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Cage Versus Noncage Laying-Hen Housings: Worker Respiratory Health

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ABSTRACT. The objective of this study was to compare respiratory health of poultry workers in conventional cage, enriched cage and aviary layer housing on a single commercial facility, motivated by changing requirements for humane housing of hens. Three workers were randomly assigned daily, one to each of conventional cage, enriched cage, and aviary housing in a crossover repeated-measures design for three observation periods (for a total of 123 worker-days, eight different workers). Workers' exposure to particles were assessed (Arteaga et al. *J Agromedicine*. 2015;20:this issue) and spirometry, exhaled nitric oxide, respiratory symptoms, and questionnaires were conducted pre- and post-shift. Personal exposures to particles and endotoxin were significantly higher in the aviary than the other housings (Arteaga et al., 2015). The use of respiratory protection was high; the median usage was 70% of the shift. Mixed-effects multivariate regression models of respiratory cross-shift changes were marginally significant, but the aviary system consistently posted the highest decrements for forced expiratory volume in 1 and 6 seconds (FEV_1 and FEV_6) compared with the enriched or conventional housing. The adjusted mean difference in FEV_1 aviary − enriched cage housing was −47 mL/s, 95% confidence interval (CI): (−99 to 4.9), $P = .07$. Similarly, for FEV_6, aviary − conventional housing adjusted mean difference was −52.9 mL/6 s, 95% CI: (−108 to 2.4), $P = .06$. Workers adopting greater than median use of respiratory protection were less likely to exhibit negative cross-shift pulmonary function changes. Although aviary housing exposed workers to significantly higher respiratory exposures, cross-shift pulmonary function changes did not differ significantly between houses. Higher levels of mask use were protective; poultry workers should wear respiratory protection as appropriate to avoid health decrements.

KEYWORDS. Laying-hen housing, occupational health, poultry workers, pulmonary function, respiratory exposure

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INTRODUCTION

Modern commercial egg-laying poultry housing overwhelmingly consists of multiple tiers of cages in indoor confinement facilities.[1,2] Commonly only one worker attends each house, which may hold in excess of 200,000 hens.[3,4] Respiratory exposures potentially harmful to worker health have long been documented in poultry farms. Modern facilities concentrate more hens into each building but have better environmental controls; therefore, the effect of modernization on worker health is uncertain.[5–8]

The concentration of airborne dust in poultry houses depends in part on the effectiveness of the ventilation system.[9,10] High concentrations of air contaminants, especially endotoxins, are associated with decreases in pulmonary function that may be exacerbated by ammonia.[11–13] These pollutants promote work-related cough, phlegm, eye irritation, chest tightness, fatigue, dyspnea, wheezing, nasal discharge, headache, throat irritation, and fever.[14] Although individual responses are variable, the most common long-term effects include the development of bronchitis and other obstructive disorders with indications of mixed effects, including some restrictive changes with relation to chronic ammonia exposures.[15,16]

The effect of different types of housing for laying hens on the respiratory health of workers has only recently been explored, motivated by animal welfare regulation in Europe[17] and California that requires more space per hen.[18] The majority of studies compare regular caging systems (battery type) with indoor cage-free housing.[11,19–24] Most of these studies measure the exposures but do not assess the health status of the workers. Larsson et al.[20] studied volunteers who were naïve to poultry exposures and compared cage with cage-less housing. Significantly higher levels of inhalable dust (inhalable particulate matter [PM]) and ammonia were found in the cage-free systems, as well as stronger negative health effects. In contrast, Kirychuk et al.[11] compared broilers/turkey floor operations with layers in cage housing and found that although floor operations had significantly more total dust, the two systems were similar in airborne endotoxin concentrations. Staff working with cages was more likely to report both current and chronic phlegm.

Due to the conflicting findings surrounding different types of poultry housing and worker respiratory health, there is a need to monitor exposure and health consequences in a controlled situation. This study was part of a national collaboration using a single commercial facility to compare conventional cages, enriched cages, and aviary-style housing systems. A holistic approach was taken to evaluate the three systems on many levels, including environmental impacts, worker health, food safety, animal health and welfare, and economic accountability. Hens in each of the housing systems were provided with normal nutrition, controlled lighting, and management procedures as similar as possible to provide as close to real-world production conditions in a controlled experimental protocol. This article the second of two companion articles, reports on the impact of hen housing systems on the respiratory health of the poultry worker. The first article[1] discusses the respiratory exposures in the three housing types and demonstrates that the aviary exposures exceeded those in the conventional or enriched cage housing.

