

# Peak Flow as a Measure of Airway Dysfunction in Swine Confinement Operators

Timothy J. Quinn, BS; Kelly J. Donham, DVM;  
James A. Merchant, MD, DrPH; and  
David A. Schwartz, MD, MPH, FCCP

To evaluate the usefulness of a portable peak flow meter in predicting airway dysfunction in symptomatic swine confinement workers, we conducted a study using an established cohort of swine workers in Iowa. Participants were randomly selected from a group of 207 swine confinement workers and a group of nonconfinement farmers who had been followed longitudinally. Swine confinement workers with work-related symptoms were identified, and two control groups (swine confinement workers and nonconfinement workers) without work-related symptoms were frequency matched by age, sex, and smoking status to the symptomatic swine confinement workers. Peak flow measures were obtained for 7 days using a mini-Wright peak flow meter and comparisons were made between the symptomatic swine confinement farmers (n=24) and both groups of asymptomatic workers: swine confinement workers (n=21) and neighborhood farmer controls (n=25). Peak flow readings were recorded by subjects five times per day for 7 days, initially on awakening, then after chores, before lunch, before dinner, and before bedtime. The actual hour of day for each measurement of peak flow was similar between the three groups. Percent changes from

initial AM peak flow did not significantly differ between subject groups. However, symptomatic swine confinement workers consistently exhibited significantly lower initial and subsequent mean peak flow values compared with asymptomatic swine confinement workers and neighborhood control farmers, controlling for age, height, gender, and smoking status. These differences occurred on most of the measures of peak flow throughout the work day. The persistence of these lower values throughout the work day is remarkably consistent during the study period and is suggestive of airway disease in the symptomatic swine confinement workers. Our findings suggest that peak flow meters are a useful indicator of potential airway injury and offer an additional portable, diagnostic tool in the assessment of symptomatic workers. (*Chest* 1995; 107:1303-08)

PEFR=peak expiratory flow rate

Key words: asthma; bronchitis; confinement dust; farmers; mini-Wright; occupational asthma; peak flow; swine confinement operators

Animal confinement operations represent a relatively new approach to livestock farming. These operations may increase animal production capacity, but also create a work environment with unique respiratory hazards. Dusts in these facilities consist of feed and aerosolized fecal material, as well as gases and animal dander.<sup>1-4</sup> This mixture of gases consists primarily of carbon dioxide, ammonia, methane, and hydrogen sulfide.<sup>5</sup> Anaerobic microbes produce an

additional 68 volatile compounds that have been identified in hog waste manure pits.<sup>2</sup> Ammonia, for example, adsorbs to particulates and becomes a component of the generated dust.<sup>1-3</sup> Animal confinement operators report a high prevalence of cough and sputum production.<sup>4-8</sup> The prevalence of bronchitis among swine confinement workers has been reported as high as 70%.<sup>5</sup> These workers as a group exhibit work-related decreases in airflow.<sup>9,10</sup> In fact, workers spending greater proportions of their day in confinement facilities have higher frequencies of cough and phlegm, as well as lower pulmonary function performance than those spending less time in the facilities.<sup>8,11,12</sup>

The peak flow meter is an established indicator of airway function in asthma<sup>13</sup> and bronchitis.<sup>14</sup> This portable, hand-held device has been used to assess diurnal range in peak flow as it relates to symptoms,<sup>13</sup> and changes within the day resulting from specific occupational and environmental exposures.<sup>15-17</sup> Daily peak flow amplitudes lower than normal have been observed in workers exposed to cotton dusts and mi-

\*From the Division of Occupational and Environmental Health and the Division of Biostatistics, Department of Preventive Medicine and the Division of Pulmonary, Critical Care and Occupational Medicine, Department of Internal Medicine, Department of Veterans Administration Medical Center, and The University of Iowa, Iowa City, Iowa.

This study was supported by an Education and Development Grant (HL33128) from the National Heart, Lung, and Blood Institute, a grant (OH00093-01) from the National Institute of Occupational Safety and Health of the Centers for Disease Control, and a grant from the National Institute of Environmental Health Sciences (ES06537).

