



# Exposure to Cooking Fumes and Acute Reversible Decrement in Lung Functional Capacity

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## Abstract

**Background:** Being exposed to cooking fumes, kitchen workers are occupationally at risk of multiple respiratory hazards. No conclusive evidence exists as to whether occupational exposure to these fumes is associated with acute and chronic pulmonary effects and symptoms of respiratory diseases.

**Objective:** To quantify the exposure levels and evaluate possible chronic and acute pulmonary effects associated with exposure to cooking fumes.

**Methods:** In this cross-sectional study, 60 kitchen workers exposed to cooking fumes and 60 unexposed employees were investigated. The prevalence of respiratory symptoms among these groups was determined through completion of a standard questionnaire. Pulmonary function parameters were also measured before and after participants' work shift. Moreover, air samples were collected and analyzed to quantify their aldehyde, particle, and volatile organic contents.

**Results:** The mean airborne concentrations of formaldehyde, acetaldehyde, and acrolein was 0.45 (SD 0.41), 0.13 (0.1), and 1.56 (0.41) mg/m<sup>3</sup>, respectively. The mean atmospheric concentrations of PM<sub>1</sub>, PM<sub>2.5</sub>, PM<sub>7</sub>, PM<sub>10</sub>, and total volatile organic compounds (TVOCs) was 3.31 (2.6), 12.21 (5.9), 44.16 (16.6), 57 (21.55) µg/m<sup>3</sup>, and 1.31 (1.11) mg/m<sup>3</sup>, respectively. All respiratory symptoms were significantly ( $p < 0.05$ ) more prevalent in exposed group. No significant difference was noted between the pre-shift mean of spirometry parameters of exposed and unexposed group. However, exposed workers showed cross-shift decrease in most spirometry parameters, significantly lower than the pre-shift values and those of the comparison group.

**Conclusion:** Exposure to cooking fumes is associated with a significant increase in the prevalence of respiratory symptoms as well as acute reversible decrease in lung functional capacity.

**Keywords:** Cooking; Aldehyde; Respiratory function tests; Signs and symptoms, respiratory; Lung diseases

## Introduction

The term "Cooking fumes" is typically used to describe the visible emissions produced during cooking pro-

cess. Taking place under high temperature, frying and grilling is a process that produces harmful products.<sup>1</sup> During cooking, submicron-sized solid particles are generated through the cooling of vapor which is

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produced while cooking oil is heated more than its boiling point.<sup>2</sup>

Cooking is one of the most important sources of indoor particles with different sizes (<0.1–10 µm). Most of the fine particles emitted by the processes of frying and grilling meat are organic compounds.<sup>3</sup> The concentration and chemical properties of emissions strongly depend on the cooking method and food ingredients.<sup>2</sup>

Free radicals are formed by fatty acids. They react with oxygen to produce peroxides, which in turn enter many chemical reactions leading to the production of various compounds such as aldehydes, ketones, acids and polymerized fats.<sup>4</sup> Aldehydes such as formaldehyde, acetaldehyde, and acrolein, are the chemicals formed from the destruction of sugar and fats and pyrolysis of proteins and amino acids during cooking process at high temperature.<sup>5,6</sup> These aldehydes, upon inhalational exposure, can cause local irritation in the airways.<sup>1</sup>

Kitchen workers are exposed to various respiratory hazards.<sup>7,8</sup> The importance of this issue becomes more evident when one takes into account the fact that cooks spend at least six hours a day in the kitchen.<sup>9</sup> The results of a few epidemiological studies show that exposure to cooking oil fumes created during Chinese cooking has a strong correlation with rhinitis, decreased lung capacity, respiratory symptoms, and lung cancer.<sup>10–12</sup> Furthermore, epidemiological studies in Europe have shown an increased risk of respiratory tract disorders and cancer in some chefs and bakers. Additionally, a Norwegian study reported a higher frequency of respiratory symptoms among kitchen workers in comparison to a referent group.<sup>1</sup> Another study reported increased mortality from respiratory disorders, such as asthma and emphysema, induced by exposure to cooking fumes in hotels and restaurants.<sup>13</sup> In contrast, Wong, *et al*, in their study on 393