MATERIALS AND METHODS

Housing Systems

One facility containing three purpose-built housing systems was assessed. The housing systems were compared for respiratory exposures and health effects and included conventional cage housing, enriched cage housing, and aviary housing. The aviary housing consisted of pens, with perches, forage and nest areas, and litter on the floor, unlike the cage systems. A full description is given in Arteaga et al.[1] and Jones et al.[25]

Participants and Study Design

Automation of the poultry industry has allowed a very efficient work force. Usually one worker attends to the needs of each hen house (here up to 200,000 hens) each day. Workers often rotated around the different types of housing, so no long-term health effect from a specific type of housing could be assigned to any one worker. We were able to assess multiple single across-shift changes in respiratory health using a randomized repeated-measures design. Workers were limited to one housing type on any single workday but were randomly assigned an equal number of times to each type of housing for three seasonal assessments lasting about 3 weeks each (12–15 workdays). Power calculations for analysis of variance model were performed using Lenth's "Java Applets for Power and Sample Size"[26] with the hypothesis that one of the housings would prove to be significantly worse or better than the other two. A total of 108 worker-day observations, with 36 from each of the three distinct housing types, were the minimum suggested by the power calculation based on a mean outcome difference of 0.80 root mean square errors between the best or worst cross-shift pulmonary function changes.

Aerosol exposures[1] and cross-shift lung function changes were collected on a worker-day unit of observation. Sampling was conducted during three monitoring periods following one flock in summer 2011, winter 2012, and spring 2012 when the hens were respectively 33–35, 63–65, and 74–76 weeks of age. For each monitoring period, four volunteer workers were enrolled from those who had been trained to tend the conventional and alternative housing systems (aviary and enriched cage). Three participants worked per day, each in one (and only one) housing type with minimal exposure to the other houses. The workers underwent pre- and post-shift pulmonary function tests (PFTs) and were surveyed using interviewer-administered questionnaires. The study protocol, specifically the treatment of participants, including individual informed consent, was approved by the institutional review board.

Health Assessment Outcomes

Respiratory health changes over each day's exposure to the poultry housing were assessed using pre- and post-shift pulmonary function testing, nitric oxide in exhaled breath (eNO), and symptoms questionnaires. The procedures took place in an office/restroom facility separate from the poultry houses to minimize contamination. An Easy One Portable Spirometer (NDD Medical Technologies, Andover, MA) was used to assess lung function in workers. Spirometry measurements included the total volume of air forcibly expelled after inhaling to maximum (forced vital capacity), in air expelled in the first second (FEV_1) of the forced vital capacity (FVC) and the forced expiratory volume in 6 seconds (FEV_6) (which is used as a more reliable surrogate for the FVC), and FEV_1/FVC. Technicians performing the tests were trained according to American Thoracic Society (ATS) standards, and recommended quality control measures were followed. If the variability between the two best maneuvers was greater than 8%, in either the pre- or post-shift, data for that measure of pulmonary function were not used in the study.[27] A NIOX MINO was used to assess eNO as a marker of lung inflammation. The outcome measures, cross-shift changes in pulmonary function or eNO, were calculated as post-shift minus pre-shift value.

Predictor Variables

The main predictor of interest was the housing type (conventional, aviary, or enriched cages). Other predictor variables considered for inclusion in statistical models included season of testing (summer, winter, spring) and the percentage time respiratory protection was worn (either an N95 mask or a P95, R95, or N95 respirator). "High mask" indicates that a mask was worn 70% or more during the work shift. Other possible covariates were considered but rejected because of their collinearity with other variables. For example, the number of birds in each house was a function of the house type, whereas the ventilation rate, temperature, and hen age were dependent on the season. Other variables observed were day of the week and whether the manure belts were running.

Because of the structure of the outcomes of interest (post-pre shift measures), the following covariates usually included when pulmonary function is assessed were not needed in the model: age of participant, height of participant, sex, race, or smoking status of the participant (none of the workers smoked while at work).

Data Analysis

Databases and statistical analyses were conducted using Statistical Analysis System (SAS) Software version 9.3 (SAS Institute, Cary, NC). Continuous variables were described by their univariate distributions and categorical by frequency tables. To account for clustering by individual workers, we used a mixed-effects multiple linear regression modeling strategy, with the cross-shift pulmonary function as the outcome variable. Covariates were included in multivariate models if they exhibited an association of $P \leq .1$ in the univariate regression. A core set of predictor variables included housing type, season, and mask use. Covariates remained in the model if they were significant ($P < .05$) or if they caused more than 15% change in the value of the estimate of interest. Appropriate interactions (e.g., season and housing) were tested in models having both those main effects and were rejected if the *P* value of the interaction was more than .05. There were too few incident respiratory symptoms to be modeled.

