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Kelley J. Donham , Donald C. Zavala & James A. Merchant

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Respiratory Symptoms and Lung Function among Workers in Swine Confinement Buildings: A Cross-Sectional Epidemiological Study

KELLEY J. DONHAM, M.S., D.V.M.
Institute of Agricultural Medicine
Department of Preventive Medicine and Environmental Health
College of Medicine
University of Iowa
Oakdale, Iowa 52319

DONALD C. ZAVALA, M.D.
Department of Internal Medicine
Pulmonary Division
College of Medicine
University of Iowa
Iowa City, Iowa 52242

JAMES A. MERCHANT, M.D., Dr.P.H.
Department of Preventive Medicine and Environmental Health
College of Medicine
University of Iowa
Iowa City, Iowa 52242

ABSTRACT. To study possible chronic respiratory problems of people working in swine confinement buildings, a cross-sectional epidemiological study was initiated. A cohort of swine confinement workers was matched for age, sex, and smoking history with nonconfinement swine producers. Pulmonary function studies and a survey questionnaire for chronic respiratory disease symptoms (the American Thoracic Society, Epidemiologic Standardization Project Questionnaire) were performed on both groups. Compared to controls, the confinement workers experienced significantly higher prevalence of chronic bronchitis and wheezing, (odds ratio 7 and 4, respectively). There were, however, no significant differences in baseline pulmonary functions.

Based on the high prevalence of chronic respiratory disease symptoms, this study emphasizes an emerging occupational concern in agriculture to the estimated 500,000 persons working in swine confinement operations and the estimated 500,000 additional persons who work in poultry, veal, beef, or dairy confinement operations. It is important to study a representative population of these workers prospectively to determine if a progressive loss in lung function is evident.

ECONOMIC, POLITICAL, AND SOCIOLOGICAL factors have effected an industrial approach to livestock production in the United States. Confinement feeding of swine exemplifies new methods of livestock production where animals are raised in high densities in structures which are totally or partially enclosed from the outside environment. Coincident with this method of livestock production is a new set of occupational health problems that are beginning to be recognized.[1-6]

We have reported three previous studies involving more than 2,000 workers in swine confinement buildings, which indicate about 70% of these workers suffer from acute adverse respiratory symptoms associated with their work.[1-3] These symptoms consist primarily of cough, excess sputum and phlegm production, wheezing, and irritation to the nose and throat.

A summary of clinical observations of about 40 ill confinement swine producers[3] revealed syndromes that could be classified into four categories: (1) acute generalized toxicosis and inflamation of the respiratory tract from inhalation of high levels of hydrogen sulfide gas, (2) acute asthmatic-like illness, (3) bronchitis, and (4) delayed or hypersensitivity pneumonitis-like illness.

Environmental analyses of swine confinement buildings indicates carbon dioxide, carbon monoxide, ammonia, hydrogen sulfide, and aerosolized particles may commonly exceed the threshold limit values or short-term exposure limit values for these substances.[1,2,5] We felt these environmental exposures may put workers at risk of developing chronic lung disease, but there have been no previous studies on this subject. We therefore initiated a cross-sectional epidemiological study to investigate chronic respiratory disease in swine confinement workers.

METHODS

A probability sample of 2,459 male swine producers was selected from the 60,000 swine farms in Iowa. This sample was stratified by county and by size of operation. A mail questionnaire was administered to collect information on the management of the operations and on acute symptoms associated with working in these buildings. From the probability sample we identified a subpopulation of confinement swine producers who were willing to participate in further studies. We then made an extensive comparison of those willing to participate to those declining, and found no significant differences in respiratory symptoms, smoking history, work history, and other factors that might confound experimental results. Twenty-four subjects were randomly selected from the potential pool, which was stratified for the type and degree of acute respiratory symptoms. We contacted these subjects in a random order until we obtained the desired number of participants from each stratum. These subjects were paired with controls who were nonconfinement swine producers, and matched for age, sex, and county of residence. The study was performed in a 27-county area of Eastern Iowa, which encompassed a radius of approximately 100 miles around Iowa City, Iowa. Cooperation was established with either the county agricultural extension office or the county Health Department as a meeting site to conduct the tests.

