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Respiratory Findings in Herd Dairy Farmworkers from the Nile Delta Region

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Abstract

Background: *Dairy farmworkers are exposed to a variety of respiratory hazards, including organic and inorganic dust, allergens, disinfectants, and gases emitted by cows and their wastes resulting in a range of adverse health effects. In Egypt, large herd dairy farms (>1,000 cattle) are growing in both size and number and thereby more workers are employed. However, there is a lack of studies on the respiratory health status of these workers. Accordingly, the present study aimed to determine the prevalence of respiratory problems, assess ventilatory functions, and highlight the predictors of abnormal spirometry patterns among Egyptian dairy farmworkers.* **Methods:** *A cross-sectional study was carried out on 282 male workers, of whom 141 were dairy farmworkers and the other 141, not involved in livestock handling, were enrolled as controls. Full history, clinical examination, and ventilatory function measurements were done for both groups.* **Results:** *Dairy farmworkers had a significantly higher prevalence of respiratory symptoms (throat irritation and/or sore throat, cough, sputum production, and difficulty breathing) than controls as well as bronchitis, wheezes on chest auscultation, and obstructive ventilatory patterns. Older age (>37 years), longer smoking duration (>10 years), and longer working duration (>4 years) were independent predictors of abnormal spirometry patterns, particularly obstructive patterns, in dairy farmworkers.* **Conclusions:** *Large herd dairy farms, despite being open and naturally ventilated, are hazardous to workers' respiratory health. Hence, the provision of personal protective equipment, periodic spirometry examinations as well as mandatory breaks and days off, are highly urged.*

1. Introduction

The global dairy industry is one of the most important sectors for combating food and nutritional insecurities, particularly on the African continent [1]. Accordingly, dairy farming in recent years has transitioned from small farms to larger ones breeding thousands of dairy animals and employing a larger workforce [2]. Airborne respiratory hazards, such as inorganic and organic particulate matter, vapors, gases, and fumes, are common in a range of occupational settings and are associated with the development of chronic work-related respiratory diseases [3]. Previous studies have increased our understanding of the various exposures in agricultural environments [4, 5, 6, 7, 8, 9]. Consequently, the respiratory health of dairy farmworkers has gained greater attention in the last decade, after being shown to have higher-than-expected proportionate mortality ratios for respiratory diseases. Dairy

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farmworkers are exposed to a complex range of respiratory hazards including inorganic and organic dust, allergens, fungi, disinfectants, smog-forming volatile organic compounds, and gases emitted by cows and their wastes, such as hydrogen sulfide, methane, and ammonia. Of these, organic dust is considered the most important clinically due to its pro-inflammatory properties [5, 10, 11, 12, 16].

Organic dust is a mixture of air-suspended particles derived from plants, animals, and microbes. On dairy farms, fecal matter, urine, animal feed, animal dander, and hair are common sources of organic dust. Inflammatory and allergic agents, including fungal spores, bacteria, viruses, and pollen, can be found in dust, in addition to microbial-associated molecules, such as endotoxins (from gram-negative bacteria), glucans, muramic acid (from gram-positive bacteria), and peptidoglycans [13].

Inhaled dust is treated as foreign material and can induce either inflammation or toxic reactions resulting in a range of adverse respiratory health effects including nonallergic flu-like illness, organic dust toxic syndrome, asthma, irreversible chronic bronchitis, and reduced lung functions, with a variety of symptoms, such as nose and throat irritation, chest tightness, cough, shortness of breath, and wheezing [14, 15, 16].

Despite technological advances in the dairy industry, the overall exposure of dairy farmers to airborne organic dust, comprising microbial agents, allergens, ammonia, and other gases remains high and represents a serious health hazard. Accordingly, the incidence and prevalence of work-related respiratory diseases, including asthma, chronic bronchitis, upper respiratory tract symptoms, as well as hypersensitivity pneumonitis have remained high [17, 18]. In Egypt, a previous study assessing the prevalence of work-related asthma (WRA) among Egyptian adult agriculture workers in great Cairo reported that 11 out of 150 (7.3%) workers had WRA with a statistically significant difference in FEV1, and FEV1/FVC ratio observed between the WRA and non-WRA groups [19].

There are approximately 134 large Egyptian farms with an average herd size of 3,100 cattle predominantly located in the Delta region and around Nobaria. These farms can be described as "business farms" as most of the work is performed by employees and the main aim of these enterprises is to generate an expected return on investment [20]. We are not aware of previously published research on the respiratory health consequences of working on large herd Egyptian dairy farms, despite the continued growth of these farms in both size and number. Accordingly, greater numbers of workers are being employed with limited access to health services. Hence, the present study aimed to determine the prevalence of respiratory problems and assess ventilatory functions among Egyptian dairy farmworkers. The secondary aim was to highlight the predictors of abnormal spirometry patterns.

