Original Research

Association between Across-Shift Spirometric Parameters and Sleep Characteristics in Workers with Inhalational Occupational Exposure

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Received: 01 Feb. 2020 Accepted: 01 May 2020

Abstract

Background and Objective: Workplace exposes workers to different hazardous chemicals. In this study, we aimed to assess the changes of pulmonary function test (PFT) parameters as the objective indicator of lung impairment and its association with demographic data and sleep characteristics.

Materials and Methods: This cross-sectional study was carried out on 200 male workers of a smelting factory located in Tehran Province, Iran. The respiratory symptoms questionnaire, Pittsburgh Sleep Quality Index (PSQI), Insomnia Severity Index (ISI), and demographic characteristics were recorded for the participants. Participants also underwent spirometry and the related parameters were recorded.

Results: A total of 200 iron foundry workers were assessed. All participants were men, and mean ± standard deviation (SD) of age was 39.1 ± 8.9 years ranging from 20 to 65 years. Of 200 workers, 153 (76.5%) were married and 72 (36.0%) were smokers. Among all participants, 131 (65.5%) reported at least one respiratory symptom, and these workers had significantly poorer sleep quality (P = 0.02) and insomnia (P = 0.01). Across-shift change in forced expiratory volume in one second (FEV1) and peak expiratory flow rate (PEFR) of spirometry parameters was significant among participants with clinical insomnia (P = 0.02 and P = 0.04, respectively) and poor sleep quality (P < 0.0001 and P = 0.04, respectively).

Conclusion: Results showed a significant cross-shift reduction in PFT values among workers with clinical insomnia or poor sleep quality. Accordingly, evaluation of sleep characteristics along with respiratory symptoms in workers with inhalational occupational exposure is recommended.

Keywords: Occupational exposure; Spirometry; Sleep; Insomnia; Industry

Citation: Mehrabinejad MM, Saraei M, Hajighaderi A, Najafi A. **Association between Across-Shift Spirometric Parameters and Sleep Characteristics in Workers with Inhalational Occupational Exposure.** J Sleep Sci 2020; 5(3): 80-85.

Introduction

Industrial environment exposes workers to different hazardous chemicals, which results in various health problems such as respiratory or sleep difficulties. Ample evidence indicates the association between inhalational occupational exposure and development of lung diseases (1-3). Occupational and environmental pulmonary diseases are major etiologies of pulmonary injuries worldwide. A global report measuring the burden of respiratory diseases estimated that 386000 deaths and nearly 6.6 million disability-adjusted life years (DALYs) were attributed to industrial airborne particles (4).

Occupational factors such as shift working, rotating shifts, and psychiatric stress affect sleep in different dimensions (5). Numerous studies investigated diverse aspects of sleep in an industrial setting. Lower sleep quality (6, 7) and higher in-

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somnia (8, 9) were reported among the workers in the different occupational settings, and a great many studies are trying to detect the work factors initiating sleep disturbances.

The association between occupational inhalational exposure and sleep disturbances reported in numerous studies and workers with exposure to different inhalational exposures demonstrated 2-fold to 6-fold increase in sleep disturbances (10, 11). Inhalational exposure can lead to pulmonary complications, and these complications are associated with sleep disturbances, including insomnia (12, 13) and poor sleep quality (14, 15).

Pulmonary function test (PFT) can show functional problems of lungs that may represent the underlying pulmonary disease (16). The relationship between the PFT and sleep parameters has rarely been discussed previously. In this study, we aimed to assess the changes of PFT parameter as the objective indicator of lung impairment and its association with demographic data and sleep characteristics, including insomnia and sleep quality of workers in the smelting factory.

Materials and Methods

This retrospective cross-sectional study was carried out on workers of a 40-year smelting factory located in Tehran Province, Iran. A total of 200 male workers were recruited in the study based on following criteria: age range from 20 to 65 years and at least 2 years of work experience in selected factory.