RESULTS

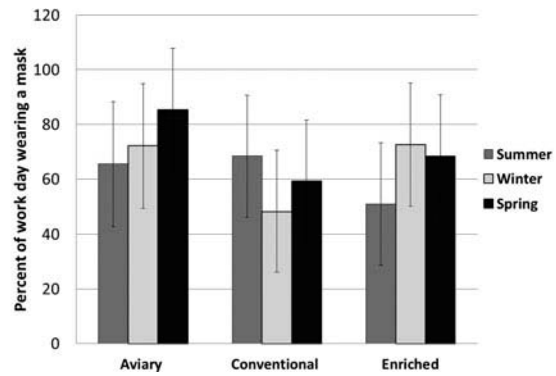
Demographics

Over the three monitoring periods a total of eight different workers participated in the study, some for more than one seasonal period. There were seven males and one female. Only three out of the eight completed high school. Four were born in the USA, the rest in Mexico. All spoke Spanish and were interviewed in Spanish. Their ages ranged from 22 to 52 years, and the number of years working in the poultry industry averaged 4.5 years, with a range from 1 to 9 years. Only one subject was a current smoker, but he did not smoke more than two cigarettes per day; none for at least an hour before work or during the workday.

Mask Use

Mask use (N-95 or respirator) in the aviary housing was consistently high, whereas mask

FIGURE 1. Variation in respiratory mask use by house and season. Mean percentage of the day a respiratory mask was worn. Error Bars indicate 95% confidence intervals.



use in the conventional and enriched housing was often lower and more variable (Figure 1). Except for the first season (summer), the mean mask use in conventional housing was lower than either of the other housing despite 4 times as many hens in the building. The overall median time at work wearing personal protective equipment was 70%; the interquartile range was 46% to 100%.

Respiratory Health

A total of 123 worker-day measurements were completed during the entire study. Few respiratory symptoms were recorded between pre- and post-shift, and a formal analysis was not conducted. The total number of incident symptoms was 10 in the aviary, 5 in the enriched cage housing, and 2 in the conventional housing. Respiratory health was assessed by cross-shift (the difference between post-shift and pre-shift) pulmonary function testing (PFT) and eNO. The mean (standard deviation, SD) [95% confidence intervals] of eNO concentrations for post-shift and pre-shift were 13.1 (7.8) [12.7–16.2] and 14.5 (9.5) [11.6–14.5] ppb respectively; the cross-shift differences were not significant either statistically or biologically (the upper limit of normal is considered to be between 20 and 30 ppb[28]). A mixed model was used to adjust cross-shift pulmonary function for covariates of building type, season, mask use, and random worker effect (Table 1). No significant changes

TABLE 1. Effect of Housing, Season, and Mask Use on Cross-Shift Pulmonary Function: Mixed-Effects Regression Models

