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The Influence of Working in Charcoal Factories on Selected Respiratory Parameters

تأثير العمل في مصانع الفحم النباتي على مقاييس تنفسية مختارة

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Abstract

Workers in charcoal factories are reported to develop respiratory problems. However, to date, no formal studies have been conducted on the effects this profession may have on respiratory health in Palestine. This study aims to determine the effects of working in charcoal factories on selected respiratory parameters. A case-control study consisted of 45 charcoal workers "cases" and 45 non-charcoal workers "controls". The working durations of cases were reported. Forced spirometry was used to measure the forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC). These values, alongside the FEV1/FVC ratios and prevalence of restrictive lung disease of the two groups were compared. The results show that there is a significant decrease in the FEV1 ($p=0.015$) and FVC ($p=0.017$) values in charcoal workers in comparison to non-workers. While the FEV1/FVC ratio is not significantly affected ($p=0.088$). The prevalence of restrictive lung pattern is 64.4% among charcoal workers, which is significantly higher than the control group ($p=0.017$). The severity of restricted lung disease increased with the increase in working duration. We conclude that working in charcoal factories resulted in significant negative changes in the spirometrical readings, and increasing prevalence of restrictive lung disease.

Key Words: Occupational lung disease, FEV1, FVC, Lung function testing, pneumoconiosis.

ملخص

ورد أن العاملون في مصانع الفحم النباتي تظهر لديهم مشاكل في الجهاز التنفسي. لكن حتى الآن، لم يتم عمل أية دراسات رسمية تثبت تأثير هذه المهنة على صحة الجهاز التنفسي. تسعى هذه الدراسة لإثبات تأثير العمل في مصانع الفحم النباتي على مقاييس تنفسية مختارة في فلسطين. تم تقسيم عينة الدراسة إلى مجموعتين, إحداهما تتكون من عمال مصانع الفحم النباتي، أخدين بعين الاعتبار سنوات العمل في تلك المصانع، والأخرى تتكون من أشخاص أصحاء غير عاملين في تلك المصانع. تم استعمال قياس التنفس القصري لحساب حجم الزفير القصري في الثانية الأولى (FEV1) والسعة الحيوية القصرية (FVC). من ثم, تمت المقارنة بين هذه القيم المحسوبة بالإضافة إلى نسبة القيمتين (FEV1/FVC ratio) ومعدل انتشار أمراض الرئة التقييدية بين المجموعتين. أظهرت النتائج أن هناك انخفاضا بارزا في حجم الزفير القصري في الثانية الأولى (p = 0.015) وأيضاً في السعة الحيوية القصرية (p=0.017) في مجموعة العاملين مقارنة بغير العاملين، بينما لم يكن هناك اختلاف ذو قيمة في قيم النسبة بينهما (p = 0.088). كان معدل انتشار أمراض الرئة التقييدية بين العاملين 64.4%، وتعد هذه النسبة أعلى منها لدى غير العاملين بشكل بارز (p=0.017). تبين أيضاً أن خطورة أمراض الرئة التقييدية تزداد بازدياد مدة العمل في مصانع الفحم النباتي. نستنتج أن العمل في مصانع الفحم النباتي يؤدي إلى تغييرات سلبية في قراءات المقاييس التنفسية بالإضافة إلى زيادة نسبة انتشار أمراض الرئة التقييدية.

الكلمات المفتاحية: الأمراض الرئوية المتعلقة بالمهنة، حجم الزفير القصري في الثانية الأولى (FEV1)، السعة الحيوية القصرية (FVC)، حسابات وظيفة الرئة، pneumoconiosis.

Introduction

Lung diseases are functionally classified as obstructive or restrictive. Obstructive lung diseases, such as asthma (Colledge, Walker, & Ralston, 2010), are characterized by the obstruction of airways such that air movement in the lung is hampered. Restrictive diseases, such as idiopathic lung fibrosis (Raghu et al., 2011), are characterized by insufficient lung expansion. Some lung diseases exhibit both obstructive and constructive traits (Gardner, Ruppel, & Kaminsky, 2011).