Each person was administered a questionnaire, containing all the questions from the American Thoracic Society—Epidemiological Standardization Project, plus a few extra questions relative to acute symptoms and occupational history. Pulmonary function tests were performed on each individual using a computerized spirometer with flow volume-loop-tracing capabilities (Eagle I, Warren E. Collins, Inc., Braintree, MA). The spirometer was calibrated statically each day with a 3-L syringe (A and M Systems, Inc., Everett, WA) and dynamically with a forced vital capacity (FVC) simulator (Jones Medical Instruments, Inc., Oakbrook, IL). The pulmonary technician instructed the subjects in the FVC maneuver and demonstrated the appropriate technique. Noseclips were mandatory since tidal respirations and the maximal inspiratory effort was performed in a closed circuit prior to the FVC maneuver.[7] Subjects performed at least three satisfactory FVC maneuvers.[8] The technician determined a FVC maneuver satisfactory if he observed that the subject understood the instructions and performed the test with a smooth continuous exhalation; with apparent maximal effort; with a good start; and without (1) coughing, (2) glottis closure, (3) early termination of expiration, (4) leakage, (5) mouthpiece obstruction by the tongue or false teeth, (6) excessive hesitation or false starts, or (7) an excessive variability among three acceptable curves [$\leq \pm 5\%$ of FVC and first-second forced expiratory volume ($FEV_{1.0}$) of best two tracings].[9] The pulmonary technician recorded the following measurements: FVC, $FEV_{1.0}$, the ratio of $FEV_{1.0}$ to FVC, and mean forced expiratory flow during the middle half of the FVC ($FEF_{25-75\%}$). For data analysis, we recorded values from the test with the highest sum of the $FEV_{1.0}$ and FVC. Comparisons were made between confinement and non-confinement workers with computer assisted analysis.

RESULTS

Table 1 indicates the subjects and controls were matched quite closely, as age, occupational variables, (other than confinement exposure), and cigarette smoking histories were similar between the two groups. The median time of confinement work was 6 yr, the mean was 6.2 yr, and the range was 2–17 yr. Personal and family illness histories and farm and nonfarm occupational histories were compared between the two groups; no differences were found at the 5% significance level. No significant differences between the groups were observed for specific diseases such as pneumonia, hay fever, allergies, and heart trouble. There were no significant differences in farm or nonfarm occupational exposures. There was a significant difference in the use of respirators; 50% of the confinement workers reported at least occasional use, while only 8.3% of the non-confinement workers used a respirator ($P = .008$).

There were statistically significant differences between confinement workers and controls relative to acute respiratory symptoms. A total of 22 (91.2%)

Table 1.—Comparison of Subjects (Swine Confinement Workers) and Controls (Nonconfinement Swine Workers)

	Mean Values for Confinement Workers (N = 24)	Mean Values for Nonconfinement Workers (N = 24)
Age	44.5 yr	46.9 yr
Length of time in farming	30.8 yr	34.8 yr
Years raised swine	24.7 yr	20.3 yr
Years in confinement	6.2 yr	N.A.
Years raised cattle	22.2 yr (N = 22)	26.2 yr (N = 23)
Years raised grain crops	14.1 yr (N = 14)	15.8 yr (N = 23)
Cigarette—pack years	19 (N = 9)	22 (N = 9)

workers reported adverse symptoms associated with work in confinement buildings. Eighteen (75%) reported experiencing symptoms which began during work and continued for a variable period afterwards, while 33.3% reported symptoms delayed by 4–6 hr following exposure. Of those with delayed symptoms, 24% reported symptoms of fever, 50% tightness of chest, 37.5% chest pain, and 24% malaise or weakness.