2. Methods

2.1 Study Design and Setting

A cross-sectional study was conducted on three large (>1,000 cattle per farm), as defined by the Food and Agriculture Organization [FAO] [21], open, naturally ventilated, privately owned dairy farms in Gamasa City, Dakahlia Governorate in the Eastern Nile Delta region of Egypt from April 1, 2021, to October 31, 2021. These farms operated 24 hours a day, 7 days a week. The produced milk was sold to large-scale dairy plants to manufacture pasteurized milk and dairy products that were distributed across Egypt. The farms were chosen due to convenience as the owners had agreed to provide informed consent after being informed of the study's purpose and procedures. Furthermore, they had a large workforce that enhanced the study's conduction and data collection.

2.2 Study Population

Participants were divided into two study groups: (i) The exposed group, consisted of male dairy farmworkers that worked daily in weekly rotating shifts. Each participant was responsible for performing a specific task throughout his shift including mechanical milking (parallel type), mixing feed and feeding cattle, routine veterinary care, birthing, breeding/caring for calves, moving cattle, scraping/removing manure (primarily by loader trucks and tractors), as well as administration and supervision. The second group (ii) was the control group and comprised participants recruited from service and office workers employed in different governmental offices in Dakahlia Governorate with no previous or current history of contact with livestock. Groups consisted of equal numbers of participants matched by age, gender, residence, and education.

2.3 Sample Size

The sample size was calculated using Open-Epi software [https://www.openepi.com/SampleSize/SSPropor.htm] based on the results of an earlier study [22], in which the prevalence of cough was 25.0% among male dairy farmers and 9.6% among office workers as controls. Using a 95.0% confidence level, and 80.0% power, the sample size was calculated as 107 participants for each group. Taking into account a non-response rate of 10.0%, the sample size was increased to 118 individuals. The total workforce in the three dairy farms, where the study was conducted, was 180 male farm workers. Of these, 160 workers agreed to participate (a response rate of 88.9%). Nineteen workers out of 160 were excluded after applying the study inclusion and exclusion criteria, leaving 141 workers eligible to participate. Inclusion criteria were adult workers aged 18 and above, that had worked on the dairy farm for at least a year. To avoid misinterpretation of spirometry results, participants with a history of COVID-19 infection, which was pandemic at the time of the study, were excluded.

2.4 Study Tools

Face-to-face interviews were conducted using a pre-designed questionnaire developed after reviewing relevant literature [2, 5, 12, 14]. The questionnaire was divided into four parts: (i) personal history involving age, gender, educational level, residence, marital status, and smoking history; (ii) current occupational history including nature of the job, working duration (years), hours of daily work, number of days worked per week, shift work and its type, breaks during working shifts, use of machinery (milking machine, loader trucks, tractors and/or feeder mixers), personal protective equipment (PPE) usage and type, keeping livestock in their homes and additional jobs besides the current job; (iii) previous occupational history involving place, nature, and duration of previous occupations; (iv) respiratory symptoms were assessed using the American Thoracic Society-division of lung disease [ATS-DLD] standardized questionnaire which included queries about the presence of cough, sputum, breathlessness, wheezing, and previous history of respiratory health problems (pneumonia, tuberculosis, bronchitis, asthma, or chest injury) [23].

Clinical examination was carried out on all study participants with an emphasis on local chest examination to detect clinical signs of respiratory problems through inspection, palpation, percussion, and auscultation for abnormal breathing or additional sounds. Body mass index (BMI) was calculated as body weight in kilograms divided by the square of height in meters (kg/m^2). Normal weight, overweight, and obesity were defined as a BMI of (18.5-24.9 kg/m^2), (25.0-29.9 kg/m^2), and (≥30 kg/m^2), respectively [24].