Pneumoconiosis, an occupational lung disease (OLD), is caused by exposure to irritating substances either repeatedly in small amounts or in one severe incident that cause acute or chronic illnesses (Longo et al., 2011). Pneumoconiosis has different forms according to the irritating agent involved. The most common of which are asbestosis, silicosis and coal worker's pneumoconiosis. As the names suggest, these forms are respectively caused by exposure to asbestos, silica and coal. Associated interstitial lung fibrosis, and to a less degree progressive massive fibrosis, affect coal miners in the US (Baum, Crapo, Celli, & Karlinsky, 1998; Morgan & Seaton, 1984). These conditions occur as a result of the progressive inflammatory processes after exposure to the dust particles leading to lung fibrosis (Longo et al., 2011). Exposure to domestic wood smoke and charcoal is proved to be toxic and irritant to the respiratory system (Orozco-Levi et al., 2006). It was found that long term exposure to domestic wood smoke resulted in chronic lung diseases with an increase in the morbidity and mortality in the affected patients (Mosier et al., 2012). In an experimental study conducted on guinea pigs, short term exposure to wood smoke resulted in oxidative stress and lung injury (Ramos et al., 2013). In order to minimize coal dust exposure, some countries issued laws and initiated technically feasible control measures as early as 1950s (Liu et al., 2009). These safety precautions cut coal worker's pneumoconiosis mortality rates by 30% between 1968 and 2000 in the US ("Centers for Disease Control and Prevention (CDC). Changing patterns of pneumoconiosis mortality--United States, 1968-2000.," 2004).

Lung function tests (LFTs) are measured using a spirometer, which is an apparatus that is used for measuring the volume and flow rate of inspired and expired air. These tests are used to differentiate between obstructive and restrictive diseases and assess the degree of associated changes (Colledge et al., 2010; Holguin, 2012). Such parameters include Forced Expiratory Volume in the first second (FEV1) and Forced Vital Capacity (FVC). The specificity and sensitivity of spirometry in diagnosis of obstructive lung disease are reported as 84% and 92%, respectively (Schneider et al., 2009). While in the diagnosis of restrictive lung disease, it has a sensitivity and specificity of 42.2% and 94.3%, respectively (Quadrelli, Bosio, Salvado, & Chertcoff, 2007).

FEV1 is the maximum air volume exhaled with maximal effort in the first second from a position of full inspiration. This value declines less severely with restrictive diseases than obstructive ones. FVC, on the other hand, is the maximal air volume exhaled with maximal effort from a position of full inspiration (Pellegrino et al., 2005), and is reduced by airflow obstruction and ventilation restriction, which result from lung-exterior factors such as skeletal pains or intrinsic lung diseases, especially restrictive ones (Derom et al., 2008). In the latter, there is a decline in the lung compliance associated with the presence of partial or diffuse lung fibrosis. These fibrotic changes render the lungs smaller and stiffer, leading to a decrease in the FVC. The FEV1/FVC ratio is reduced in obstructive patterns, but it is normal or increased in restrictive patterns as both nominator and denominator proportionally change (Longo et al., 2011).

A traditional trend was to use a lower limit of 80% for normal lung function results. However, this is only applicable for FVC, FEV1 and total lung capacity (TLC) and in middle aged adults. On the other hand, it gives a higher rate of false positive and false negative findings in case of FEV1/FVC, especially if used for adolescents and adults over 60 years of age (Pellegrino et al., 2005). Therefore, it is now recognized that the 5th percentile is better used as a lower limit of normal (Quanjer et al., 2011).

Cases of restrictive lung disease in charcoal workers are reported. However, no studies have been conducted on these workers to detect the prevalence and association between charcoal exposure and lung disease. Similarly, to our knowledge, in literature no study investigated the effect of exposure to charcoal among charcoal workers.

This study aims to investigate the influence of working in charcoal factories on selected respiratory parameters, as a reflection of the pulmonary function. It investigated the effect of working in these factories on the FEV1 by comparing the spirometrical readings of both the workers and non- workers. Similar application was done for both FVC and FEV1/FVC.

Material and Methods

In order to achieve the study objectives, which need a comparison between the charcoal factories' workers group and the non-workers group, a case-control study was performed. The cases involved 45 male charcoal workers in Ya'abad town. Ya'abad was chosen because it is the Palestinian city with the biggest cluster of charcoal factories and the highest percentage of charcoal workers among its residents.

Criteria used for cases selection included working for at least one year in charcoal factories without interruption; as this period should be enough for chronic inflammatory changes to occur. There must also be lack of involvement, during or before the time of the study, in similar occupations such as stone manufacturing, glassmaking, or farming that may affect the lungs by causing inflammatory changes. The study subjects' in ages were between 15 and 51 years, and working duration between 1 and 27 years.

In order to study the effect of working duration in charcoal factories on the lung function, the workers were divided into two groups, the first one are those who worked for a duration of less than 10 years, while the second group are the workers who worked for 10 years or more in the charcoal factories.