Exclusion criteria were: history of respiratory diseases, e.g., asthma, bronchitis, emphysema, bronchiectasis, or lung cancer, and any other chronic condition including sleep or mental disorders (i.e., psychiatric disorders, insomnia, daytime hypersomnolence, and etc.) in the pre-employment assessment. Among participants, 51 (25.5%) were from the production process staff (furnace, sand casting, molding, or surface cleaning), and others were office workers. Their work time was from 6 AM to 5 PM.

Demographic variables included age, marital status, and educational status. The respiratory symptoms questionnaire, as suggested by the American Thoracic Society (ATS) (17), was completed by one of the authors through the interview for each participant. Besides respiratory symptoms (i.e., chronic cough, wheezing, phlegm, bronchitis), this questionnaire contained questions regarding using a mask during work and smoking habits. The weight and height of all participants were measured, and the body mass index (BMI) was calculated (kg/m^2). We divided age and BMI indexes into two subgroups with a cut-point of 30 based on receiver operating characteristic (ROC) curve analysis.

PFT: All participants were examined and evaluated by a physician of occupational medicine for respiratory problems. To assess the cross-shift changes in PFT parameters according to ATS (17), PFTs were applied once in the morning before the shift began and once in the afternoon at the end of the shift by experienced technical staff using a calibrated spirometry apparatus (model: MIR spirolab). Spirometric parameters consisting of forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC, peak expiratory flow rate (PEFR), and forced expiratory flow at 25%-75% of the FVC (FEF25-75) were measured according to ATS criteria (18).

Sleep measurements (sleep quality and insomnia): All participants answered validated Persian versions of the Insomnia Severity Index (ISI) (19) and the Pittsburgh Sleep Quality Index (PSQI) to assess the sleep complications (20).

PSQI: The PSQI is a 19-item questionnaire that is designed to assess subjective sleep quality over the last four weeks. Each question should be answered on a 4-point Likert scale ranging from 0 to 3, which results in a total global score from 0 to 21, with higher scores showing less sleep quality.

An overall score of more than or equal to 5 indicates poor sleep quality (21).

ISI: The ISI questionnaire comprises seven items and assesses different aspects of insomnia over the preceding two weeks on a 5-point Likert scale (0 = none to 4 = very severe). The total score ranges from 0 to 28, in which, a higher score indicates greater symptoms of severity. An overall score of more than or equal to 15 indicates clinical insomnia (22).

Ethical considerations: This study was carried out in concordance with the latest version of Declaration of Helsinki code of ethics and approved by the Ethics Committee of Tehran University of Medical Sciences (IR.TUMS.VCR.REC.1395.202). After explaining the objectives of the study, verbal and written consents were obtained from participants.

Statistical analyses: Data analysis was performed using SPSS software (version 16, SPSS Inc., Chicago, IL, USA). A P-value of less than

0.05 was considered statistically significant. The independent t-test was used to assess the relationship between baseline characteristics (demographic variables, smoking, respiratory symptoms) and the mean scores of ISI, PSQI, and duration of sleep. The chi-square test was performed to determine the relationship between qualitative variables. Multinomial regression was performed to evaluate the effects of independent variables on having poor sleep quality, clinical insomnia, and sleep duration while adjusting for potential confounding variables (age, marital status, education level, and BMI). The spirometric parameters were compared before and after shifts among workers with or without clinical insomnia or poor sleep quality using the paired t-test.

Results

A total of 200 iron foundry workers were assessed. All participants were men, and mean ± standard deviation (SD) of age was 39.1 ± 8.9 years ranging from 20 to 65 years. While 153 workers (76.5%) were married, 72 (36.0%) were smokers, and 145 (72.5%) had a high school diploma or higher education.

The mean ± SD of PSQI score of workers was 4.78 ± 2.50, and 96 workers (48.0%) experienced poor sleep quality. The mean ± SD of night sleep duration was 6.40 ± 0.96 hours. The mean ± SD of ISI score of workers was 7.69 ± 4.30, and 87 (43.5%) and 10 (5.0%) workers had subthreshold and clinical insomnia, respectively.