For Ventilatory Lung function testing, a portable calibrated spirometer with a built-in computer program [SpiroLab III, MIR, Italy], was used to assess ventilatory lung function parameters with adherence to the American Thoracic Society guidelines [25]. Participants were asked to sit upright, inhale maximally, and then maximally exhale into a disposable mouthpiece attached to the spirometer with the nose clipped, or the nostrils should be manually closed, to allow airflow to and from the lungs only through the mouthpiece with the lips tightened around the mouthpiece to prevent air leakage. The procedure was repeated three times with adequate rest between measurements (≥30 seconds). The best of the three values was recorded. The measured lung-function parameters were FVC (forced vital capacity), FEV1 (forced expiratory volume in one second), and FEV1 /FVC ratio (the fraction of air exhaled in the first second relative to the total volume exhaled). These were read off the spirometer screen. Participants were advised not to smoke or perform any vigorous exercise for at least one hour before testing, not to eat a large meal two hours before testing, and not to wear tight-fitting clothing [26]. FEV1, FVC, and FEV1 /FVC were expressed as percentages of predicted values based on age, gender, ethnicity, weight, and height parameters. The interpretation was performed according to the American Thoracic Society/European Respiratory Society guidelines (ATS-ETS), which use the lower limit of normal (LLN) as a cutoff. The LLN is defined as less than the fifth percentile of spirometry data obtained from the third national health and nutrition examination survey (NHANES III) [27]. When the measured FEV1 /FVC ratio was less than the LLN of the corresponding predicted value and the measured FVC was more than the LLN value, participants were assumed to have airway obstruction. Lung restriction was defined as an FVC of less than the LLN value and an FEV1 / FVC ratio greater than or equal to the LLN. Finally, a mixed pattern of abnormal ventilatory function was considered when both the FEV1 /FVC ratio and FVC were less than the LLN [28]. Precautionary measures for conducting spirometry during the COVID-19 pandemic were taken according to the recommendations of Crimi et al. [29].

2.5 Study Workflow

Dairy farmworkers were interviewed and examined in the farm manager's office during the working day at times suitable to them without interrupting farm operations. For the control group, interviews and examinations were conducted in the director's office. Study visits were conducted 2-3 times weekly, with an average of 8-10 subjects evaluated per visit. The questionnaire was completed first, followed by a clinical examination, and then ventilatory function measurements with 20-30 minutes between each.

2.6 Statistical Analyses

Collected data were analyzed using Statistical Package for Social Sciences version 28. Categorical data were presented as numbers and percentages. The Chi-square test, Fisher's exact test, and Monte Carlo test were used for comparisons between groups, as appropriate. Numerical data were presented as mean ± standard deviation if parametric or the median (minimum-maximum) if non-parametric. The independent sample t-test was used to compare parametric variables and the Mann-Whitney test was used to compare non-parametric variables between groups. A binary stepwise logistic regression analysis was used to detect independent predictors of abnormal spirometry patterns as dichotomous outcome variables. Using the forward (Wald) method, significant predictors in the bivariate analysis were entered into the regression model. Adjusted odds ratio (OR) and corresponding 95% Confidence Interval were calculated. P values less than 0.05 were considered statistically significant.

3. Results

In the present study, 53.2% of dairy farmworkers were below 37 years of age with a mean age of 35.8±10.7 years while 54.6% of the control group were 37 years of age or older with a mean age of 37.8±6.2 years (Table 1). The majority of dairy farmworkers and the control group were married (73.8% and 77.3%, respectively) and rural residents (81.6% and 75.9%, respectively). More than three-quarters of dairy farmworkers and the control group were educated to secondary school levels and above (84.4% and 87.2%, respectively).

Less than half of dairy farmworkers (41.1%) and the control group (34.8%) were current smokers, with cigarette smokers accounting for the majority of current smokers in both groups (93.1% and 85.7%, respectively). Dairy farmworkers reported smoking for a longer duration (10 years) than the control group (6.5 years), with a median of 9 and 8 cigarettes smoked per day by dairy farmworkers and the control group, respectively. More than half of the dairy farmworkers had a normal weight (53.9%) while approximately half of the control group were overweight (50.4%).

Regarding occupational parameters (Table 1), the median working duration of dairy farmworkers was 4 years with a mean number of hours worked by the week of 72.5±22.0 hours. Among dairy farmworkers, (31.9%) were parlor workers followed by veterinary workers (23.4%) and feeders (22.0%). The majority of dairy farmworkers worked in rotating shifts (92.2%), with more than two-thirds taking breaks during working shifts (71.6%). Less than

Table 1. Personal characteristics of the studied groups and occupational profile of dairy farmworkers.

	Dairy farmworkers (n=141)		Control group (n=141)		
Personal characteristic	**No.**	**%**	**No.**	**%**	**p-value**
Age, y (Mean±SD)	35.8±10.7		37.8±6.2		0.052
Married	104	73.8	109	77.3	0.489
Unmarried[a]	37	26.2	32	22.7	
Rural Residence	115	81.6	107	75.9	0.244
Urban Residence	26	18.4	34	24.1	
Illiterate/ read and write	11	7.8	8	5.7	0.745
Basic Education	11	7.8	10	7.1	
Secondary degree and above	119	84.4	123	87.2	
Current Smoker	58	41.1	49	34.8	0.389
Ex-smoker	6	4.3	4	2.8	
Nonsmoker	77	54.6	88	62.4	
Smoking[b] Cigarettes	54	93.1	42	85.7	0.233
Smoking[b] Shisha	0	0.0	2	4.1	
Cigarettes and shisha	4	6.9	5	10.2	
Years smoking[c] Median (range)	10 (1-40)		6.5 (2-15)		0.087
Cigarettes/day, Median (range)	9 (2-30)		8 (2-20)		0.350
BMI Normal	76	53.9	68	48.2	0.062
Overweight	57	40.4	71	50.4	
Obese	8	5.7	2	1.4	