Manuscript received July 27, 1994; revision accepted October 13. Reprint requests: Dr. Schwartz, Division of Pulmonary, Critical Care, and Occupational Medicine, Dept. of Internal Medicine, The University of Iowa Hospitals and Clinics, Iowa City, Iowa 52242

crobial contaminants.<sup>17</sup> The portable peak flow meter provides an accurate measure of airflow. It has been shown to be accurate within 3% in the 450 to 600 L/min range when standardized against a pneumotachometer.<sup>18</sup> Shapiro also found consistent results for subjects using the mini-Wright meters,<sup>18</sup> the exception being variability at less than 300 L/min or use of the device greater than 200 times.<sup>18</sup> This device provides a measure of peak expiratory flow rate (PEFR) that is significantly correlated with PEFR measured by the Wright peak flow meter<sup>19</sup> and the standard spirometer.<sup>16</sup>

The purpose of the current investigation was to determine whether the portable peak flow meter could detect physiologic differences between symptomatic hog confinement farmers and asymptomatic controls. A previous study of this group of farmers revealed that symptomatic hog confinement workers had evidence of airway disease manifested by air trapping, enhanced responses to methacholine, and thickening of the bronchiolar basement membrane when compared with controls.<sup>20</sup> Thus in this study, we are interested in determining whether a simple noninvasive portable device, such as the mini-Wright flow meter, is able to detect airway dysfunction in a population of symptomatic swine confinement workers that has been previously studied.<sup>20</sup>

## METHODS

### *Study Population*

Cases and controls were systematically selected from an ongoing longitudinal study so that results could be generalized to subjects in the longitudinal investigation. The population-based, longitudinal cohort was established in 1984 and consisted of a random sample of all swine confinement operators in Eastern Iowa. The sample was stratified by size of operation and geographic locale. After the 207 swine confinement operators were selected, 158 neighborhood farmers were matched by geographic locale (within a radius of 5 miles) to the swine confinement operators. Neighborhood farmers had a history of swine production, but none had swine confinement exposure for 5 years before beginning the study.

### *Swine Confinement Cases*

Of the 207 swine confinement operators, 43 met the case definition of work-related symptoms; they experienced chest tightness or difficulty breathing on returning to work 2 days after last exposure, frequent episodes of either chest tightness, or dyspnea while working in a confinement building or at least two delayed constitutional symptoms—fever, chills, muscle aches, weakness, cough, chest tightness, dyspnea—occurring 2 to 6 h after exposure to dust in a confinement building. Thirty-one swine confinement operators were randomly selected from the 43 eligible swine confinement cases of whom 9 (29%) had chest tightness or difficulty breathing after returning to work, 17 (55%) had frequent episodes of chest tightness or dyspnea while working in a confinement building, and 17 (55%) had delayed constitutional symptoms several hours after exposure to dust.

### *Control Subjects*

Subjects who did not fit the case definition were selected from each of the cohorts: swine confinement operators and neighborhood farmers. For each cohort, controls were randomly selected from the appropriate age (using 10-year intervals), sex, and smoking status (never, former, or current) strata, such that each control group had a similar number of subjects within each of these strata.

### *Rate of Participation*

Ninety six subjects took part in the earlier case-control investigation.<sup>20</sup> Thirteen of these subjects did not follow up in the peak flow study. Of these, five were cases that did not participate (four were no longer in swine confinement farming and one subject declined to participate), five swine controls dropped (three were no longer raising hogs and two declined to participate), and three farmer controls were lost to follow-up (two were no longer in farming and one subject declined). Peak flow meters were given to the 83 participants that remained. Participation rates varied, and some subjects reported little or no information. Excluded from the analysis were those returning no peak flow information: two swine confinement subjects, seven swine controls, and three neighborhood controls. An additional subject from the swine confinement control group was not included because they reported only one peak flow measurement. Of those 83 subjects asked to participate, 70 (84%) actually participated and were included in the analysis.

### *Study Protocol*

Subjects were given a hand held mini-Wright peak flow meter (Clement Clarke; Columbus, Ohio) by a respiratory therapist on the day of the visit to their hog confinement operation. Study subjects and the therapist were blinded to the case/control status of the participant. Each study subject was instructed to make all measurements while standing and to blow as hard and fast as they could while holding the meter in a horizontal position on its bottom side with one hand. To minimize sensitivity, those exposed to cold air were told to wait several minutes before completing the test. Peak flow results were recorded for 7 days, beginning the day of the site visit with five reading times each day: after awakening, after chores, before lunch, before dinner, and before bedtime. Three attempts were made at each reading time, and participants were asked to take readings at the same times every day in the same location. We retained the best two peak flow results at each reading and averaged them. Percent changes from baseline were calculated using the following formula: [(2nd reading - 1st reading)/1st reading] \* 100%. A form was given to each subject for recording the results and times, as well as a stamped, addressed envelope for the return of the meter and data sheet.