Chinese kitchen workers, did not find any significant increase in the prevalence of respiratory symptoms except for phlegm.<sup>7</sup> Similarly, in another study, the authors did not observe any significant changes in the parameters of pulmonary function after a short exposure to cooking fumes.<sup>14</sup>

Given the above-mentioned controversies, the objective of the current study was to quantify the level of exposure of a group of cooks to aldehydes (formaldehyde, acetaldehyde, and acrolein), total volatile organic compounds (TVOCs), and suspended particulates, and to examine the possible respiratory effects, if any, associated with occupational exposure to these airborne pollutants.

## Materials and Methods

This cross-sectional study was conducted on the catering staff of Shiraz University of Medical Sciences (SUMS) and Shiraz University, Shiraz, southern Iran. The exposed population consisted of all catering staff (60 men) of both universities. For the selection of the comparison group, an internal comparison approach was used to compare the exposed and unexposed groups. For this purpose, a group of 60 unexposed men whose age, smoking habits, and other main variables were comparable to those of the exposed group, were selected from ordinary office staff of SUMS by simple random sampling. The exclusion criteria were history of any pre-existing respiratory disorders, family history of respiratory illnesses, chest operations or injuries, and any prior exposure from other occupations to chemicals known to have pulmonotoxicity properties.

Written informed consent forms were obtained from all participants before entering the study. The study protocol was approved by the SUMS Ethics Committee.

### Prevalence of Respiratory Symptoms

Standard respiratory symptom questionnaires, as suggested by the European Community Respiratory Health Survey,<sup>15</sup> was used to assess the prevalence of respiratory symptoms. This questionnaire included questions about respiratory symptoms (wheezing, shortness of breath, asthma, nasal allergies, phlegm, *etc*), smoking habits, as well as occupational, medical and family history of each participant. The criteria for work-related respiratory symptoms in this questionnaire were defined by Matheson and Lúdvíksdóttir.<sup>16,17</sup>

### Pulmonary Function Tests

Pulmonary function tests (PFTs) were performed using a portable calibrated Vitalograph spirometer (Model ST-150; manufactured by a joint Japanese-Philippinian company, Fukuda Sangyo Co, Ltd) on-site. The pulmonary function parameters including mean percentage predicted vital capacity (VC), forced vital capacity (FVC), forced expiratory volume during the first second (FEV<sub>1</sub>), and peak expiratory flow (PEF) were measured twice for the exposed group (pre-shift, following a 48-hour exposure-free period, and post-shift, after 8 hours of consecutive exposure) and once for the comparison group according to the standard method.<sup>18</sup> The mean percentage predicted value was calculated and adjusted based on the subjects' age, weight, standing height, sex, and ethnic group by spirometer device.

### Measurement of Atmospheric Concentrations of Cooking Fumes

To assess the extent of subjects' exposure to airborne contaminants, atmospheric concentrations of cooking fumes including aldehydes (formaldehyde, acetaldehyde, and acrolein), total suspended particulates (TSPs), and TVOCs were measured. Sampling of aldehydes was performed by che-