	Dairy farmworkers (n=141)	
Occupational characteristic	**No.**	**%**
Years with the job, Median (range)	4 (1-30)	
Working hours/week, Mean±SD	72.5±22.0	
Parlor workers	45	31.9
Veterinary workers	33	23.4
Feeders	31	22.0
Drivers	12	8.5
Veterinary doctors	5	3.5
Others [d]	15	10.6
Rotating shift work [e]	130	92.2
Breaks during working shifts	101	71.6
Use of machinery at work [f]	32	22.7
Personal protective equipment (PPE) usage	88	62.4

Table 1. (*Continued*)

Occupational characteristic	Dairy farmworkers (n=141)	
	No.	%
Type of PPE [g]		
Boots	84	59.6
Gloves	51	36.2
Aprons	23	16.3
Overall	4	2.8
Face masks	0	0.0
Previous job on dairy farms	15	10.6
Years with the job, Median (range)[h]	10 (1.5-17.0)	
Keeping livestock in their homes	0	0.0

[a] *The unmarried group only includes single dairy farmworkers, whereas the control group includes single, divorced & widowed.*
[b] *No other types were reported.*
[c] *Among smokers.*
[d] *Others include farm managers and security personnel.*
[e] *Rotating shifts involve 2 shifts in all workers (morning and evening /night shift), except parlor workers who work 3 shifts (morning, evening, and night shift).*
[f] *Including milking machines, loader trucks, tractors, and/or feeder mixers.*
[g] *Categories are not mutually exclusive.*
[h] *Among those who previously worked on dairy farms.*

one-quarter of dairy farmworkers used machinery at work (22.7%) and more than half used PPE (62.4%) with boots being the most frequently used form of PPE (59.6%) followed by gloves (36.2%), aprons (16.3%), and overall (2.8%). No dairy farmworkers reported wearing face masks. Only (10.6%) of dairy farmworkers had previously worked on dairy farms with a median working duration of 10 years. No dairy farmworkers kept livestock in their homes.

Table 2 summarizes symptoms. Throat irritation and/or sore throat was the most frequent respiratory symptom among dairy farmworkers (22.0%) followed by cough (19.9%), difficulty breathing (17.0%), and sputum production (15.6%) with higher overall respiratory symptoms than the control group (34.0% vs. 14.9%). Bronchitis was the most common respiratory disease among dairy farmworkers (10.6%), followed by allergic rhinitis and/or sinusitis (5.0%) and bronchial asthma (2.1%). Dairy farmworkers had a significantly higher prevalence of respiratory symptoms (throat irritation and/or sore throat, cough, sputum production, and difficulty breathing) than controls. Dairy farmworkers also had significantly higher rates of bronchitis and wheezes on chest auscultation compared to the control group.

Both measured, and percent predicted values of FEV1 and FEV1 /FVC ratio were significantly lower in the dairy farmworkers compared to the control group indicating an obstructive ventilatory change (Table 3). Regarding spirometry patterns, the normal pattern was the most frequent in both groups, with a significantly higher prevalence in the control group compared to the dairy farmworkers (90.6% vs. 78.2%, respectively). Obstructive patterns were significantly more common in dairy farmworkers than in the control group (19.4% vs. 3.1%, respectively) ($p \leq 0.001$).

The prevalence of obstructive spirometry patterns was highest among parlor workers (50.0%), followed by feeders and veterinary workers (16.7% for each) (Table 4). Restrictive ventilatory patterns were found in two workers: a feeder and a driver. Only one subject had a mixed spirometry pattern and was a parlor worker.

Bivariate analysis of dairy farmworkers' personal and occupational characteristics associated with abnormal spirometry patterns (Table 5) shows that

Table 2. Respiratory history and examination of the studied groups.