The control group included 45 healthy male subjects, who must have never worked in charcoal factories or been exposed to charcoal dusts, or are current or former workers in any place that may affect their lung function. They were selected from Jenin city, a nearby city for Ya'abad town that is not exposed to charcoal dust. Multistage sampling method for the control was used. The center of Jenin city, where the central taxies park is, leads to five main streets. From the right side of each street, one building's door every ten doors was chosen using systemic sampling starting from the tenth door. One house from each building was chosen using simple random sampling, and one person matched to the selection criteria was chosen from the house for spirometry using simple random sampling. Nine persons were sampled from each street leading to a total number of 45 persons from the 5 main streets from Jenin city center, forming the control group. The ages of the control group were between 17 and 53 years.

Smoking affects the lung function readings by increasing the degree of airway obstruction detected by decrease in FEV1/FVC ratio (Yeoh & Yang, 2002). It is, thus, an important confounding variable, and its effect was overcome using stratification method.

For ethical considerations, an approval to conduct this study was obtained from the Institutional Review Board (IRB) of An-Najah National University. All test subjects were required to sign consent forms explaining the study’s aims and potential risks. Anonymity of the study subjects was ensured, and confidentiality was strictly maintained during and after the study period.

Information about every subject’s age, height, weight (Holguin, 2012), health history, occupational history, and use of airway protective means were obtained at the time of spirometry. Health history questions pertained to pneumonia diagnoses, smoking status (Kotz, Wesseling, Huibers, & van Schayck, 2009), any significant respiratory symptoms, neuromuscular disorders, diabetes and hypertension (Yeoh & Yang, 2002).

Thereafter, LFTs were performed using a Microlab Spirometer by Care Fusion compliant to ATS/ERS 2005 standards (Pellegrino et al., 2005). Regular guidelines for spirometer testing were followed (Broekhuizen et al.). The subjects were seated during the test, with the nose clipped to prevent air leakage through the nares. Forced spirometry was measured for each subject. For each subject, FEV1, FVC, FEV1/FVC ratios were measured. It is also important that no one of the workers administered his bronchodilator -if used- for at least 4 hours before the test, as it has an effect on the PFTs, especially by masking the obstructive respiratory pattern (Longo et al., 2011).

The statistical analysis of the data was carried out by SPSS Statistics V.17.0 (SPSS Ink, Chicago, Illinois, USA), using Chi-square test to measure the P value to find out the significance of the associations. The level of significance was considered significant at a p value < 0.05.

Results

Statistical analysis of the collected data was done. The null hypothesis for each objective was that there is no association between working in charcoal factories and changing in each of the used respiratory parameters and the restrictive pattern. The test results indicated that 64.4% of charcoal workers showed a restrictive pattern of lung function, whereas only 40% of the control group did. As table 1 shows, this association was statistically significant (p=0.017) and the null hypothesis is refused.

Table (1): The relation between working in charcoal factories and the pattern of lung function.

	Non-restrictive Count (percent)	**Restriction Count (percent)**	**Total**
Non Worker	27 (60%)	18 (40%)	45
Worker	16 (35.6%)	29 (64.4%)	45
Total	**43 (42.2%)**	**47 (52.2%)**	**90 (100%)**

[*] P-value = 0.017

[*] P-value was calculated by chi-square Test for the significance of the relation.

Table 2 shows that charcoal workers had more subjects with decreased FEV1 values than members of the control group (P =0.015). Charcoal workers also exhibited more subjects with decreased FVC values, as shown in Table 3. (P=0.017). The null hypotheses are refused here. On the other hand, FEV1/FVC ratio increased or remained normal in charcoal workers. However, this association was not statistically significant (P = 0.088) and the null hypothesis is accepted (see table 4).

Table (2): The relation between working in charcoal factories and FEV1.

	Decreased Count (percent)	Not-decreased Count (percent)	Total
Non Worker	4 (8.9%)	41 (91.1%)	45
Worker	13 (28.9%)	32 (71.1%)	45
Total	**17 (18.9%)**	**73 (81.1%)**	**90 (100%)**

* P-value = 0.015

\# FEV1= Forced Expiratory Volume in the first second.

* P-value was calculated by Chi-Square Test for the significance of the relation.

Table (3): The relation between working in charcoal factories and FVC.

	Decreased Count (percent)	Not-decreased Count (percent)	Total
Non worker	16 (35.6%)	29 (64.4%)	45
Worker	27 (60%)	18 (40%)	45
Total	**43 (47.8%)**	**47 (52.2%)**	**90 (100%)**

* P-value = 0.017

\# FVC = Forced Vital Capacity.

* P-value was calculated by chi square for the significance of the relation.