Demographic variables (age, marital status, and education), BMI, and smoking did not have any significant effect on ISI and PSQI scores, and were not significantly different among workers with or without poor sleep quality or clinical insomnia (Tables 1 and 2).

Among all participants, 131 (65.5%) reported at least one respiratory symptom, and these workers had significantly poorer sleep quality (P = 0.02) (Table 2) and insomnia (P = 0.01) (Table 1). After adjusting for age, marital status, education, and BMI on regression analysis, workers with respiratory symptoms still had lower PSQI scores [P = 0.024, exp(B) = 2.04], while the ISI score was not significant after controlling for demographic variables.

Data analysis revealed that almost all spirometric parameters declined after the participants' shift compared with that before the shifts. This change was significant among participants with clinical insomnia in some parameters, including FEV1 and PEFR (P = 0.02 and P = 0.04, respectively) (Table 3).

The same change was observed among participants with poor sleep quality in FVC, FEV1, and PEFR (P < 0.0001, P < 0.0001, and P = 0.04, respectively) (Table 4). It is noteworthy that the changes in FVC and PEFR were not significant among workers with normal sleep quality (P = 0.10 and P = 0.19, respectively) (Table 4).

Table 1. General and occupational characteristics of study subjects by insomnia

Variables		ISI		Insomnia		
		Mean ± SD	P-value	No clinical insomnia [n (%)]	Clinical insomnia [n (%)]	P-value
Age (year)						
	≤ 30	7.93 ± 4.23	0.687	40 (93.0)	3 (7.0)	0.500
	> 30	7.62 ± 4.45		150 (95.5)	7 (4.5)	
BMI (kg/m^2)						
	≤ 30	7.48 ± 4.41	0.648	145 (94.8)	8 (5.2)	0.930
	> 30	7.86 ± 4.63		34 (94.4)	2 (5.6)	
Marital status						
	Single	7.89 ± 4.63	0.718	44 (93.6)	3 (6.4)	0.610
	Married	7.62 ± 4.33		146 (95.4)	7 (4.6)	
Education						
	< Diploma	7.21 ± 4.34	0.351	53 (96.4)	2 (3.6)	0.580
	≥ Diploma	7.86 ± 4.41		137 (94.5)	8 (5.5)	
Smoking						
	Yes	7.59 ± 4.42	0.798	70 (97.2)	2 (2.8)	0.535
	No	7.77 ± 4.40		119 (93.7)	8 (6.3)	
Air pollutant exposure						
	Yes	8.84 ± 4.91	0.034*	45 (88.2)	6 (11.8)	0.037*
	No	7.33 ± 4.13		114 (97.3)	4 (2.7)	
Respiratory symptoms						
	Yes	8.23 ± 4.26	0.015*	124 (94.7)	7 (5.3)	0.759
	No	6.65 ± 4.49		66 (95.7)	3 (4.3)	

ISI: Insomnia Severity Index; BMI: Body mass index; SD: Standard deviation
*: Statistically significant

Table 2. General and occupational characteristics of study subjects by sleep quality and night sleep duration

Variables		Sleep duration		PSQI score		Sleep quality		
		Mean ± SD	P-value	Mean ± SD	P-value	Normal [n (%)]	Poor [n (%)]	P-value
Age (year)								
	≤ 30	6.43 ± 0.90	0.87	4.83 ± 2.50	0.89	19 (45.2)	23 (54.8)	0.24
	> 30	6.40 ± 0.90		4.77 ± 2.50		82 (52.9)	73 (47.1)	
BMI (kg/m^2)								
	≤ 30	6.48 ± 0.90	0.04*	4.64 ± 2.50	0.15	81 (54.0)	69 (46.0)	0.11
	> 30	6.16 ± 1.00		5.23 ± 2.60		20 (42.6)	27 (57.4)	
Marital status								
	Single	6.53 ± 0.90	0.30	5.00 ± 2.90	0.52	23 (50.0)	23 (50.0)	0.48
	Married	6.37 ± 0.90		4.72 ± 2.40		78 (51.7)	73 (48.3)	
Education								
	< Diploma	6.52 ± 0.90	0.30	4.45 ± 2.30	0.26	33 (60.0)	22 (40.0)	0.08
	≥ Diploma	6.36 ± 0.90		4.91 ± 2.60		68 (47.9)	74 (52.1)	
Smoking								
	Yes	6.40 ± 0.80	0.97	4.80 ± 2.30	0.94	31 (43.7)	40 (56.3)	0.07
	No	6.41 ± 1.00		4.77 ± 2.70		70 (55.6)	56 (44.4)	
Air pollutant exposure								
	Yes	6.23 ± 1.00	0.12	5.36 ± 2.90	0.07	22 (44.0)	28 (56.0)	0.15
	No	6.47 ± 0.90		4.60 ± 2.40		79 (53.7)	68 (46.3)	
Respiratory symptoms								
	Yes	6.32 ± 0.90	0.10	5.06 ± 2.40	0.03*	42 (62.7)	25 (37.3)	0.02*
	No	6.56 ± 1.00		4.23 ± 2.60		59 (45.4)	71 (54.6)	