	Dairy farmworkers n=141		Control group n=141		
Respiratory variable	**No.**	**%**	**No.**	**%**	**p-value**
Respiratory symptoms [a]					
One or more symptoms	48	34.0	21	14.9	≤ 0.001
Runny nose, sneezing, and/or itching	6	4.3	4	2.8	0.520
Nasal congestion	15	10.6	7	5.0	0.076
Throat irritation and/or sore throat	31	22.0	14	9.9	0.006
Cough	28	19.9	14	9.9	0.019
Sputum production	22	15.6	11	7.8	0.042
Wheezes	5	3.5	4	2.8	1.000
Difficulty breathing	24	17.0	7	5.0	≤ 0.001
Respiratory diseases [a]					
Allergic rhinitis and/or sinusitis	7	5.0	2	1.4	0.173
Bronchial asthma	3	2.1	2	1.4	1.000
Bronchitis	15	10.6	6	4.3	0.041
Chest examination					
Wheezes	9	6.4	0	0.0	0.003

[a] *Self-reported.*

Table 3. Spirometry parameters and patterns of the studied groups.

	Dairy farmworkers [a] n=124		Control group [a] n=128		
Spirometry parameter	**Mean±SD**		**Mean±SD**		**p**
FVC [b]					
Measured (liters)	4.42±0.45		4.40±0.49		0.820
% predicted	95.37±11.39		94.73±11.57		0.657
FEV1 [c]					
Measured (liters)	3.44±0.66		3.63±0.46		0.008
% predicted	88.52±16.57		94.56±12.83		≤0.001
FEV1/FVC [d]					
Measured	77.43±11.44		82.57±5.99		≤0.001
% predicted	95.68±13.71		102.94±6.72		≤ 0.001
Spirometry pattern	**No.**	**%**	**No.**	**%**	**p**
Normal	97	78.2	116	90.6	0.007
Obstructive	24	19.4	4	3.1	0.001
Restrictive	2	1.6	6	4.7	0.282
Mixed	1	0.8	2	1.6	1.000

[a] *Seventeen of the 141 dairy farmworkers and 13 of the 141 in the control group declined spirometry.*
[b] *FVC: forced vital capacity.*
[c] *FEV1: forced expiratory volume in the first second.*
[d] *FEV1/FVC: the ratio of two volumes.*

Table 4. Frequency distribution of dairy farmworkers' abnormal spirometry patterns by job category.

Spirometry pattern Job category	Obstructive (n=24)		Restrictive (n=2)		Mixed (n=1)	
	No.	%	No.	%	No.	%
Parlor workers [a]	12	50.0	0	0.0	1	100.0
Feeders [b]	4	16.7	1	50.0	0	0.0
Veterinary workers [c]	4	16.7	0	0.0	0	0.0
Drivers [d]	3	12.5	1	50.0	0	0.0
Veterinary doctors [e]	0	0.0	0	0.0	0	0.0
Others [f]	1	4.2	0	0.0	0	0.0
p-value	0.509		0.266		0.880	

[a] *Parlor worker: mechanical milking of the dairy animals.*
[b] *Feeders: mixing, using feeder mixers, and distributing feed into different animal yards.*
[c] *Veterinary workers: breeding/caring for calves, as well as moving cattle from one location to another on the dairy farm.*
[d] *Drivers: using loader trucks and tractors to scrape, and remove manure from animal yards.*
[e] *Veterinary doctors: routine dairy animals medical care, such as examination, in vitro fertilization, and birthing, as well as vaccine and medication administration.*
[f] *Others include farm managers (administration and supervision), and security personnel (dairy farm guarding and general maintenance).*

dairy farmworkers with normal spirometry patterns and those with abnormal spirometry patterns differ significantly in age, smoking duration (years), working duration (years), and breaks during working shifts (P≤0.05), with these differences particularly evident among dairy farmworkers with obstructive ventilatory patterns. Significant risk factors from the bivariate analysis were entered into a binary forward stepwise logistic regression analysis to detect independent predictors of abnormal spirometry patterns. In the final model, older age (>37 years), longer smoking duration (>10 years), and longer working duration (>4 years) were independent predictors of abnormal spirometry patterns, particularly obstructive patterns, in dairy farmworkers after adjustment for breaks during working shifts.

4. Discussion

Occupational exposures remain an under-recognized and preventable cause of lung diseases, worldwide [30]. Dairy farmworkers are exposed to endotoxins and other potential respiratory risk factors, including gram-positive bacteria, molds, and fungi, as well as gases such as ammonia, methane, and hydrogen sulfide. The interactions between these agents are complex, and synergistic effects are likely. Clinical symptoms in exposed workers can range from asymptomatic sensitization, and rhinitis to bronchitis, and severe asthmatic attacks with impaired lung functions [14, 31].

