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Original Article

Respiratory Disorders Among Workers in Slaughterhouses

Abbasali Kasaeinasab [1], Mehdi Jahangiri [2,*], Ali Karimi [3], Hamid Reza Tabatabaei [4], Sonia Safari [5]

[1] Department of Occupational Health Engineering, School of Health, Student Research Committee, Shiraz University of Medical Sciences, Shiraz, Iran
[2] Research Center for Health Sciences, Department of Occupational Health Engineering, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran
[3] Department of Occupational Health, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran
[4] Department of Epidemiology, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran
[5] Enthusiast, London, UK

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ABSTRACT

Background: Workers in slaughterhouses are exposed to a wide range of biological contaminants, such as bacteria and fungi, due to their working environment. This study aimed to assess the prevalence of respiratory disorders among workers in slaughterhouses.
Methods: This study was conducted on 81 workers in slaughterhouses and 81 healthy office workers as a reference group. The American Thoracic Society standard respiratory symptoms questionnaire was used to determine the prevalence of respiratory disorders. Besides, lung function tests were conducted using a calibrated spirometer at the beginning (preshift) and at the end (postshift) of the 1st working day. Single-stage Anderson sampler was used to measure the concentration of bioaerosols in different parts of slaughterhouses.
Results: The prevalence of respiratory disorders, such as cough, productive cough, breathlessness, phlegm, and wheezing, was 3.17, 4.02, 3.07, 4.66, and 3.94 times, respectively, higher among workers in slaughterhouses compared with the reference group.
Conclusion: The prevalence of respiratory disorders was significantly higher among workers in slaughterhouses. Thus, the significant reduction in the percentage predicted lung function among workers in slaughterhouses might be associated with exposure to bioaerosols in their work environment.
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1. Introduction

Industrial slaughterhouses' workers are exposed to a wide range of biological contaminants, such as bacteria and fungi, due to their working environment. The aforementioned contaminants called "bioaerosols" can be produced and spread in the working environment during different processes of slaughtering, such as head hair removal, cleaning the rumen, cleaning the colon. Evidence has indicated that bioaerosols, such as fungi and volatile compounds, can cause inflammation in the respiratory system and be the main cause of nonallergic inflammation [1]. Usually, exposure to bioaerosols can cause respiratory symptoms similar to those of flu and increase the risk of chronic obstructive lung diseases [1]. Studies have demonstrated that exposure to bioaerosols can lead to respiratory disorders, defect of respiratory function, infectious diseases, acute toxic effects, chronic respiratory inflammation, and occupational asthma among the individuals exposed to bioaerosols [2]. Respiratory symptoms and lung functions are considered as the most important health effects associated with exposure to bioaerosols [3]. Viegas et al [4] conducted a study on occupational exposure to bioaerosols in poultry farm workers and found that the prevalence of obstructive diseases was higher among the workers with long-term exposure to bioaerosols. In addition, the prevalence of asthma and nasal symptoms was 42.5% and 51.1%, respectively, among the poultry farm workers exposed to bioaerosols. Moreover, a previous study demonstrated that the prevalence of chronic rhinitis and chronic coughs were 30% and 11%, respectively, among slaughterhouse and precooked food workers [5]. Lecours et al [6] also evaluated the concentration of bioaerosols in dairy barns and revealed a significant reduction in lung function parameters, such as forced expiratory volume (FEV) and forced vital capacity (FVC), among workers because of their exposure to bioaerosols.

* Corresponding author. Department of Occupational Health, Shiraz University of Medical Sciences, School of Health, Koy-e-Zahra Street, PO Box: 71645-11, Shiraz, Iran.
E-mail address: jahangiri_m@sums.ac.ir (M. Jahangiri).

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Moreover, lung disorders, such as hypersensitivity pneumonitis, chronic bronchitis, and asthma, were found among sheep-shearing workers exposed to microbial air contamination [7]. Furthermore, the prevalence of allergy caused by exposure to bioaerosols was reported to be 8.6% among Scottish agricultural workers [8].

Most of the investigations performed around the world have focused on foster-keeping animals and several previous studies have only emphasized on the health of animal in these working places [7]. Therefore, these studies have not made significant contributions to occupational health. Moreover, based on what was mentioned above and a comprehensive literature review, we found that no studies have been conducted on the respiratory health effects of bioaerosols among workers in slaughterhouses. Therefore, this study aims at investigating the respiratory disorders resulting from exposure to bioaerosols among workers in slaughterhouses in Iran.