PSQI: Pittsburgh Sleep Quality Index; BMI: Body mass index; SD: Standard deviation; BMI: Body mass index; SD: Standard deviation
*: Statistically significant

Discussion

Decremental changes were observed in nearly all spirometric parameters across the participants' shifts, which were significant in FEV1 and PEFR among participants who had clinical insomnia or poor sleep quality; meanwhile, as expected, there was a less decrease in respiratory parameters among workers with normal sleep. Therefore, respiratory dysfunction can be considered a risk factor for sleep problems which are also affected by occupational exposures.

Participants with exposure to inhalational materials had more respiratory symptoms. Moreover, workers who had at least one respiratory symptom had a worse sleep quality and more clinical insomnia. Overall, it can be inferred that exposure to respiratory pollutants during work can lead to respiratory dysfunction and symptoms, which can cause sleep disturbance in workers.

In the current study, the mean PSQI and ISI scores were 4.78 ± 2.50 and 7.69 ± 4.30, respectively.

The prevalence of poor sleep quality was 48.0%, and subthreshold and clinical insomnia were detected in 43.5% and 5.0%, respectively.

Similar to the current results, several studies showed a significant relationship between respirable dust exposure and respiratory symptoms. For instance, Abrahamsen et al. showed more severe respiratory symptoms and asthma with flour, welding/soldering fumes, and vehicle/motor exhaust exposures (23).

Table 3. Across-shift changes in pulmonary function tests (PFTs) in subjects with or without clinical insomnia

Spirometric parameters	Clinical insomnia	Before shift	After shift	Paired t-test		P-value
		Mean ± SD		t	df	
FVC						
	Yes	4.83 ± 1.25	4.67 ± 1.20	-1.84	9	0.0900
	No	4.76 ± 0.77	4.59 ± 0.83	-5.59	189	< 0.0001*
FEV1						
	Yes	3.67 ± 0.83	3.50 ± 0.80	-2.65	9	0.0200*
	No	3.74 ± 0.60	3.63 ± 0.61	-7.57	189	< 0.0001*
FEV1/FVC						
	Yes	76.80 ± 6.60	75.70 ± 6.90	-1.53	9	0.1500
	No	78.90 ± 6.40	78.60 ± 9.80	-0.59	189	0.5500
FEF_{25-75}						
	Yes	8.13 ± 1.40	8.16 ± 1.30	0.19	9	0.8500
	No	8.70 ± 1.60	8.70 ± 1.50	-0.76	189	0.4400
PEFR						
	Yes	3.15 ± 0.81	2.89 ± 0.88	-2.38	9	0.0400*
	No	3.54 ± 0.99	3.47 ± 1.01	-1.93	189	0.0500

FVC: Forced vital capacity; PEFR: Peak expiratory flow rate; FEV1: Forced expiratory volume in one second; FEF25-75: Forced expiratory flow at 25%-75% of the FVC; SD: Standard deviation; df: Degree of freedom
*: Statistically significant