In the present study, throat irritation and/or sore throat was the most frequent respiratory symptom among dairy farmworkers (22.0%) followed by cough (19.9%), difficulty breathing (17.0%), and sputum production (15.6%) with higher overall respiratory symptoms than controls (34.0% vs.14.9%), all of which were significantly more prevalent in dairy farmworkers than the control group [Table 2]. These findings are in keeping with a previous study conducted in Macedonia by Stoleski et al. [22] reporting that dairy farmers had a higher prevalence of work-related respiratory symptoms than office controls, being significant for overall symptoms (30.8% vs. 13.5%), cough (25.0% vs. 9.6%), and phlegm (15.4% vs. 3.8%). On contrary, these prevalences were higher than those reported by Eastman et al. [11] in a study of workers of large Californian dairies (>1000 lactating cattle per farm), in the United States where cough was the most frequently reported symptom (9.7%) followed by phlegm (8.1%), throat irritation (6.5%) and chest

Table 5. Association between dairy farmworkers' spirometry patterns and their personal and occupational characteristics.

Variable	pattern				p^f	COR (95%CI)	p^h	Pattern		p^g		p^h
	Normal (n=97)		Abnormal (n=27)				AOR (95%CI)[h]	Obstructive (n = 24)			COR (95%CI)	AOR (95% CI)[h]
	No.	%	No.	%				No.	%			
Age (years)												
< 37	68	70.1	3	11.1	**≤ 0.001**	Reference	**0.017**	2	8.3	**≤ 0.001**	Reference	**≤ 0.001**
≥ 37	29	29.9	24	88.9		18.7(5.2-67.2)	7.0 (1.7-173.6)	22	91.7		25.8(5.7-116.9)	23.1(2.0-264.6)
Residence												
Rural	80	82.5	21	77.8	0.579	Reference		18	75.0	0.396	Reference	
Urban	17	17.5	6	22.2		1.3(0.5-3.8)		6	25.0		1.6 (0.5-4.5)	
Current smoking habits												
Smoker	37	38.1	13	8.1	0.349	1.5(0.6-3.6)		12	50.0	0.289	1.6 (0.7-3.9)	
Nonsmoker [a]	60	61.9	14	1.9		Reference		12	50.0		Reference	
Duration of smoking (years) [b]												
<10	24	64.9	2	15.4	**0.002**	Reference	**0.038**	2	16.7	**0.004**	Reference	**≤ 0.001**
≥10	13	35.1	11	84.6		10.2(1.9-52.9)	3.8 (1.6-165.1)	10	83.3		9.2 (1.7-48.6)	11.9(1.1-150.4)
BMI (kg/m²)												
Obese [c]	5	5.2	2	7.4	0.646	1.5 (0.3-8.0)		2	8.3	0.624	1.6 (0.3-9.2)	
Non-obese	92	94.8	25	92.6		Reference		22	91.7		Reference	
Duration of work (years)												
< 4	57	58.8	2	7.4	**≤ 0.001**	Reference	**0.008**	2	8.3	**≤ 0.001**	Reference	**≤ 0.001**
≥ 4	40	41.2	25	92.6		7.8(4.0-79.5)	8.0 (2.7-840.0)	22	91.7		15.6 (3.5-70.4)	42.6(2.4-760.9)
Working hours/week												
< 72	62	63.9	22	81.5	0.084	Reference		19	79.2	0.155	Reference	
≥ 72	35	36.1	5	18.5		0.4 (0.1-1.2)		5	20.8		0.5 (0.2-1.3)	

Table 5. (*Continued*)

Variable	pattern				p[f]	COR (95%CI)	p[h]	Pattern		p[g]		p[h]
	Normal (n=97)		Abnormal (n=27)				AOR (95%CI)[h]	Obstructive (n = 24)			COR (95%CI)	AOR (95% CI)[h]
	No.	%	No.	%				No.	%			
Job category												
Parlor workers	32	33.0	13	8.1	0.371	3.2(0.4-28.6)		12	50.0	0.454	3.0 (0.3-26.6)	
Feeders	24	24.7	5	8.5		1.7(0.2-16.5)		4	16.7		1.3 (0.1-13.7)	
Veterinary workers	25	25.8	4	14.8		1.3(0.1-13.2)		4	16.7		1.3 (0.1-13.2)	
Drivers	6	6.2	4	4.8		5.3(0.5-60.8)		3	12.5		4.0 (0.3-48.6)	
Veterinary doctors	2	2.1	0	0.0				0	0.0			
Others [d]	8	8.2	1	3.7		Undefined[e] Reference		1	4.2		Undefined Reference	
Breaks during working shift												
Yes	70	72.2	14	1.9	**0.046**	Reference		12	50.0	**0.038**	Reference	
No	27	27.8	13	8.1		2.4 (1.03 -5.8)		12	50.0		2.6 (1.04-6.5)	
Previous job in dairy farms												
Yes	9	9.3	2	7.4	1.000	0.8 (0.2-3.8)		2	8.3	1.000	0.9 (0.2-4.4)	
No	88	90.7	25	92.6		Reference		22	91.7		Reference	

