always" wearing all three types of PPE at work reported increased odds of allergies. This is potentially a case of reverse causation or reporting errors, as this finding was not corroborated in our longitudinal analyses.

In weeks when wearing PPE or washing hands at or above the median frequency, workers had decreased odds of symptoms compared to when they did not wear PPE or washed their hands less frequently. It has been shown that exposure to pesticides and other respiratory irritants can be modified by the use of PPE[37]. In particular, N95 masks have been shown to block the harmful pathogens found on IHOs[38].

While IHO workers in our study were not queried on which masks were used, an assessment of a small number of different workers in a follow-up study (n=18) suggested that most IHO workers wear an employer-provided N95 respirator (15/17) or a surgical mask (2/17)[39]. Of those whose employer provided them a mask, all 17 reported using the mask provided[39]. Ferguson *et al.* have also documented that IHO workers are willing to become educated in personal protection and that they found value in learning about methods to protect themselves from exposures[40]. Intervention studies that examine employer-provided handwashing stations and increased access to PPE are areas of future interest.

Design considerations

Several limitations potentially temper the current analysis. First, recruitment was non-random which may lead to selection bias. That said, the recruited population reflects the occupational demographics of the area. Second, in order to maintain worker confidentiality, operations could not be accessed and therefore air sampling and personal monitoring could not be conducted to corroborate survey responses. Third, the small sample size of the cross-sectional analyses (n=103) makes the results highly sensitive to outliers. Also, because of small numbers of varying reports of exposures or outcomes between weeks, the confidence intervals for longitudinal main and trend analyses are wide. However, the number, magnitude, and direction of estimates of association demonstrate strong consistency, which indicates that IHO work is detrimental to physical health. Finally, these data are from IHO workers, who may represent a healthy-worker population, but this bias would most likely drive associations toward to the null.

Strengths

Fixed-effects regression was used to account for the vast array of unmeasurable confounders arising from a lack of IHO access and from the differences due to between-person perception of magnitude of work conditions and symptoms. The use of fixed-effects modeling also controls for characteristics on IHOs that do not change during our study, such as feed type or barn construction. Another strength of our study was the ability to recruit day-to-day IHO workers. By working in tandem with a local organization who has strong ties to the community we were able to establish trust in our data security and provide laborers with information which may help them protect their health in the future.

Conclusions

In this analysis of 103 IHO employees, we observed positive associations between self-reported work activities and eye, nose, and throat irritation and respiratory health symptoms.

Further, when handwashing increased or PPE was employed, the risk of reporting these symptoms was reduced. Our study differed from prior work as we recruited day-to-day workers and women leading to a more representative sample of the in-barn workforce. Also novel, we also used fixed-effect regression to control for unmeasured/unmeasurable confounders. Future research should focus on what types of PPE are most appropriate and functional in this workplace environment and employers may wish to focus on activities that increase job task rotation, decrease dust exposure, and provide adequate access to handwashing stations and PPE.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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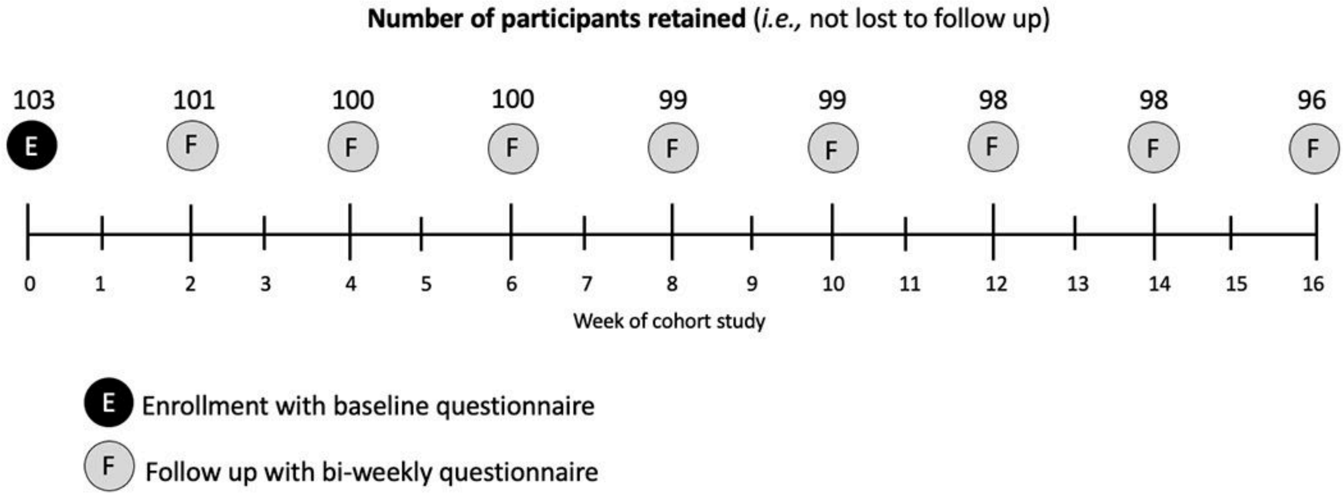