Covariate	Estimate (95%CI)			Difference	LSM (95%CI)	*P*
FEV_1 (ml/sec)						
Building	**Conventional**	**Aviary**	**Enriched**			
β-coefficient	−5.4	−47.3	Referent			
(95% CI)	(−59 to 48.1)	(−99.5 to 4.9)				
LSM	26.4	−15.5	31.9	A–C	−41.9	.13
(95% CI)	(−21.8 to 74.7)	(−63.6 to 32.7)	(−16.0 to 79.6)		(−97 to 13)	
				A–E	−47.3	**.07**
					(−99 to 4.9)	
				C–E	−5.4	.84
					(−59 to 48)	
Season	**Summer**	**Winter**	**Spring**			
β-coefficient	−30.5	Referent	17.8			
(95% CI)	(−97.1 to 36.2)		(−37.2 to 72.9)			
LSM	−12.0	18.5	36.3	Su–W	−30.5	.37
(95% CI)	(−64.5 to 40.5)	(−32.7 to 69.6)	(−15.7 to 88.3)		(−97 to 36)	
				W–Sp	−17.8	.52
					(−73 to 37)	
				Su−Sp	−48.3	.16
					(−115 to +19)	
Mask use	**<70%**	**≥70%**				
β-coefficient	Referent	35.9				
(95% CI)		(−21.8 to 93.6)				
LSM	−3.7	32.2		≥70% to <70%	35.9	.55
(95% CI)	(−51.2 to 43.9)	−13.8 to 78.3)			(−21 to 93)	
FEV_6 (ml/6 sec)						
Building	**Conventional**	**Aviary**	**Enriched**			
β-coefficient	10.3	−42.6	Referent			
(95% CI)	(−44 to 64.7)	(−95.9 to 10.7)				
LSM	26.9	−26.0	16.6	**A–C**	−52.9	**.06**
(95% CI)	(−18.2 to 72.1)	(−70.9 to 18.9)	(−27.8 to 61.0)		(−108 to 2.4)	
				A–E	−42.6	.11
					(−96 to 11)	
				C–E	+10.3	.71
					(−44 to 65)	
Season	**Summer**	**Winter**	**Spring**			
β-coefficient	−82.4	Referent	−11.5			
(95% CI)	(−147 to −18)		(−67 to 44)			
LSM	−45.2	37.2	25.7	**Su–W**	−82.4	**.01**
(95% CI)	(−93.9 to 3.4)	(−10.2 to 84.5)	(−21.3 to 72.7)		(−146 to −18)	
				W–Sp	11.5	.68
					(−44 to 67)	
				Su–Sp	−70.9	**.03**
					(−134 to −7.3)	
Mask use	**<70%**	**≥70%**				
β-coefficient	Referent	76				
(95% CI)		(20.9 to 131)				
LSM	−32.1	43.9		**≥70%** to **<70%**	76.0	**.007**
(95% CI)	(−74.6 to 10.3)	(1.9 to 85.8)			(20.9 to131)	

Note. Each mixed-effects model included building, season, and percent of day a mask was used and was adjusted for the participant as a random variable. The β-coefficient estimates and least squares means (LSM) estimates are reported for FEV_1 (forced expiratory volume in 1 second) and FEV_6 (forced expiratory volume in 6 seconds). A = aviary; C = conventional cages; E = enriched cages. Su = summer; W= winter; Sp = spring. Mask use was bivariate, split at the median, with less than 70% = lower mask use. Significant and marginally significant associations are bolded.

or models were found for eNO or for the ratios FEV_1/FVC or FEV_1/FEV_6. For FEV_1, housing type was not significant when adjusted for season and mask use. Aviary work demonstrated a marginally larger decrement across a shift compared with enriched housing ($P = .07$). For FEV_6, a measure of lung capacity, overall housing also did not achieve statistical significance, with aviary housing marginally worse than conventional ($P = .06$). Compared with the spring, the summer season proved significantly worse for cross-shift FEV_6 ($P = .03$). If a mask was worn more than the median amount of time, cross-shift change was significantly better ($P = .0073$).

DISCUSSION

We monitored the exposures across shifts and changes in pulmonary function of workers in an egg-laying facility with three different types of housing. The monitoring consisted of three sets of 13–15-day periods over the lifetime of a single flock. We found that the aviary system exposed workers to more airborne particles, both total matter and endotoxin, in the inhalable PM and $PM_{2.5}$ ranges than either the conventional or enriched cage systems.[1] Very few investigations have been conducted that specifically compare cross-shift pulmonary function changes or monitor respiratory symptoms in these types of alternative housing systems.[11,20,29,30]

Respiratory Protection

Mask (N95 and respirator) use was high; the median percentage of the day wearing respiratory protection was 70%. Currently, very few reports of common practices in the modern poultry housing systems exist. Although respiratory protection is recommended under an OSHA (Occupational and Safety Health Administration) rule when "nuisance dust" averages >15 mg/m^3 for inhalable PM or >5 mg/m^3 for respirable PM over an 8-hour workday,[31] it is rare to find these time-weighted average concentrations exceeded in modern conventional cage systems. Workers exposed to lower ambient concentrations have to decide on an individual basis when they need to don a mask. In our previous study of respiratory exposures and health on dairies, workers rarely wore respiratory protection, and only 13.3% of the dairy workers wore a mask even when exposed to high levels of dust.[32] Historically, respiratory protection was rarely used, although mask use was found to negate the mean percent decrement in FEV_1 over the work shift in animal housing.[33] Two more recent studies found 78% of poultry workers never wore a mask,[34] and 82% of poultry layer workers rarely or never wore respiratory protection.[29]

We found that FEV_1 and FEV_6 cross-shift decrements were larger in the summer, which coincided with lower mask use and lower concentrations of pollutants in all houses. The high rate of protective mask use likely uncoupled the effect of ambient pollutant concentrations on the cross-shift respiratory changes experienced by the workers in this study population.