### *Statistics*

The Mann Whitney U statistic<sup>21</sup> was initially used to evaluate portable peak flow results. Our evaluation included variation from baseline as well as the mean peak flow performance of the symptomatic swine confinement workers in relation to the two control groups. Comparisons between the swine cases and control groups were then analyzed using linear regression models<sup>22</sup> to control for age, height, gender, and smoking status. Since our hypothesis was that peak flow would be lower among symptomatic swine confinement workers, a one-tailed statistical test was used.

## RESULTS

Demographics of the study participants are presented in Table 1. Characteristics of age, sex, and

**Table 1—Demographic and Clinical Characteristics of Study Subjects\***

Variable	Swine Confinement Cases, n=24 (%)	Swine Confinement Controls, n=21 (%)	Neighborhood Farmer Controls, n=25 (%)
Age, yrs	42.17 ± 11.09	41.95 ± 9.11	40.28 ± 10.29
Height, inches	69.79 ± 2.73	70.76 ± 3.38	71.38 ± 2.59
Male	22 (92)	18 (86)	23 (92)
Smoking history			
Never	17 (71)	18 (86)	14 (56)
Former	4 (17)	2 (10)	8 (32)
Current	3 (12)	1 (4)	3 (12)
Pack-years of smoking	7.48 ± 17.33	1.43 ± 5.26	5.61 ± 10.20
Swine farming, n	24 (100)	21 (100)	17 (68)
Swine confinement work within past 5 yrs	24 (100)	21 (100)	0 (0)
Farming, yrs	23.13 ± 11.28	24.24 ± 8.46	22.04 ± 10.06

\*Values in the table are expressed as the mean ± SD for continuous variables and as n (%) for categorical variables.

smoking status of the three groups are similar, as the study design would predict. While over 50% of each group were never smokers, the pack years of confinement controls were lower relative to the swine confinement cases and farmer controls. All subjects had a history of farming, and the number of years of farming experience was similar between the groups. Of note, over half of the neighborhood controls participated in raising hogs; however, none of the neighborhood farmers had worked in confinement facilities within 5 years of the initiation of this study.

Comparing each study group, the compliance obtaining and reporting peak flow measurements was

quite similar. Thirty five potential reading times existed for each subject (five times per day for 7 consecutive days). Of the total possible readings, the three groups combined reported 1,730 of 2,450 readings (71%). Of the subjects included in the analysis, swine cases reported 576 of 805 possible readings (72%), swine controls reported 447 of 735 (61%), and neighborhood farmer controls reported 707 of 910 (77%). Fifteen subjects reported values at every one of the 35 possible readings: 4 confinement cases, 4 confinement controls, and 7 neighborhood farmers. Subjects were asked to take peak flow measurements after specific events throughout the day. Using an event instead of a specific time of day created ranges in data collection times in the three groups. These ranges in time, however, were remarkably consistent between groups. For example, symptomatic swine workers reported first readings of the day between 0535 and 0920, swine confinement controls between 0440 and 0940, and asymptomatic neighborhood farmers between 0530 and 0920.

Swine cases as a group showed consistently lower mean peak flow values than both swine controls and neighborhood controls (Fig 1). Table 2 presents the mean peak flow values at the first reading (after awakening) for each day and shows that the symptomatic swine confinement cases tended to have lower values than either of the control groups. The symptomatic workers also tended to be significantly lower for the second (Table 3), third (Table 4), fourth (Table 5), and fifth (Table 6) readings when compared with the control groups. While there were no significant differences between the mean peak flow of swine controls and neighborhood farmer controls, the symptomatic swine workers clearly exhibit lower