2. Materials and methods

This cross-sectional study was performed on 81 workers in two industrial slaughterhouses (cow and sheep) in Iran, as well as on 81 randomly selected healthy office workers in a same industry with similar socioeconomic and demographic status (sex, ethnic background, education, and smoking habits) without history of exposure to other contaminants known to cause respiratory disorders. Both exposed and unexposed individuals voluntarily participated in the study. Besides, all the participants had no medical or family history of respiratory diseases, any injuries, or chest operation.

2.1. Respiratory symptoms and lung function tests

The prevalence of respiratory symptoms (cough, breathlessness, phlegm, productive cough, and wheezing) was investigated using the respiratory symptoms questionnaire suggested by the American Thoracic Society [9]. The workers in different sections of the industrial slaughterhouses and the reference group were interviewed, and then the researchers completed the questionnaire. In addition, a portable calibrated vitalograph (Model ST-150; Fukuda Sangyo Co. Ltd, Nagareyama-shi, Japan) was used to assess lung function parameters, including mean percentage predicted vital capacity (VC), forced expiratory volume in the first second (FEV_1), and FVC, according to the guidelines provided by the AST (AST statement 1979) [10]. The spirometer was calibrated two times a day according to the standard protocol of the instrument. The mean percentage predicted value was calculated according to the participant's age, standing height, weight, ethnic background, and sex. The participants were then provided with some information about the test. They were advised not to eat heavy food, take shower, or smoke at least 2 hours before the test. Before running the test, participants were asked to rest for 5 minutes. Lung function tests were performed before and after the shift on the 1st working day of the week. At least three acceptable tests were performed for each worker and the largest values (calculated as percentage predicted lung function) were defined as acceptable for analysis.

2.2. Bioaerosol sampling

The concentration of bioaerosols in the studied workplaces was measured according to a National Institute for Occupational Safety and Health analytical method [11]. For this purpose, air samples were collected on Blood agar (Merck, Germany) and Dextrose Agar (Merck, Germany) in Andersen single-stage sampler (Model 710-10) with a flow rate of 28.3 L/min for 10 minutes.

The samples were collected at the height of 145 cm above the ground level. Blood agar containing cycloheximide and Sabouraud dextrose agar supplemented with chloramphenicol were used as the sampling media for bacteria and fungi, respectively. The collected samples were incubated at 35–37°C for 48 hours and the number of colonies was determined by counting the colonies formed on the samples. To determine the concentration of the samples [colony-forming units (CFU)/m^3], the sampling air volume was adjusted based on temperature and ambient pressure values. In addition, the distinctive fungal isolates were identified according to the morphological features of fungi by performing microscopic examinations. The bacteria that had been collected in sample plates were placed in the incubator. Afterward, the subcultures of all the colonies in each plate were used to evaluate the number of colonies in each plate. Finally, isolation and identification of microorganisms were performed using conventional microbiological methods, including Gram staining; colonial morphology on media; growth on selective and differential media; lactose and mannitol fermentation; hydrogen sulfide production; utilization of catalase, oxidase, coagulase, indole, and citrate; and urease test [12].

2.3. Statistical analysis

Statistical analyses were performed using the SPSS statistical software, version 20 (SPSS Inc., Chicago, IL, USA). Chi-square test and independent sample t test were used for comparing the demographic characteristics of the exposed and unexposed workers. Besides, the Kolmogorov–Smirnov test was used for comparison of the means between two normally distributed groups. Paired t test was also used to compare the lung function parameters between workers in slaughterhouses and the reference group. The prevalence of respiratory symptoms was assessed using a Chi-square test. In addition, Fisher exact test was used to control the effect of smoking. Multiple linear regression was used to control the effects of confounding variables (smoking, age, weight, height, etc.) on the changes in lung function parameters. Moreover, logistic regression analysis was used to assess the association between exposure to bioaerosols and prevalence of respiratory symptoms. A p value less than 0.05 was considered to be statistically significant.

3. Results

Some characteristics of the exposed and unexposed workers, such as age, standing height, weight, body mass index (BMI), and smoking habits, are presented in Table 1. No significant difference was found between the exposed and unexposed workers regarding the distribution of age, BMI, and smoking habits ($p > 0.05$).

Table 1
Demographic characteristics of the participants

Variables	Exposed ($n = 81$)	Nonexposed ($n = 81$)	p
Age (y)	36.01 ± 8.83	38.89 ± 10.34	0.059*
Weight (kg)	78.25 ± 15.62	71.95 ± 10.06	0.003*
Height (cm)	174.62 ± 7.73	171.14 ± 7.61	0.004*
Body mass index (kg/m^2)	25.55 ± 4.11	24.55 ± 2.92	0.074*
Length of exposure/ employment (y)	9.32 ± 6.55	11.9 ± 8.6	0.034*
No. of smokers	24 (29.6)	15 (18.5)	0.141†
Concentration of bacteria (CFU/m^3)	2,106.33 ± 92.43	47.66 ± 13.2	0.001*
Concentration of fungi (CFU/m^3)	119.07 ± 99.77	5.53 ± 1.95	0.001*

Data are presented as mean ± SD or n (%).
* Independent sample t test ($p < 0.05$).
† Chi-square test ($p < 0.05$).