Chronic respiratory symptoms (primarily chronic bronchitis and wheezing complaints) were significantly more prevalent in confinement swine producers than controls (Table 2). Chronic cough was experienced by 33% of the confinement workers, and 8.3% of non-confinement group (P = .055). Chronic phlegm was more pronounced in the confinement group, which was 58% as compared to 21% for non-confinement (P = .035). Symptoms of chronic wheezing associated with a cold (62.5%) and occasionally apart from a cold (37.5%) were respectively significantly higher (P = .029, P = .055) than non-confinement workers (29.2% and 12.5%). The odds ratios for these symptoms ranged from about 4 to 7 (Table 2). Confinement workers reported more frequent chest colds (45.8% compared to 20.8%), but this difference was not significant at the 5% level (P = .073). There was no difference in continuous wheezing, shortness of breath, or work absence from chest illness. A relative quantitation of chronic symptoms (respiratory sum) in the two groups was determined by comparing the mean of positive responses to 9 chronic symptoms listed in Table 2. The mean for the confinement group was 3, which was significantly higher (P = .008) than 1.2 in the non-confinement group.

The relationship between chronic symptoms and exposure time to confinement swine buildings was examined by computing Spearman correlation coefficients. There was a significant positive correlation (0.60, P = .031) between the number of years chronic wheezing was experienced and the number of years worked in confinement. No other significant correlation was observed in confinement or non-confinement for either chronic cough, chronic phlegm, or chronic episodes of cough with phlegm.

Smoking was examined for possible additive effects for chronic respiratory symptoms. The workers were divided into four groups for comparison: nonsmokers (confinement and non-confinement) and smokers (confinement and non-confinement). For symptoms of chronic bronchitis and chronic wheezing, smoking appeared to have an additive effect with confinement work (Table 2). Frequent chest colds were associated with confinement work plus smoking, but not with confinement only. There were too few responses to make a valid comparison for continual wheezing, shortness of breath, or work absence from chest illness. Examining the combined chronic respiratory symptoms (respiratory sum), reinforced the apparent additive effect of smoking and confinement work. There was a gradient of increasing respiratory sum score for the following situations: nonsmoking and non-confinement (0.70), smoking and non-confinement (2.10), nonsmoking and confinement (2.50), and smoking confinement (3.80).

In contrast to the significant differences in respiratory symptoms between confinement and non-confinement workers, the pulmonary function tests (PFT's) for the two groups were comparable (Table 3). The mean values for FVC, $FEV_{1.0}$, FEV_{25-75}, and $FEV_{1.0}$/FVC of confinement workers were slightly greater than the non-confinement swine producers; these differences, however, were not significant at the 5% level.

The effects of smoking and confinement work in combination were examined by comparing PFT's of smokers and nonsmokers (Table 3). The nonsmokers in the non-confinement group had higher PFT's in all categories, but the differences were not statistically significant at the 5% level. Within the confinement group, the nonsmokers had a significantly higher $FEV_{1.0}$ to FVC ratio. The remainder of the PFT's within the confinement group were similar.

DISCUSSION

This report represents the first study that has looked systematically for chronic lung disease in livestock confinement workers. Even though the number of subjects

Table 2.—Chronic Respiratory Disease Symptoms* of Confinement and Nonconfinement Swine Producers

Question Number	Symptoms	Confinement Swine Producers (N = 24)	Nonconfinement Swine Producers (N = 24)	Probability Value	Estimate of Odds Ratio
7E	Chronic cough	33% (NS = 20%, S = 55.6%)†	8.3% (NS = 0, S = 22.2%)	.055	4.00
8E	Chronic phlegm	58% (NS = 53.3%, S = 66.6%)	21.0% (NS = 6.7%, S = 44.4%)	.012	4.00
9A	Chronic episodic cough with phlegm	29.2% (NS = 26.7%, S = 33.3%)	4.2% (NS = 0, S = 11.1%)	.035	7.00
10A.1	Chronic wheezing, associated with a cold	62.5% (NS = 46.7%, S = 88.9%)	29.2% (NS = 26.7%, S = 22.2%)	.029	3.67
10A.2	Chronic wheezing, occasionally apart from a cold	37.5% (NS = 33.3%, S = 44.4%)	12.5% (NS = 6.7%, S = 22.2%)	.055	4.00
10A.3	Chronic wheezing, most days or nights	4.2% (NS = 6.7%, S = 0)	4.2% (NS = 0, S = 11.1%)	.750	1.00
13A	Shortness of breath	20.8% (NS = 20%, S = 22.2%)	20.8% (NS = 6.7%, S = 44.4%)	.637	1.00
14A	Frequent chest colds	45.8% (NS = 6.7%, S = 66.6%)	20.8% (NS = 20.0%, S = 22.2%)	.073	3.00
15A	Off work from chest illness	8.3% (NS = 13.3%, S = 11.1%)	0 (NS = 0, S = 0)	.250	—
Mean respiratory sum‡		3.0 (NS = 2.5, S = 3.8)	1.2 (NS = 0.7, S = 2.1)	.008	N.A.