misorption tubes containing high-purity silica gel (ultra-low control), treated with 2, 4-dinitrophenyl hydrazine (2, 4-DNPH), 6×110-mm size, 2 sections, 150/300 mg sorbent, 20/40 mesh, using a personal air sampling pump (SKC, Model 222-mL/COUNT) at an air flow rate of 0.2 L/min. Air samples were collected from four central kitchens during active cooking processes (grilling and frying) at different stationary sampling points near the breathing zone of cooks (1.5 m above the ground). Similarly, the control air samples were collected from outdoor air. Sorbent tubes were protected from light by wrapping them in aluminum foil. The 2, 4-DNPH derivatives of aldehydes were extracted with high-purity acetonitrile. The eluate was analyzed by high-performance liquid chromatography (HPLC, YL9100, Model Waters 1525), C18 reverse phase column and a UV detector, operating at 360 nm.<sup>6,19,20</sup> The detection and quantification limits of this method were, respectively, 0.001 and 0.003 µg/m<sup>3</sup> for formaldehyde, 0.001 and 0.003 for acetaldehyde and 0.002 and 0.006 µg/m<sup>3</sup> for acrolein. The recovery rates were calculated to be 99.2%, 97.8%, and 98.9% for formaldehyde, acetaldehyde, and acrolein, respectively. The mean relative standard deviations (RSDs) were found to be <4% for these three aldehydes.

Particulate matters ranging in size from PM<sub>1</sub>, PM<sub>2.5</sub>, PM<sub>7</sub>, to PM<sub>10</sub> were measured by aerosol mass monitor (Model GT-331, SIBATA Company, USA). TVOCs were monitored using online reading Phocheck Tiger (Ion Science Inc, UK). In addition, the concentrations of suspended particulates and TVOCs were measured in official building as control levels.<sup>21</sup>

### Statistical Analysis

SPSS® for Windows® ver 19 was used for data analysis. Data were analyzed using *Student's t* test, and  $\chi^2$  or Fisher's exact tests, where applicable. Continuous vari-

**Table 1:** Demographic characteristics of the studied groups. Figures are either mean (SD) or n (%).

Variable	Exposed group (n=60)	Unexposed group (n=60)	p value
Age (yr)	35.8 (9.2)	38.5 (8.7)	0.958
Height (cm)	174.1 (7.2)	175.1 (6.3)	0.326
Weight (kg)	78.2 (13.0)	80.5 (11.5)	0.174
BMI (kg/m <sup>2</sup> )	25.8 (3.9)	26.3 (3.7)	0.689
Length of employment (yr)	11.1 (7.1)	12.5 (8.7)	0.052
Level of education			
Illiterate	42 (70%)	7 (12%)	0.001
Diploma	15 (25%)	14 (23%)	
Graduate	2 (3%)	23 (38%)	
Post graduate	1 (2%)	16 (27%)	
Marital status			
Single	4 (7%)	10 (17%)	0.084
Married	56 (93%)	50 (83%)	
Smokers			
Yes	26 (43%)	16 (27%)	0.084
No	34 (57%)	44 (73%)	
Length of smoking (yr)	3.7 (5.9)	2.7 (8.2)	0.100
Number of cigarettes smoked per day	2.3 (5.3)	1.1 (3.4)	0.073

ables with normal distribution were presented as mean (SD). Age, weight, height, smoking habits, level of education, and marital status were considered potential confounders and their effects on the prevalence of respiratory symptoms and changes in pulmonary function indices were controlled. Models for logistic and multiple linear regression analyses, were constructed based on the exposure variable as well as all potential confounding variables. Using the backward elimination method and keeping the main exposure variable, cooking fumes, in the model, the final model was obtained.

## Results

Demographic characteristics and smoking habits of the studied groups are presented in Table 1. There were no significant differences between two studied groups in terms of age, height, weight, body mass index (BMI), length of employment, marital status, and duration and intensity of smoking. Nonetheless, the comparison group had a significantly ( $p < 0.05$ ) higher level of education than kitchen workers. The results of airborne concentrations of cooking fumes are presented in Table 2. The mean atmospheric concentrations of formaldehyde and acrolein exceeded the current threshold limit values (TLVs) of 0.24 mg/

**Table 2:** Airborne concentrations of cooking fumes. Figures are mean (SD; range). The difference between two groups is significant ( $p < 0.001$ ) for all variables.