Figure 1.

Sampling scheme and loss-to-follow-up between the baseline and bi-weekly study visits within a cohort of industrial hog operation (IHO) workers, North Carolina, 2013-2014**.**

Table I.

Baseline demographic and household characteristics of the industrial hog operation worker cohort, North Carolina, 2013-2014.

Characteristic	Reports
Workers in cohort, *n*	103
Age in years, *mean ± SD*	38 ± 11
Sex, *n (%)*	
Male	55 (54)
Female	46 (46)
Race/ethnicity, *n (%)*	
Hispanic, non-black	88 (88)
Black	12 (12)
Education status, *n (%)*	
Less than high school education	47 (47)
High school degree/GED or higher	52 (53)
Body mass index (BMI), *n (%)*	
<30.0	58 (56)
≥30.0	38 (37)
Used a gym or workout facility in the last three months, *n (%)*	
Yes	9 (9)
No	92 (91)
Current cigarette smoker, *n (%)*	
Yes	13 (17)
No	65 (83)
Health insurance, *n (%)*	
Yes	48 (48)
No	52 (52)
Place where IHO workers seek medical care,[a] *n (%)*	
Private doctor	49 (49)
Emergency department or urgent care center	29 (28)
Hospital	18 (17)
Free clinic	16 (16)
Other	3 (3)
Does not seek medical care under any circumstance	4 (4)
Had a cat or dog, *n (%)*	
Yes	44 (43)
No	50 (47)
Lived on same property as an IHO, *n (%)*	
Yes	8 (8)
No	89 (92)
Month of baseline visit, *n (%)*	
January	1 (1)

Characteristic	Reports
February	50 (49)
October	30 (29)
November	22 (21)
Received a flu vaccine within the past year, *n (%)*	
Yes	34 (34)
No	66 (66)

Note. IHO = industrial hog operation.

[a]. Categories are not mutually exclusive.

Table II.

Crude baseline associations between binary (unless noted as tertiles) self-reported industrial hog operation (IHO) work activities and binary self-reported symptoms among IHO workers, North Carolina, 2013-2014, clustered at the household level.