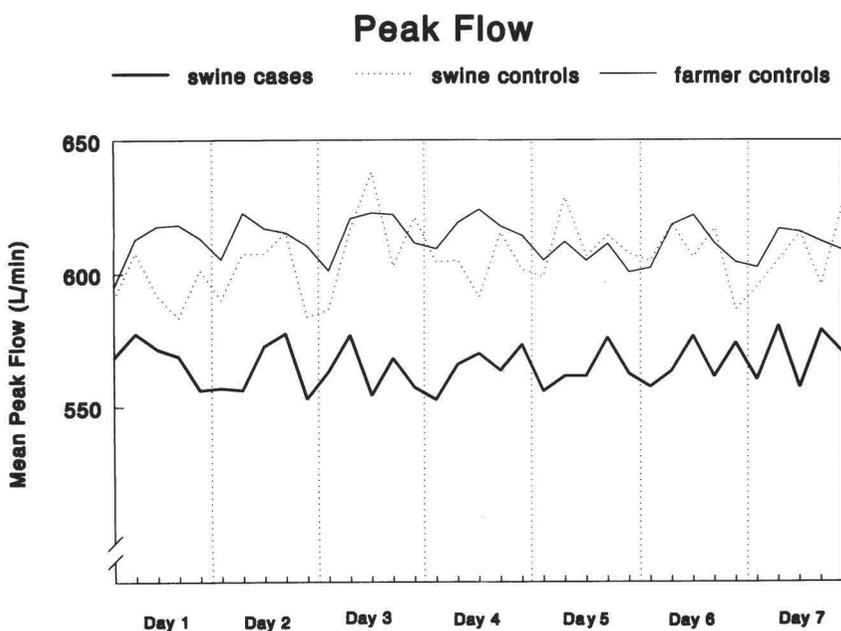


FIGURE 1. Mean peak flow values for the three groups during the observation period. Standard error bars are not shown.

**Table 2—Mean Peak Flow After Awakening\***

Variable	Swine Confinement Cases (n=24)	Swine Confinement Controls (n=21)	Neighborhood Farmer Controls (n=25)
Day 1	568.6 ± 76.9 (24)	590.4 ± 65.6 (21)	595.0 ± 68.8 (25)
Day 2	556.9 ± 82.1 (21)	590.1 ± 68.7 (17)	605.4 ± 62.1 (23)
Day 3	563.2 ± 81.9 (18)	586.5 ± 63.1 (14)	601.1 ± 63.9 (22)
Day 4	552.7 ± 77.4 (20)	604.4 ± 71.3 (17) <sup>†</sup>	609.4 ± 63.0 (22) <sup>†</sup>
Day 5	555.9 ± 89.8 (18)	598.9 ± 66.3 (14)	605.1 ± 65.6 (21)
Day 6	557.5 ± 83.8 (16)	604.7 ± 70.6 (15)	602.2 ± 65.4 (22)
Day 7	560.2 ± 80.5 (18)	595.3 ± 59.4 (15)	602.3 ± 63.5 (21)

\*Values are means ± SD followed by (n). Swine cases were individually compared with each of the two control groups, using linear regression to control for age, height, gender, and smoking status.  
<sup>†</sup>p ≤ 0.05.

peak flow performance when compared with both control groups at each time point.

Evaluations of percent changes from baseline peak flow across each day reveal mild increases for all three groups of workers. The increases were consistently higher for neighborhood farmer controls than for swine cases, but those differences were slight and of infrequent statistical significance (data not shown). Slightly larger improvements in peak flow by neighborhood controls are seen from first to second readings. The average percent increase was 1.7% for swine cases, 2.3% for swine controls, and 2.6% for neighborhood controls. While the percentage increase in peak flow performance for controls was not generally significant throughout the work day relative to the swine cases, both control groups did have consistently higher mean peak flow readings (Tables 2 to 6). Thus, the lower baseline values of swine cases tended to persist throughout the work day. Comparisons across consecutive days are not relevant among these workers since swine operators and farmers work every day of the week.

**Table 3—Mean Peak Flow After Chores\***

Variable	Swine Confinement Cases (n=24)	Swine Confinement Controls (n=21)	Neighborhood Farmer Controls (n=25)
Day 1	577.5 ± 72.5 (23)	607.9 ± 73.6 (21)	612.9 ± 58.3 (25)
Day 2	556.2 ± 77.6 (16)	607.4 ± 58.4 (11) <sup>†</sup>	622.7 ± 55.8 (20) <sup>†</sup>
Day 3	576.9 ± 74.1 (17)	616.6 ± 48.2 (11) <sup>†</sup>	620.7 ± 56.2 (23) <sup>†</sup>
Day 4	566.1 ± 82.4 (16)	605.0 ± 61.6 (12) <sup>†</sup>	619.2 ± 64.0 (19) <sup>†</sup>
Day 5	561.5 ± 79.8 (14)	628.7 ± 50.6 (9) <sup>†</sup>	612.0 ± 61.3 (19) <sup>†</sup>
Day 6	563.4 ± 85.2 (14)	618.7 ± 62.4 (9)	618.4 ± 54.7 (18)
Day 7	580.5 ± 85.8 (15)	605.1 ± 65.3 (10)	616.8 ± 55.0 (17)