Variable	n	Kitchen workers	Comparison group (n=10)
Formaldehyde (mg/m <sup>3</sup> )	16	0.45 (0.41; 0.12 to 1.73)	0.001 (<0.001; 0.0011 to 0.0014)
Acetaldehyde (mg/m <sup>3</sup> )	16	0.13 (0.1; 0.02 to 0.51)	Not detected
Acrolein (mg/m <sup>3</sup> )	16	1.56 (0.41; 0.48 to 2.11)	Not detected
TVOCs (mg/m <sup>3</sup> )	720	1.31 (1.1; 0.34 to 6.9)	0.85 (0.26; 0.48 to 1.27)
PM <sub>1</sub> (µg/m <sup>3</sup> )	576	3.31 (2.6; 1 to 8.5)	0.5 (0.15; 0.3 to 0.8)
PM <sub>2.5</sub> (µg/m <sup>3</sup> )	576	12.21 (5.9; 5.6 to 23)	3.7 (0.69; 3.1 to 5.4)
PM <sub>7</sub> (µg/m <sup>3</sup> )	576	44.5 (16.6; 17.1 to 67.9)	17.7 (1.8; 16.2 to 21.12)

m<sup>3</sup> and 0.04 mg/m<sup>3</sup> set by the American Conference of Governmental Industrial Hygienists (ACGIH) for these compounds, respectively.<sup>22</sup> In addition, the mean levels of TVOCs were higher than the Chinese standard of air quality for these compounds (0.6 mg/m<sup>3</sup>).<sup>23</sup> The mean concentrations of suspended particulates and VOCs were higher than those of the comparison group (Table 2).

Table 3 shows the frequency of respiratory symptoms. The prevalence of respiratory symptoms (wheezing, shortness of breath, chest tightness, cough, chronic cough, phlegm, and chronic bronchitis) in the exposed subjects was significantly

( $p < 0.05$ ) higher than those of the comparison group. The relationship between exposure to cooking fumes and the prevalence of respiratory symptoms is presented in Table 3. Logistic regression analysis showed that after adjusting for age, weight, height, BMI, level of education, marital status, and smoking habits, significant associations existed between exposure and the prevalence of respiratory symptoms.

Table 4 shows the results of pulmonary function tests. Significant ( $p < 0.05$ ) decrements were noted in the mean values of VC, FVC, FEV<sub>1</sub>, and FEV<sub>1</sub>/VC after a working shift. Likewise, post-shift mean values of VC, FVC, FEV<sub>1</sub>, and PEF were signifi-

**Table 3:** Frequency of respiratory symptoms in the exposed and unexposed groups and their corresponding odds ratios

Symptom	Kitchen workers (n=60)	Comparison group (n=60)	p value	OR (95% CI)
Wheezing	12 (20%)	3 (5%)	0.025	4.8 (1.3 to 17.8)
Shortness of breath	38 (63%)	13 (22%)	<0.001	7.6 (2.3 to 24.7)
Chest tightness	19 (32%)	4 (7%)	0.001	6.2 (2.8 to 14.0)
Cough	17 (28%)	1 (2%)	<0.001	27.3 (3.3 to 224.5)
Chronic cough	9 (15%)	0 (0%)	0.003	3.05 (0.8 to 12.8)
Phlegm	20 (33%)	9 (15%)	0.032	3.5 (0.9 to 14.0)
Chronic bronchitis	12 (20%)	3 (5%)	0.025	5.2 (1.4 to 19.9)

**Table 4:** Pulmonary function indices of catering staff and unexposed group (before and after exposure). Values are mean (SD) percent predicted value.