Respiratory Health Effects of the Three Housings

This study is one of a few that has compared the respiratory health of poultry workers attending different types of poultry housing. To our knowledge, it is the only one to exclusively use laying hens, the same management practices, and the same workers to compare the effect of different housing systems. Working in aviary housing was associated with decrements in the cross-shift (post − pre) pulmonary function for FEV_1, FEV_6, and FVC (but not FEV_1/FVC). The contrast between aviary and conventional housing was marginally significant for FEV_6 (estimate -26 mL/6 s for aviary, and 26.9 mL/6 s for conventional; $P = .06$), and the contrast between aviary and the enriched system for FEV_1 was also marginally significant, $P = .07$ (aviary estimate -15.5 mL and enriched $+31.9$ mL).

A wide variety of factors influence respiratory exposures in poultry facilities. The breed of hen, age, waste management, flooring or litter, bird density, method of feeding, composition of the feed, building structure and age, ventilation, and season all influence the respiratory exposures in addition to the style of caging and task types of the worker. This study aimed at minimizing those differences with all three housings located within one facility, with similar management styles, feed, task routines, ventilation environmental controls, and workers. Previous studies of poultry workers in general found high rates of respiratory symptoms and greater across-shift declines in FEV_1.[15,35–37] These deleterious effects have been associated with dust, endotoxin, and ammonia in a dose-response relationship.[15]

Comparison of Cage and Cage-Less Systems

Most studies comparing cage versus noncage housings have investigated a mix of species and types of birds complicating the comparisons. Over 20 years ago, Donham et al.[38] compared broiler workers with those in layer facilities and controls and recorded larger cross-shift decrements in FEV_1 in the broiler (floor-based housing) workers. Kirychuk et al., one of the very few groups to compare health effects of different poultry housings monitored aviary/floor systems (broilers and turkeys) and layers in conventional cages.[11] They determined the floor-based workers were exposed to significantly higher total inhalable PM and ammonia but similar concentrations of endotoxin compared with the conventional cage-based workers. Cross-shift pulmonary function changes were not significantly different between the two groups,[11] but the cage-based workers attending the laying hens experienced more current and chronic respiratory symptoms.

A study between two systems on the same facility using only laying hens[20] compared naïve subjects working in aviary and conventional housing. The main difference between housing systems was that the inhalable PM concentration was lower in the conventional cage housing (2.4 versus 4.1–4.8 mg/m^3). There were inflammatory reactions in both groups, but a higher incidence in the aviary, accompanied by a small, nonsignificant decrement in those workers' cross-shift FEV_1. A recent study comparing worker health in two different types of housing for laying hens: cages and floor-based, predicted a long-term association between personal dust exposure and chronic respiratory symptoms.[30] However, although the floor system exposed workers to significantly higher levels of respirable PM, they were unable to detect a significant difference between the two systems with respect to respiratory symptoms or pulmonary function (not cross-shift).

Our study's results are consistent with these previous investigations with respect to exposures and cross-shift pulmonary function changes when comparing cage and cage-less systems. Although the health decrements we reported were small, there was a consistent pattern: the conventional and/or enriched cage systems present fewer health exposures and risks for the worker over the lifetime of the laying flock. Very few studies of the respiratory health of workers in poultry facilities state the level of respiratory protection, Senthilselvan et al.[29] and Viegas et al.[37] are two recent exceptions. Respiratory protection rates in poultry facilities should be more closely studied and reported in occupational health investigations.

Limitations

Our population size was limited, as only four workers cycled through the three buildings each week. To gather sufficient data for the respiratory health of the workers, we constructed a repeated-measures random block design. The mixed-effects multivariate regression model allowed for the clustering of observations by the individual and adjusted for those correlations. Only one farm facility was monitored, so generalizability is difficult, as management practices directly influence the work environment. It is highly likely that there is a healthy worker effect, as the employees were not recent hires. Therefore, the workers may self-select for this type of work, which would likely reduce both the number of respiratory symptoms and the amplitude of cross-shift respiratory changes. As mask use was high, we were limited in our ability to see effects of ambient housing pollution on the worker's respiratory health. The N95s in general remove close to 100% of particulate air pollutants and are changed at least daily. Similarly, the respirators are routinely cleaned, and this would decrease the respiratory load of air pollutants still further.

CONCLUSION

This study concludes that the aviary system, under commercial scale production and similar management conditions, poses higher respiratory risk to the poultry workers than either the conventional or enriched laying systems investigated. Respiratory protection is strongly recommended for workers in aviary housing similar to those in this study.

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