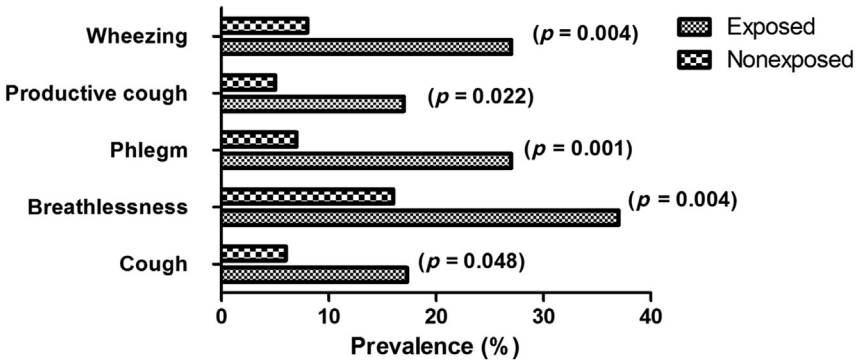

Fig. 1. Prevalence of respiratory symptoms among exposed and nonexposed workers of the studied industrial slaughterhouses ($n = 81$). Chi-square/Fisher exact test was used for calculating the p values.

However, differences in weight, standing height, and length of exposure/employment were statistically significant ($p < 0.05$). In addition, a significant difference was observed between the slaughterhouses' workers and the reference group regarding the level of exposure to bacteria and fungi ($p < 0.05$).

The prevalence of respiratory symptoms among the exposed and unexposed workers is shown in Fig. 1. The results revealed a significant difference between the two groups with respect to the prevalence of respiratory symptoms, such as cough, breathlessness, productive cough, phlegm, and wheezing ($p < 0.05$). The odds ratios (95% confidence interval) of cough, productive cough, breathlessness, phlegm, and wheezing were 3.17, 4.02, 4.66, 3.07, and 3.94 times, respectively, higher among workers in slaughterhouses compared with the reference group, which is probably due to their exposure to bioaerosols.

The results showed no significant relationship between smoking and prevalence of respiratory symptoms in both study groups. The results of lung function tests are presented in Table 2. Accordingly, a comparison of the pretest and post-test results of the slaughterhouses' workers indicated a significant reduction in VC, FVC, FEV_1, and FEV_1/FVC after exposure to bioaerosols. Moreover, these parameters were significantly lower among workers in slaughterhouses in comparison with the reference group.

The concentration of the bacteria ranged from 825.6 CFU/m^3 in cleaning the rumen to 3,665.7 CFU/m^3 in sheep slaughtering in Slaughterhouse A and from 1,680.8 CFU/m^3 in cleaning the rumen to 3,163.4 CFU/m^3 in head dehairing in Slaughterhouse B.

After adjusting for age, weight, height, smoking, and length of exposure, multiple linear regression analysis demonstrated a significant negative correlation between exposure to bioaerosols and lung function parameters (Table 3). In addition, after adjusting for age, weight, height, and smoking, logistic regression analysis revealed statistically significant associations between exposure to bioaerosols and all respiratory symptoms (Table 4).

Table 3
Association between exposure to bioaerosols and changes in lung function parameters

Dependent variable	Regression coefficient β (95% confidence interval)*
VC	−47.66 (−73.68 to −21.64)
FVC	−52.65 (−69.92 to −35.38)
FEV_1	−60.15 (−83.52 to −36.78)
FEV_1/FVC	−0.51 (−1.48 to +0.46)

FEV_1, forced expiratory volume in the first second; FVC, forced vital capacity; VC, vital capacity.
* Multiple linear regressions.

4. Discussion

This study aimed to assess the respiratory symptoms and lung function parameters among workers in slaughterhouses. The study results revealed no significant difference between the two groups regarding age, BMI, and smoking. However, standing height and weight were significantly higher among workers in slaughterhouses, which could result in higher lung capacities. In addition, the length of employment was lower among the workers compared with the reference group. Therefore, these findings support the idea

Table 4
Association between exposure to bioaerosols and prevalence of respiratory symptoms

Outcome	Odds ratio (95 % confidence interval)*
Cough	3.17 (1.08–9.28)
Breathlessness	3.07 (1.46–6.48)
Phlegm	4.66 (1.77–12.23)
Productive cough	4.02 (1.26–12.81)
Wheezing	3.94 (1.57–9.85)

* Binary logistic regression analysis.