	Eye, nose, or throat symptoms			Any allergies			Doctor-diagnosed asthma		
Reported characteristic	***n***	**PR (95% CI)**	***p*-value**	***n***	**PR (95% CI)**	***p*-value**	***n***	**PR (95% CI)**	***p*-value**
Have you ever									
Given pigs shots and/or antibiotics	96	2.2 (0.8, 6.6)		97	0.6 (0.2, 1.5)		97	1.0 (0.2, 5.2)	
Drawn pig's blood	97	3.7 (1.9, 7.0)		98	4.4 (1.7, 12)		98	3.3 (0.9, 12)	
Handled pig manure	90	1.0 (0.4, 2.4)		91	1.3 (0.4, 4.6)		91	1.5 (0.3, 7.0)	
Applied pesticides in or around the barns	97	2.2 (1.0, 4.8)		98	2.3 (0.8, 6.9)		98	1.0 (0.2, 4.7)	
Washed work clothes with household laundry	95	2.3 (1.0, 5.3)		96	0.5 (0.1, 3.3)		96	0.7 (0.1, 5.7)	
Do you typically									
Work exclusively in sow, nursery, and/or farrow barns	93	0.8 (0.3, 1.7)		94	0.5 (0.2, 1.6)		94	2.1 (0.4, 11)	
Work exclusively in feeder and/or finisher barns	93	1.3 (0.5, 3.1)		94	1.0 (0.3, 3.4)		-	-	
Always wear coveralls/full body suit, mask, and eye protection	96	1.3 (0.5, 3.4)		97	3.8 (1.4, 9.9)		97	2.6 (0.6, 12)	
Work 7 days per week	96	0.4 (0.1, 1.1)		97	0.1 (0.01, 0.6)		97	0.3 (0.1, 1.7)	
Years worked on any IHO	85			85			87		
Tertile 1 (1-5 years)		Ref (1.0)			Ref (1.0)			Ref (1.0)	
Tertile 2 (6–10 years)		1.9 (0.5, 7.6)			0.6 (0.1, 2.6)			3.6 (0.4, 35)	
Tertile 3 (11–27 years)		4.3 (1.5, 12)			0.8 (0.2, 2.7)			3.0 (0.3, 30)	
Trend			0.01			0.6			0.3
Percent of life working on any IHO	82			83			55		
Tertile 1 (2.4–11.6%)		Ref (1.0)			Ref (1.0)			Ref (1.0)	
Tertile 2 (11.7–26.3%)		1.8 (0.4, 7.2)			1.04 (0.3, 3.8)			1.5 (0.3, 8.4)	
Tertile 3 (26.4–51.9%)		3.4 (0.99, 11)			0.84 (0.2, 3.5)			-	
Trend			0.04			0.8			0.1

Note. PR = prevalence ratio. CI = confidence interval. - = model did not converge. IHO = Industrial hog operation. Crude models are presented as main tables in this analysis due to convergence issues in adjusted models and the consistency between point estimates in crude and adjusted regressions. In alternative sensitivity analyses (not shown) prevalence odds ratios (PORs) were calculated and showed to overestimate the exposure-response association. Due to this, prevalence ratios (PRs) were presented for baseline analyses.

Table III.

Time-varying occupational exposure activities occurring during the week immediately preceding the bi-weekly study visit among industrial hog operation workers, North Carolina, 2013-2014.

Activities in the past week	**Affirmative responses**
Number of days worked, *mean ± SD*	6 ± 1
Number of hours worked, *mean ± SD*	42 ± 12
Number of hours in direct contact, *mean ± SD*	38 ± 14
Number of sick pigs, *mean ± SD*	61 ± 166
Number of dead pigs, *mean ± SD*	42 ± 120
% of time coveralls/full body suit were worn, *mean ± SD*	81 ± 38
% of time a mask was used, *mean ± SD*	54 ± 46
% of time eye protection used, *mean ± SD*	28 ± 42
Number of times washed hands at the IHO, *mean ± SD*	8 ± 6
Barn condition score factors, *n (%)*	
Vent fans were off	178 (34)
Malodor	
None, moderate	564 (76)
Extreme	175 (24)
Temperature in the barns, *n (%)*	
Cold, comfortable	614 (85)
Hot	111 (15)
A new herd entered the barn(s), *n (%)*	47 (6)
Dustiness in barns, *n (%)*	
None, moderate	705 (96)
Extreme	32 (4)
Cleaning and pesticide score factors, *n (%)*	
Used cleaning chemical(s) at the IHO	414 (56)
Pressure washed	290 (39)
Applied pesticides	224 (30)
Used a torch	20 (3)
Pig contact score factors, *n (%)*	
Gave pigs medicine	241 (68)
Gave pigs shots	363 (49)
Received an influenza vaccine since the last study visit, *n (%)*	21 (3)

Note. SD = standard deviation. IHO = industrial hog operation.