\*Values are means ± SD followed by (n). Swine cases were individually compared with each of the two control groups, using linear regression to control for age, height, gender, and smoking status.  
<sup>†</sup>p ≤ 0.05.

**Table 4—Mean Peak Flow Before Lunch\***

Variable	Swine Confinement Cases (n=24)	Swine Confinement Controls (n=21)	Neighborhood Farmer Controls (n=25)
Day 1	571.7 ± 75.4 (20)	591.7 ± 60.0 (13)	617.8 ± 60.3 (22)
Day 2	572.8 ± 74.5 (16)	607.5 ± 76.0 (14)	617.0 ± 63.1 (21)
Day 3	554.3 ± 76.3 (16)	638.1 ± 79.8 (10) <sup>†</sup>	622.8 ± 64.4 (20) <sup>†</sup>
Day 4	570.1 ± 80.5 (17)	591.3 ± 63.1 (12) <sup>†</sup>	624.2 ± 67.2 (19) <sup>†</sup>
Day 5	561.5 ± 95.1 (11)	606.6 ± 80.2 (13)	604.9 ± 61.1 (18)
Day 6	576.6 ± 77.0 (14)	606.2 ± 62.1 (9)	621.9 ± 62.5 (21)
Day 7	557.2 ± 77.4 (14)	615.6 ± 70.6 (14)	615.7 ± 56.0 (18) <sup>†</sup>

\*Values are means ± SD followed by (n). Swine cases were individually compared with each of the two control groups, using linear regression to control for age, height, gender, and smoking status.  
<sup>†</sup>p ≤ 0.05.

DISCUSSION

Our findings suggest that swine confinement operators with work-related symptoms have consistently lower peak flow performance when compared with controls. While percent changes from baseline do not differ between symptomatic and asymptomatic workers, the lower measures of peak airflow for

**Table 5—Mean Peak Flow Before Dinner\***

Variable	Swine Confinement Cases (n=24)	Swine Confinement Controls (n=22)	Neighborhood Farmer Controls (n=25)
Day 1	569.0 ± 69.1 (21)	583.4 ± 57.4 (14) <sup>†</sup>	618.3 ± 62.5 (23) <sup>†</sup>
Day 2	577.6 ± 73.4 (18)	615.5 ± 79.5 (12)	615.3 ± 66.7 (21)
Day 3	568.2 ± 72.4 (16)	602.8 ± 76.1 (9) <sup>†</sup>	622.2 ± 64.7 (20) <sup>†</sup>
Day 4	563.6 ± 84.8 (17)	615.5 ± 88.1 (11)	617.9 ± 63.6 (19)
Day 5	576.0 ± 77.8 (15)	614.4 ± 57.9 (11)	611.2 ± 49.3 (18)
Day 6	561.3 ± 70.0 (18)	617.3 ± 74.2 (11)	611.4 ± 67.2 (17)
Day 7	578.9 ± 71.0 (13)	595.8 ± 62.4 (12)	612.1 ± 53.7 (20)

\*Values are means ± SD followed by (n). Swine cases were individually compared with each of the two control groups, using linear regression to control for age, height, gender, and smoking status.  
<sup>†</sup>p ≤ 0.05.

**Table 6—Mean Peak Flow Before Bedtime\***

Variable	Swine Confinement Cases (n=24)	Swine Confinement Controls (n=21)	Neighborhood Farmer Controls (n=25)
Day 1	556.17 ± 74.93 (18)	601.35 ± 64.28 (17)	613.30 ± 60.31 (23) <sup>†</sup>
Day 2	552.93 ± 81.30 (15)	583.69 ± 60.21 (13)	610.47 ± 64.06 (19)
Day 3	557.21 ± 75.84 (14)	621.23 ± 82.79 (13) <sup>†</sup>	611.55 ± 60.35 (20) <sup>†</sup>
Day 4	573.36 ± 80.38 (14)	601.50 ± 56.62 (10)	614.26 ± 69.09 (19)
Day 5	562.38 ± 70.83 (13)	607.50 ± 81.69 (10)	600.56 ± 66.69 (16)
Day 6	574.00 ± 70.41 (12)	586.50 ± 68.59 (12)	604.22 ± 66.75 (18)
Day 7	570.43 ± 77.43 (14)	626.64 ± 73.92 (11)	608.80 ± 58.90 (20)