Table (4): The relation between working in charcoal factories and FEV1/FVC.

	Non-increased Count (percent)	Increased Count (percent)	Total
Non worker	34 (75.6%)	11(24.4%)	45
Worker	27 (60%)	18 (40%)	45
Total	**61(67.8%)**	**29 (32.2%)**	**90 (100%)**

* P-value = 0.088.

\# FEV1: Forced Expiratory Volume within 1st second, FVC: Forced Vital Capacity.

* P-value was calculated by chi-square Test for the significant of the relation.

Duration of working was inversely correlated to the lung spirometry. In other words, patients with longer work duration have worse lung function of restrictive pattern. Table 5 shows that 44% of the workers who worked for less than 10 years showed normal lung function as measured by the spirometer, compared to 5% of those who worked for 10 years or more. In the other hand, 40% of the workers who worked for 10 years or more showed moderate and sever restrictive pattern of lung function compared to only 8% of the workers who worked for less than 10 years.

Table (5): The relation between the duration of working in factories and lung function status.

Working duration	Normal Count (percent)	Obstructive Count (percent)	Mild restriction Count (percent)	Moderate and sever restriction Count (percent)	total
Years <10	11 (44%)	2 (8%)	10 (40%)	2 (8%)	**25**
Years=>10	1 (5%)	2 (10%)	9 (45%)	8 (40%)	**20**
Total	**12 (26.7%)**	**4 (8.9%)**	**19 (42.2%)**	**10 (22.2%)**	**45 (100%)**

Although smoking plays an important role in reducing FEV1 and FVC values, it has no significant effect on the prevalence of restrictive lung disease in smokers compared to non smokers, as the p value (0.015) remains significant among the smokers after stratification of the study population according to the smoking status as shown in Table 6.

Table (5): Stratification of the population depending on the smoking status.

Smoking status	**Working in charcoal factories**	**FEV1**		**FVC**		**Lung function pattern**	
		Decreased	**Not decreased**	**decreased**	**Not decreased**	**Non-restrictive**	**restrictive**
Non-smokers	Non-workers	2	21	7	16	13	10
	Workers	4	8	7	5	6	6
Total		**6**	**29**	**14**	**21**	**19**	**16**
P values		**P= 0.089**		**P= 0.109**		**P= 0.495**	
Smokers	Non-workers	2	20	9	13	14	8
	Workers	9	24	20	13	10	23
Total		**11**	**44**	**29**	**26**	**24**	**31**
P values		**P= 0.093**		**P= 0.123**		**P= 0.015**	

Discussion

The charcoal effect on lung function can be explained by the common pathogenesis of occupational lung diseases. Entrance of dust particles into lungs could result in inflammatory reactions that lead to lung fibrosis, which is a common cause of restrictive lung diseases (Longo et al., 2011). This restrictive pattern was signified by the decreased FVC and FEV1 values in charcoal workers. However, this explanation needs pathological evidence. FEV1/FVC ratio, on the other hand, was not significantly changed in charcoal workers. This result is compatible with the fact that the FEV1/FVC may be normal or increased in restrictive lung diseases depending on the severity of the condition (Colledge et al., 2010).

Regarding the effect of duration of working on the lung function, there was an increase in number of cases with moderate and severe restrictive lung pattern with increased duration. This can be explained by the progressive pattern of occupational lung diseases, as lung inflammation and fibrosis increase with increased duration of dust exposure (Webe et al., 1996).

The results of this study support other studies conducted on the effect of charcoal and wood smoke exposure on the respiratory system. In a study conducted in Spain, Orozco-Levi et al (2006) showed that there is an association between charcoal and wood smoke exposure and chronic obstructive lung diseases (COPD) after adjusting for age and smoking status (Orozco-Levi et al., 2006).

Conclusion

Working in charcoal factories leads to a significant decrease in the FVC and FEV1 values, while it has no effect on the FEV1/FVC ratio. These readings reflect the negative effect of charcoal exposure on the lung function, evident by increased severity of restrictive lung disease compared to control group. An inverse relation between the duration of working and lung function was found. These negative effects of charcoal exposure detected in this study necessitate intervention and implementation of protective measures to prevent the occurrence and progression of health problems among the workers. It also necessitates the conduction of studies on pathological changes that result from exposure to charcoal in order to have an explanation of the spirometrical changes found in this study.

Recommendations

Based upon the above mentioned results, safety precautions for workers and limitation of working hours are recommended. This study has only investigated the effects on respiratory parameters, so it is recommended that further pathological and clinical studies in this field are carried on.

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