Table 4. Across-shift changes in pulmonary function tests (PFTs) in subjects with or without poor sleep quality

Spirometric parameters	Sleep quality	Before shift	After shift	Paired t-test		P-value
		Mean ± SD		t	df	
FVC						
	Poor	4.71 ± 0.81	4.59 ± 0.80	-5.10	95	< 0.0001*
	Normal	5.16 ± 3.62	4.60 ± 0.90	-1.67	103	0.1000
FEV1						
	Poor	3.66 ± 0.55	3.57 ± 0.57	-5.20	95	< 0.0001*
	Normal	3.81 ± 0.66	3.68 ± 0.66	-6.00	103	< 0.0001*
FEV1/FVC						
	Poor	78.20 ± 6.60	78.40 ± 6.80	0.32	95	0.7400
	Normal	79.40 ± 6.20	78.50 ± 11.80	-0.81	103	0.4100
FEF_{25-75}						
	Poor	8.59 ± 1.60	8.56 ± 1.60	-0.32	95	0.7400
	Normal	8.84 ± 1.60	8.78 ± 1.50	-0.70	103	0.4800
PEFR						
	Poor	3.38 ± 0.85	3.28 ± 0.90	-2.00	95	0.0400*
	Normal	3.66 ± 1.07	3.59 ± 1.09	-1.29	103	0.1980

FVC: Forced vital capacity; PEFR: Peak expiratory flow rate; FEV1: Forced expiratory volume in one second; FEF25-75: Forced expiratory flow at 25-75 percent of the FVC; SD: Standard deviation; df: Degree of freedom

Akpinar-Elci et al. found this association among nutmeg workers (24). Furthermore, a previous study reviewed the link between occupational exposure to pesticide and respiratory symptoms and suggested a positive relationship, but it did not demonstrate a causal relationship (25).

There is a significant number of studies which explored the effects of lung impairment on sleep problems. According to previous studies (12, 13), insomnia was higher among patients with chronic obstructive pulmonary disease (COPD).

Sleep quality also drops by lung problems, and as Geiger-Brown et al. (15) showed, 53.0% of patients with COPD suffered from poor sleep quality, but a limited number of studies have investigated the adverse effects of respiratory problems and disrupted PFTs on sleep health. A case-control study carried out in Iran reported a significant connection between respiratory symptoms and sleep quality (26), and other studies have shown impaired respiratory function tests as a reason for poor sleep quality among diabetics (27) and asthmatic patients (28). Moreover, Luyster et al. investigated the relationship between respiratory problems and insomnia (29).

Similar to the current study, previous studies also had the same range of poor sleep quality and insomnia in the occupational setting. Madrid-Valero et al. reported that 38.2% of participants suffered from poor sleep quality, and mean PSQI score was 5.74 (30). Deguchi et al. also indicated that 36.1% of Japanese workers had insomnia (2). The minor or significant differences between the prevalence of poor sleep quality and insomnia among current study and previous studies might-stemmed from different occupational settings, different cultures, and different tools and cut-points for measuring the sleep quality and insomnia.

In an occupational setting, diverse causes can lead to insomnia among the workers, including shift working (31), occupational stress (2), and occupational exposure (11). In further studies, a comprehensive evaluation of different aspects causing insomnia would clarify the strength of each cause.

Conclusion

Results of this study showed a significant cross-shift reduction in PFT values among workers with clinical insomnia or poor sleep quality. According to these findings, in workplaces with hazardous chemical exposures, employers must be concerned about the sleep problems of workers besides workers' respiratory complaints.

***Limitations*:** In the current study, insomnia and sleep quality were assessed by self-report questionnaires without objective validation. Furthermore, design of this study was cross-sectional; therefore, it is impossible to draw conclusions about causal directions, requiring more studies in this regard. Future studies should also consider the objective assessment of sleep by full-time polysomnography (PSG) and actinography.

Conflict of Interests

Authors have no conflict of interests.

Acknowledgments

This study was supported by Tehran University of Medical Sciences. The authors are thankful to

the managers and staff of cast iron foundry for their collaboration.

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