Index	Kitchen workers			p value		
	Pre-shift (n=60)	Post-shift (n=60)	Comparison group (n=60)	Pre-shift vs post-shift exposed group	Pre-shift exposed vs unexposed group	post-shift exposed vs unexposed group
VC	93.6 (11.3)	85 (8.9)	93.5 (11.3)	<0.001	0.941	<0.001
FVC	91 (11.3)	86.5 (11.1)	92 (11.2)	<0.001	0.636	0.014
FEV <sub>1</sub>	90 (10.7)	85.4 (11.7)	90.8 (17.5)	<0.001	0.795	0.008
PEF	93.3 (19.5)	89.9 (20.2)	97.8 (17.8)	0.051	0.180	0.007
FEV <sub>1</sub> /FVC	83 (8.3)	82 (9.4)	82.3 (6.3)	0.682	0.734	0.826
FEV <sub>1</sub> /VC	77.4 (11.7)	80.6 (10.2)	78.2 (14.1)	0.008	0.597	0.328

cantly ( $p < 0.05$ ) lower than their corresponding values for the comparison group. However, there were no significant differences in pulmonary function parameters measured pre-shift between kitchen workers and the comparison group.

Similarly, the association between exposure to cooking fumes and changes in the pulmonary function parameters is shown in Table 5. Multiple linear regression analysis revealed that after adjusting for age, weight, height, smoking habit, and

education level, there were significant associations between exposure to cooking fumes and FVC, FEV<sub>1</sub>, and PEF ratio.

### Discussion

In the present study, levels of exposure to selected important cooking fumes were evaluated and the prevalence of respiratory symptoms was investigated among a group of catering staff. Additionally, parameters of pulmonary function were measured and compared to those of a non-exposed comparison group. Both groups were similar in terms of demographic variables, but education level.

According to our results, mean concentrations of formaldehyde, acrolein, and TVOCs were higher than the recommended values for these substances. Additionally, the proportions of PM<sub>10</sub> and PM<sub>7</sub> were significantly higher than smaller particles ( $p < 0.05$ ). Furthermore, the mean values of suspended particles were higher than those in the comparison group.

Lee, *et al.*<sup>24</sup> showed that the mean concentration of PM<sub>2.5</sub> during cooking process

### TAKE-HOME MESSAGE

- Kitchen workers are occupationally at risk of multiple respiratory hazards.
- In our study, the mean concentrations of indoor cooking fumes measured (formaldehyde, acrolein, and total volatile organic compounds) were higher than the recommended values.
- Exposure to cooking fumes is associate with increased prevalence of respiratory symptoms (wheezing, shortness of breath, chest tightness, chronic cough, phlegm, and chronic bronchitis), and decreased spirometry indices.

was 21.9 µg/m<sup>3</sup>. Similarly, some other studies reported that the mean concentration of PM<sub>2.5</sub> ranged from 1.9 to 56 µg/m<sup>3</sup> and those of PM<sub>10</sub> from 15 to 482 µg/m<sup>3</sup>.<sup>22,25-27</sup> In contrast, significantly higher levels of suspended particles have been reported by See, *et al*.<sup>28</sup> The authors, reported that the mean concentration of PM<sub>2.5</sub> during peak exposure was about 312.4 µg/m<sup>3</sup>. In contrast, Abt, *et al*, found that the highest level of particulate matter was attributed to PM<sub>1</sub>.<sup>29</sup> McDonald and Buonanno propose that the reason for these differences can be related to the methods and materials used for cooking, type of food and condition of kitchens.<sup>30,31</sup>

In the current study, airborne concentrations of formaldehyde, acetaldehyde, and acrolein were found to be 0.45, 0.13 and 1.56 mg/m<sup>3</sup>. Quantitatively, similar findings have been reported by other researchers where the concentrations of formaldehyde, acetaldehyde, and acrolein have been found to be 0.7–0.24, 0.67–1.5, and 0.01–0.59 mg/m<sup>3</sup>, respectively.<sup>6</sup>

In contrast, Svendsen, *et al*, reported very low levels of these aldehydes (60, 162, and 32 µg/m<sup>3</sup> for formaldehyde, acetaldehyde, and acrolein, respectively).<sup>19</sup> Likewise, Yu Huang, *et al*, studied the effects of VOCs and carbonyls, which form during cooking process, on health of exposed workers in Hong Kong and found that acetaldehyde is the most abundant carbonyl in the kitchens.<sup>32</sup>

The reasons for these discrepancies probably related to the methods and materials used for cooking, type of food and fuel and the condition of kitchens (work load, area, ventilation, *etc*).