* Results from a survey using the American Thoracic Society, Epidemiologic Standardization Project Questionnaire.

† NS = Nonsmokers (N = 15); S = Smoker (N = 9).

‡ Respiratory sum is the total of positive responses to the chronic respiratory symptoms listed in the Table.

studied (N = 24) is small in comparison to other epidemiology studies of occupational respiratory disease, the study was well controlled, helping to assure reliability of the data. Of critical importance in the study is the assurance that participants were not biased toward answering questions positively based on selection. This question may arise since subjects were selected from a population previously studied who indicated a willingness to participate in possible future studies. Selection bias was minimized by showing that: (a) a comparison of the group who volunteered for further studies to the group who declined revealed no significant differences in major factors that might cause them to answer questions positively; (b) since the subjects were all owner-operators of these units (rather than employees) there was no vested interest for subjects to demonstrate health problems; (c) both principals and controls were volunteers and were randomly selected from a previously identified representative population of farmers; and (d) we promoted the survey as a study of swine producers, not confinement workers.

The comparison of the volunteer group to the group who declined further study revealed no statistically significant differences in acute symptoms associated with their work, included among other symptoms, cough, sputum or phlegm production, wheezing, and tightness of chest. Additionally, there were no differences in the prevalence of self-reported intercurrent illnesses such as hay fever, asthma, emphysema, or allergies. Other factors compared with no differences found included size of operation, amount of time spent working in the buildings, smoking histories, the age of the building, and plans for future expansion.

Once subjects were chosen we attempted to match them closely with controls. The smoking histories, the agricultural and non-agricultural occupational histories, and the personal and family health histories suggest that non-confinement risk factors for pulmonary disease were quite similar between confinement workers and controls.

Ninty-one percent of the confinement subjects reported adverse symptoms associated with confinement work. Most of these (75%) reported bronchitic symptoms associated in time with work in the buildings. This agrees closely with our previous surveys which indicate 65–75% of confinement workers experience symptoms of bronchitis.[1,3]

Delayed symptoms were experienced in 33% of these individuals, which is higher than our previous studies (12–15%). These delayed symptoms suggest a significant number of workers are experiencing condi-

Table 3.—Pulmonary Functions* in Confinement and Nonconfinement Workers

	Nonconfinement	Confinement
FVC	97.33 (NS = 98.27, S = 95.78)†	101.71 (NS = 100.53, S = 103.67)
$FEV_{1.0}$	100.96 (NS = 103.60, S = 95.56)	109.04 (NS = 108.53, S = 109.89)
FEF_{25-75}	94.50 (NS = 101.13, S = 85.11)	111.54 (NS = 111.33, S = 111.89)
$FEV_{1.0}$/FVC	0.763 (NS = 0.771, S = 0.750)	0.795 (NS = 0.801,‡ S = 0.785)

* Pulmonary functions expressed as percent of predicted value.
† NS = Nonsmoker (N = 15); S = Smoker (N = 9).
‡ P = .008.

tions that may be similar to hypersensitivity pneumonitis. This area needs further investigation, as multiple episodes of hypersensitivity pneumonitis are known to result in chronic interstitial fibrosis.[10]

Fifty-eight percent of the confinement group had chronic bronchitis, based on the definition of chronic phlegm production with cough, which is significantly higher than the 21% seen in the control group. This condition is the most obvious difference between the groups, and probably represents the overall most common respiratory problem among confinement workers. The significant excess of wheezing in the confinement subject group further highlights chronic adverse symptoms induced by the confinement environment. Smoking was found to have an additive effect with confinement exposure relative to chronic bronchitis and airway obstructive symptoms.