COR, crude odds ratio; CI, confidence interval; AOR, adjusted odds ratio.
[a] *Non-smokers and ex-smokers are both included in this group.*
[b] *Among smokers.*
[c] *BMI ≥30 kg/m^2.*
[d] *Others include farm managers and security personnel.*
[e] *Undefined as one of the studied cells in the 2 by 2 table is zero.*
[f] *Dairy farmworkers with normal spirometry patterns vs. dairy farmworkers with abnormal spirometry patterns (obstructive, restrictive, and mixed).*
[g] *Dairy farmworkers with normal spirometry patterns vs. dairy farmworkers with obstructive spirometry patterns.*
[h] *Variables with P ≤ 0.05 in bivariate analysis were considered significant (age, smoking duration (years), working duration (years), and breaks during working shifts) and were entered into binary forward stepwise logistic regression for prediction of abnormal spirometry patterns, particularly obstructive patterns, in dairy farmworkers.*

tightness (4.8%). The significantly higher prevalence of respiratory symptoms among dairy farmworkers in the present study may be attributable to their continuous and prolonged exposure to numerous respiratory hazards in the working environment including inorganic and organic dust, allergens, fungi, disinfectants (such as iodine, formaldehyde, and phenol, for the control of zoonotic diseases in dairy farms), smog-forming volatile organic compounds and gases emitted by cows and their wastes, such as hydrogen sulfide, methane, and ammonia. The combination of these exposures may result in respiratory irritation and inflammation.

The prevalence of bronchitis was significantly higher in dairy farmworkers than in controls in the present study (10.6% vs. 4.3%) [Table 2]. This finding corroborates the results of previous studies conducted in France [32, 33], and Norway [34]; all reported an increased risk of chronic bronchitis among dairy farming workers. Chest auscultation revealed a significantly higher prevalence of wheezes among dairy farmworkers than controls in the present study (Table 2). This finding is supported by the results of a study by Hoppin et al. [35] who demonstrated that interaction with animals increases the risk of developing wheezes (OR:1.26, 95%CI=1.08-1.48), and a dose-response relationship between wheezes and the frequency of milking *or* veterinary interactions.

In the present study, three out of 141 dairy farmworkers (2.1%) had bronchial asthma (Table 2). On contrary, a higher prevalence was reported by studies conducted in France (7.0%) [36] and the United States (5.0%) [12]. Additionally, the prevalence of bronchial asthma observed in the current study was lower than reported in a comparable study in Egypt among agriculture farmworkers (grape and strawberry farms) (7.3%) [19]. No significant difference in the prevalence of bronchial asthma was observed between dairy farmworkers and the control group in the present study, contradicting the results of Jenkins et al. [37] who reported that dairy farming in the United States was associated with a significantly increased risk of asthma ($p<0.001$; OR=1.542) and Eastman et al. [11], who reported that dairy workers had an OR of 2.73 for developing asthma compared to control workers. The finding in the present study may be attributable to the young age of dairy farmworkers (mean age, 35.8±10.7 years) and short working duration (median, 4 years). However, the development of bronchial asthma can be prolonged and is not often diagnosed as related to workplace exposure. Furthermore, dairy farmworkers accept respiratory symptoms as part of their jobs and do not seek medical help until symptoms become severe enough to preclude them from working.

Spirometry has long been used in occupational settings as part of medical surveillance to detect changes in lung functions [16]. The present study revealed that both measured, and percent predicted values of FEV1 and FEV1/FVC ratio were significantly lower in dairy farmworkers compared to controls; with a significantly higher prevalence ($p \leq 0.001$) of obstructive patterns in dairy farmworkers than in the control group (19.4% vs. 3.1%, respectively) (Table 3). This was in concordance with a previous study conducted in France; in which cross-sectional and longitudinal analyses were performed in 1994 and 1999 in a cohort of dairy farmers demonstrated lower FEV1 in dairy farmers than in controls, with an accelerated decline in FEV1 / VC over time [32]. Thaon et al. [36] carried out a 12-year follow-up study on the same cohort to investigate lung function decline and found that dairy farmers had greater declines in FEV1 and FEV1 / FVC compared to controls. Further, Eduard et al. [34] reported that Norwegian livestock farmers had significantly reduced FEV1 compared to crop farmers. Eastman et al. [38] conducted a study on American farmworkers and reported that working in large California dairies was associated with mild acute airway obstruction, with both baseline and cross-shift reductions in FEV1 and FVC. In addition, Stoleski et al. [22] demonstrated a significantly lower FEV1/FVC % in Macedonian dairy farmers compared to office based workers.