Table IV.

Crude time-varying acute health outcomes and binary work activities the week immediately preceding the bi-weekly study visit among industrial hog operation workers, North Carolina, 2013-2014.

	At least one respiratory symptom[a]		At least one symptom interfered with sleep[b]		Sneezing		Headache		Eye or nose irritation	
Reported in the past week	**obs. (groups)**	**OR (95% CI)**	**obs. (groups)**	**OR (95% CI)**	**obs. (groups)**	**OR (95% CI)**	**obs. (groups)**	**OR (95% CI)**	**obs. (groups)**	**OR (95% CI)**
Any hot or dusty barn conditions[c]	225 (31)	4.0 (1.4, 12)	152 (21)	1.7 (0.5, 5.3)	85 (12)	0.8 (0.2, 3.3)	92 (12)	2.6 (0.8, 9.0)	84 (11)	8.4 (1.0, 71)
Conducted any pesticide application or cleaning activity[d]	229 (31)	3.0 (1.2, 7.5)	147 (20)	4.5 (1.1, 18)	86 (12)	3.5 (0.97, 12)	93 (12)	1.9 (0.5, 7.1)	85 (11)	2.6 (0.6, 11)
Administered pigs medicine or shots[e]	223 (30)	6.8 (1.8, 25)	-	-	87 (12)	12 (1.3, 105)	93 (12)	4.6 (0.8, 25)	70 (9)	15 (1.7, 133)
Two or three of the above categories[f]	215 (30)	10 (2.2, 46)	144 (20)	19 (2.1, 171)	85 (12)	4.1 (1.1, 16)	92 (12)	7.5 (1.4, 40)	67 (9)	6.1 (1.3, 28)
Used any PPE[g]	226 (31)	0.3 (0.1, 1.5)	154 (21)	0.1 (0.01, 0.8)	85 (12)	0.1 (0.01, 1.0)	90 (12)	0.9 (0.1, 6.2)	82 (11)	0.1 (0.02, 0.9)
Washed hands at least 8 times per shift[h]	228 (31)	0.3 (0.1, 0.8)	147 (20)	0.6 (0.2, 1.8)	87 (12)	0.9 (0.24, 3.2)	93 (12)	1.3 (0.3, 5.4)	85 (11)	0.6 (0.2, 2.2)

Note. OR = odds ratio. CI = confidence interval. PPE = personal protective equipment. OR (95% CI) estimates are derived from conditional logistic fixed-effects regression models, which estimate the average of all within-person differences between time-varying exposure and outcome.

[a]. Excessive coughing, runny nose, difficulty breathing, or sore throat.

[b]. Any sleep symptoms reported, waking from sleep due to coughing, waking from sleep due to wheezing, or waking from sleep due to phlegm.

[c]. Sum of vents off (yes=1, no=0), extreme malodor (yes=1, no=0), hot temperature (yes=1, no=0), a new herd entering the barn(s) (yes=1, no=0), and extreme dust (yes=1, no=0)

[d]. Sum of used cleaning chemicals (yes=1, no=0), pressure washed (yes=1, no=0), used pesticides (yes=1, no=0), and used a torch (yes=1, no=0)

[e]. Sum of gave pigs medicine (yes=1, no=0) and gave pigs shots (yes=1, no=0)

[f]. Number of individual activities/conditions (maximum 10)

[g]. Sum of consistently (≥80% of the time at work) wore the following: coveralls/full body suit (yes=1, no=0), mask (yes=1, no=0), and glasses (yes=1, no=0)

[h]. 8 is the median number of times workers reported washing their hands per IHO work shift.