Table 2
Percentage predicted lung function among exposed and nonexposed workers

Variables	Exposed ($n = 81$)		Nonexposed ($n = 81$)	p*		
	Preshift	Postshift		Preshift vs. postshift	Preshift vs. nonexposed	Postshift vs. nonexposed
VC	81.5 ± 15.49	74.49 ± 15.9	87.26 ± 17.49	0.001	0.257	0.175
FVC	58.13 ± 12.6	54.53 ± 12.27	72.39 ± 12.48	0.002	0.001	0.001
FEV_1	67.55 ± 15.56	63.27 ± 14.62	76.49 ± 11.6	0.006	0.001	0.001
FEV_1/FVC	80.66 ± 1.59	80.7 ± 1.63	106.6 ± 11.3	0.474	0.001	0.001

Data are presented as mean ± SD.
FEV_1, forced expiratory volume in the first second; FVC, forced vital capacity; SD, standard deviation; VC, vital capacity.
* Paired samples t test ($p < 0.05$).

that exposure to bioaerosols among workers in slaughterhouses is associated with a significant reduction in lung function parameters and increase in the prevalence of respiratory symptoms. The prevalence rates of cough, productive cough, breathlessness, phlegm, and wheezing among workers in slaughterhouses were 17.3%, 37%, 27.2%, 17.3%, and 27.2%, respectively, and these were significantly higher in comparison with the unexposed workers (Fig. 1). These findings were in line with those obtained by Viegas et al [4] in a study on poultry farm workers.

To the best of our knowledge, no studies have been conducted so far on the prevalence of respiratory symptoms among workers in slaughterhouses, thus eliminating the possibility to compare the results. However, the prevalence of respiratory symptoms resulting from exposure to bioaerosols among workers in slaughterhouses was in agreement with that reported in wastewater treatment, compost facility, and solid-waste workers [13–15]. A comparison of the lung function parameters of exposed workers at different times (before and after the shift on the 1st working day of the week) showed acute, partially reversible, and chronic irreversible ventilator disorders (Table 2). After discontinuation of exposure, despite the relative improvement in lung function parameters, there was a significant difference between the workers in slaughterhouses and the reference group regarding most of the lung function parameters (preshift comparison of the workers in slaughterhouses and the reference group concerning lung function parameters). This, in fact, supports the acute, partially reversible, and chronic irreversible nature of ventilator disorders among the studied workers in slaughterhouses.

The preshift lung function parameters were significantly lower among workers in slaughterhouses compared with the reference group. Furthermore, a significant difference was observed in the exposed workers with respect to preshift and postshift lung function parameters; the postshift parameters were less than the preshift parameters. This decline in the lung function parameters was not improved even after a rest and was significantly different from the reference group. The significant decrease in lung function parameters and increase in the prevalence of respiratory symptoms among workers in slaughterhouses can be attributed to exposure to bioaerosols. Moreover, some other factors can also be considered to relate respiratory symptoms to bioaerosols among workers in slaughterhouses, including absence of any respiratory disorders in pre-employment examinations among workers in slaughterhouses, shorter length of employment in comparison with the reference group, and relative improvement in lung function parameters after discontinuing exposure to bioaerosols.

So far, few exposure standards have been proposed for bioaerosols. In some studies, exposure limits of 10^3–10^8 CFU/m^3 have been proposed for bioarosols [3,16,17]. However, if 10^3 CFU/m^3 is taken as the exposure limit of bioaerosols in a conservative approach, the concentrations of bacterial bioaerosols in this study were higher than this limit. High concentrations of bioaerosols have also been reported among the workers of aviculture, slaughterhouses, wastewater treatment plants, and food industries [3,18–22]. Considering the high concentration of bacterial bioaerosols and respiratory pathogenicity of the identified bacterial species (including *Staphylococcus epidermidis* and *Staphylococcus aureus*) and fungal species (*Penicillium* sp., *Aspergillus flavus*, *Aspergillus fumigatus*, and *Aspergillus niger*), respiratory disorders found in this study might be attributed to exposure to bioaerosols released during slaughtering of animals.

Overall, the results of this study showed an increase in the prevalence of respiratory symptoms and a decrement in lung function test parameters among workers in slaughterhouses. However, due to the cross-sectional design of the study, more longitudinal and follow-up studies with larger sample sizes and more extensive atmospheric measurements are needed to illustrate the presence of a causal relationship between occupational exposure to bioaerosols and respiratory disorders.

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Conflicts of interest

None declared.

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