\*Values are means ± SD followed by (n). Swine cases were individually compared with each of the two control groups, using linear regression to control for age, height, gender, and smoking status.  
<sup>†</sup>p ≤ 0.05.

symptomatic swine operators persisted throughout the work week. These findings are consistent with our previous results that suggest that swine confinement workers who have work-related symptoms are at risk for airway injury. Moreover, these findings suggest that a portable hand-held device may be a useful indicator of airway injury in symptomatic workers.

Our results indicate that symptomatic swine confinement workers have objective measures of airflow obstruction. These findings are supported by our earlier investigation in this population which showed that work-related symptoms among confinement workers were associated with air trapping, enhanced bronchial responsiveness, and thickening of the subepithelial basement membrane.<sup>20</sup> Increased residual volume in symptomatic farmers has also been noted by Iversen.<sup>23</sup> Findings by others are consistent with the increased responses to methacholine challenge.<sup>23,24</sup> Further results indicate that symptomatic confinement workers with lower FEV<sub>1</sub> to FVC ratios are significantly more responsive to methacholine than asymptomatic confinement operators.<sup>25</sup> In aggregate, these results suggest that swine confinement workers are at risk of developing airway disease, and that work-related symptoms are useful indicators of those who are likely to have this problem.

Our results indicate that the portable peak flow meter is a reliable and valid screening tool for airway injury among swine confinement workers. The peak flow meter has been used to determine the presence of occupational asthma, a condition that is associated with lower peak flow on work days in comparison to nonwork days.<sup>15,26</sup> However, two investigators did find that results from the mini-Wright overestimated peak flows when compared with a pneumotachometer<sup>27</sup> and a standard Wright peak flow meter.<sup>19</sup> Since our cases and controls have values within the mini-Wright's range of accuracy,<sup>18</sup> this tendency for overestimation should be minimized. More importantly, the case-control design of this study relied on the relative differences in peak flow between the study groups. Thus, consistently inflated values would not obscure the group differences.

The pattern of decreased peak flow in swine cases appears to represent an airway response characteristic of agricultural workers exposed to organic dusts that are almost always contaminated with microorganisms and microbial byproducts. About 30% of the agricultural dusts are respirable.<sup>28</sup> When comparing settled dust to airborne dust, endotoxin was shown to be predominantly airborne in a confinement facility,<sup>29</sup> and was actually more concentrated in the respirable fraction when compared with the nonrespirable fraction.<sup>1</sup> Attwood found that about 90% of the measured endotoxin in buildings accompanies respirable sized fractions of dust.<sup>1</sup> Inhaled endotoxin

causes airflow obstruction in normal subjects<sup>30</sup> and asthmatics,<sup>31</sup> and among cotton workers endotoxin was found to be a better predictor of airflow obstruction than dust levels.<sup>30,32-34</sup> Thus, microorganisms and their products may be, at least in part, responsible for the airway disease that is consistently shown among agricultural workers.

The concentration of organic dust and irritant gases, *ie*, ammonia, that confinement farmers are exposed to is higher than other agricultural workers.<sup>6</sup> This work exposure is aggravated in the winter season when confinement facilities have less ventilation and dust levels are higher.<sup>1,35</sup> Although the precise cause of airway disease in agricultural workers is not known, simple industrial hygiene measures can be used to minimize the development of this process. It has been shown that those spending greater proportions of their day in the confinement facilities have a higher frequency of cough and phlegm, as well as lower pulmonary function performance when compared with those workers spending less time in the facilities.<sup>8,11,12</sup> Lowering the dust levels by improving ventilation and using personal respirators would serve to reduce potential introduction of dust as well as endotoxin, since most endotoxin adheres to respirable sized dust particles.<sup>1</sup> Attention to airborne dusts and endotoxin exposures could possibly assist in identifying and minimizing the risk of respiratory injury to swine confinement workers.

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