On the other hand, a study comprising dairy farmworkers in the USA by Mitchell et al. [14] demonstrated a statistically significant association between working in large dairies and a cross-shift decrease in FVC. However, Nonnenmann et al. [12] found no association between working in dairy parlors and cross-shift measures of pulmonary health. The disparities in results may be attributable to a variety of factors, including differences in the demographics, and occupational characteristics of study participants, measures of occupational health and safety enforcement in the workplace, type of spirometry performed, and levels of exposure to respiratory hazards.

The reduction in the ventilatory functions observed among large herd dairy farmworkers in the current study may be due to proximity to aerosol sources (e.g. cattle), which contain a mixture of manure, animal dander, hair, animal feed, molecules derived from gram-positive and gram-negative bacteria (i.e. endotoxins), with large herd size (>1000 cattle). Moreover, prolonged duration of exposure in which the majority of dairy farmworkers with abnormal spirometry patterns had worked for four years or longer (92.6%), with nearly half not taking any breaks during their work shifts (48.1%). Further, no dairy farmworkers in the present study reported wearing face masks possibly due to a lack of awareness of the importance of wearing them. All these reasons could result in cumulative workplace exposure over time.

Older age (>37 years), longer smoking duration (>10 years), and longer working duration (>4 years) were independent predictors of abnormal spirometry patterns, particularly obstructive patterns, in dairy farm workers in the present study (Table 5). These findings are comparable to the previous studies conducted in France by Venier et al. [39] and Gainet et al. [33] who reported that older age and smoking were associated with accelerated declines in lung function parameters (VC and FEV1) among dairy farmers. A separate longitudinal study was conducted by Thaon et al. [36] to explore the influence of exposure to organic dust in French dairy and nondairy agricultural workers and reported that greater declines in FEV1 among all workers were associated with longer durations of exposure to animal feed handling and that current smoking was associated with accelerated declines in FEV1 and FEV1 /FVC. In addition, Arteaga et al. [2] conducted a study of dairy farmworkers in the United States and found that age-related decreases in lung functions were higher in dairy workers compared to controls ($p<0.001$), with FEV1 and FVC decreasing by 1 ml instead of 0.2 ml for every 10-year increase in age, and the number of consecutive days worked, was associated with decreases in FEV1. However, the aforementioned findings contradict a study conducted by Ahmed et al. [19] comprising 150 Egyptian agriculture farmworkers who reported lower age and duration of farming occupation were significantly associated with WRA. Our findings may be attributable to older workers being more likely to have a longer duration of exposure to hazardous substances, thereby increasing their susceptibility to declines in ventilatory functions. Furthermore, younger workers may find it easier to change jobs to avoid exposure [40].

5. Conclusions and recommendations

Large herd dairy farms, despite being open and naturally ventilated, are hazardous to the respiratory health of the workers and increase the risk of developing respiratory symptoms, bronchitis, and obstructive lung function changes. Accordingly, we strongly recommend the provision of PPE, particularly face masks and respirators, with proper training on appropriate usage, respiratory health screening using spirometry at baseline and periodically thereafter with more specific examinations, such as post-bronchodilation spirometry testing and plain chest radiography, smoking cessation programs, as well as mandatory breaks during working shifts and days off to allow time away from dust exposure. Future studies should focus on task-based dust inhalation exposure measurement and developing recommendations tailored to individual tasks.

Strengths: We believe this to be the first study conducted in Egypt focusing on the respiratory health of large herd dairy farmworkers.

Limitations: A proportion of participants declined spirometry due to fear of infection, even after explaining that all precautionary measures for conducting spirometry during the COVID-19 pandemic had been applied according to recommendations of Crimi et al. [29]. The reference values used to interpret spirometry results were based on age, sex, height, and ethnicity retrieved from the USA Population [27]. However, there are no current reference values specific to Egyptian populations. Due to a lack of funding and lack of devices due to unaffordability, measuring inhalable dust and bioaerosol concentrations in worker breathing zones was challenging.

Institutional Review Board Statement: The study protocol was approved by the Institutional Review Board (IRB), Faculty of Medicine, Mansoura University, (code number: MD.21.02.427).

Informed Consent Statement: Prior to the start of the study, informed written consent was obtained from both the farm owners and interviewees. Participants and farm owners were provided detailed information regarding the study including the title, objectives, and procedures, as well as assurances of participant data confidentiality and anonymity with data never to be used for purposes other than scientific research. Participation in the present study was completely voluntary, and study participants were free to withdraw at any time.

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Declaration of Interest: The authors declare that they have no conflicts of interest.

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