Duration of exposure was not correlated to the length of time that symptoms had been experienced. However, in the majority of cases, chronic symptoms were reported within 2 yr after the beginning of confinement work. This finding suggests that development of chronic bronchitis is dependent on a minimum exposure period (1–2 yr) and that the rate of occurrence does not necessarily increase after this 1–2 yr exposure period. However, migration of affected subjects out of this work may account for this finding. This issue could not be evaluated in this study.

Migration out of the work force (or healthy worker effect) might also be a reason why pulmonary function tests were similar between the confinement and nonconfinement groups. Empirical observations indicate many hired workers leave this occupation yearly because of respiratory symptoms. Those remaining, as a group, may well be selected by functional capability, despite frequent respiratory symptoms.

The swine confinement industry is relatively new. The average exposure time for this group is 6.2 yr. Relative to other occupational respiratory diseases, this is a short time to expect objective signs (e.g., decreased pulmonary function tests) to manifest. Certainly the high prevalence of acute and chronic respiratory symptoms reported here suggests further studies are needed to elucidate this situation, including a longitudinal study, a dose-response study, and a study of intervention strategies.

With estimates of the large and growing numbers of exposed workers (nearly 1 million) combined with the high prevalence of respiratory symptoms, we may find in the future that confinement livestock production presents respiratory disease risks which are equal or more important than the more commonly recognized grain handlers illnesses and byssinosis.

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Requests for reprints should be sent to: Kelley J. Donham, D.V.M., Institute of Agricultural Medicine and Occupational Health, College of Medicine, Univesity of Iowa, Oakdale, Iowa 52319.

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Pulmonary Function of Exposed and Control Workers in a Nigerian Nonsoapy Detergent Factory

U. G. OLERU
College of Medicine
University of Lagos
P.M.B. 12003
Lagos, Nigeria

ABSTRACT. Respiratory symptoms and spirometric pulmonary function data [i.e., first-second forced expiratory volume ($FEV_{1.0}$) and forced vital capacity (FVC)] for 128 (30%) males who were exposed to alkyl benzene sulphonate in a detergent factory and for 56 (76%) unexposed workers in the same factory are reported herein. Exposed subjects had been employed for 1 month to 15 yr, and they generally complained of cough and mucus secretions, nasal catarrh, chest pain, and breathlessness. Unexposed workers had been employed for 1 month to 13 yr and had a significantly lower ($P < .001$) frequency of symptoms, as well as significantly higher ($.01 > P > .001$) $FEV_{1.0}$ and FVC than the exposed workers. The reduction in pulmonary function of exposed subjects from the predicted was significantly higher ($.01 > P > .001$) than that experienced by the unexposed subjects. There was a significant 8-hr workshift depression in lung function. There was radiological evidence of pulmonary fibrosis, but lack of pre-employment chest radiographs renders this inconclusive. Respiratory symptoms in exposed subjects decreased with duration of employment, which probably indicates the exodus from the work force of those who could not tolerate the nonsoapy detergent.

INDUSTRIAL PROGRESS in many developing countries, like Nigeria, is made against a backdrop of mass illiteracy and is not matched by the development of an awareness by the general public or the specific group at risk of the dangers associated with industrial exposures. There are no statutory regulations for occupational exposure, and instead of demanding protective devices, workers in the developing countries request milk allowances in the hope that milk will alleviate the impact of the exposure suffered in the workplace.

In several studies, nonsoapy detergent or akyl benzene sulphonate (ABS) has been associated with skin and respiratory track infections, chest constriction, cough, mucus secretion, breathlessness, nasal stuffiness, and nocturnal asthma.[1-3] The primary focus of some of these studies on the enzyme additive to ABS did not, however, permit examination of the role of ABS in the development of the reported symptoms.

In this study, the impact of nonsoapy detergent (ABS) exposure on pulmonary function of workers was investigated. The study is part of a series designed to evaluate the current impact of industrialization on the health of Nigerian workers.[4-6]

MATERIALS AND METHODS

Description of factory. The factory in this study is