In this study, kitchens were located in underground levels where natural and artificial ventilation were inadequate; they were not spacious and had a very high load of food to process for about 5000 university students on a daily basis.

Our findings indicated that prevalence

**Table 5:** Association between exposure to cooking fumes and change in pulmonary function test indices (multiple linear regression analysis)

Index	β (95% CI)
FVC	-5.25 (-9.13 to -1.16)
FEV <sub>1</sub>	-5.40 (-10.78 to -0.10)
PEF	-7.34 (-13.81 to -0.87)

of respiratory symptoms such as wheezing, shortness of breath, chest tightness, chronic cough, phlegm, and chronic bronchitis in exposed group was significantly higher than that in the comparison group. After adjusting for potential confounders, significant associations were found between exposure and the prevalence of respiratory symptoms (ORs ranging from 3 to 27).

These findings are in agreement with the results of the study conducted by Agnes Mahembe, *et al*, on 360 kitchen workers. They indicated that about 70% of subjects suffered from respiratory symptoms, as a result of exposure to cooking fumes.<sup>9</sup>

Furthermore, findings reported by National Institute for Occupational Safety and Health (NIOSH) on 116 catering staff showed that work-related respiratory symptoms was 3–4-fold more prevalent than in other occupations.<sup>7,8</sup>

Results from other cross-sectional studies have shown a significant increase in the prevalence of respiratory symptoms following exposure to cooking fumes.<sup>1,11,33</sup> In contrast, Wong, *et al*, who assessed respiratory symptoms in 393 Chinese kitchen workers, did not find any significant increase in the prevalence of respiratory symptoms except for phlegm.<sup>7</sup>

Contrary to our findings, where no asthma was reported in exposed subjects, other studies revealed increased risk of hospitalization due to asthma and bronchial hyper-responsiveness.<sup>34,35</sup>

The results of spirometry of exposed

subjects showed significant cross-shift decrements in all parameters of pulmonary function except for FEV<sub>1</sub>/FVC. Linear regression analysis showed that after adjusting for potential confounders, significant associations existed between exposure and decrements in FVC, FEV<sub>1</sub>, and PEF.

Similar findings have been reported by other studies. For instance, the results of pulmonary function tests of 37 chefs showed that for each year of cooking, FEV<sub>1</sub> reduced by 2.5%.<sup>36</sup> Furthermore, Wan, *et al*, reported increased risk of respiratory disorders among women chefs following exposure to cooking fumes.<sup>11</sup> In contrast, Jarvise and Svendahle did not find any evidence of significant decrement in parameters of lung function as a consequence of exposure to cooking fumes.<sup>14,37</sup>

Our findings indicated that no significant difference existed between the pre-shift mean values of the pulmonary function indices of exposed subjects and the comparison group. This finding ruled out the presence of a chronic respiratory effect as a result of exposure to cooking fumes. However, significant cross-shift decrements in the indices indicated that exposure to cooking fumes would result in acute reversible decrement in most studied spirometry parameters. These findings were in agreement with those of Wong, *et al*, who found significant post-shift decrements in FVC and FEV<sub>1</sub> among kitchen workers. They also showed that the reductions may be reversible after cessation of the exposure.<sup>7</sup>

Despite the fact that 43% of exposed subjects were smokers, a few lines of evidence indicated that our findings could not be attributed to smoking. First, the proportion of smokers in both groups was not significantly different. Additionally, after adjusting for smoking habit, significant associations remained between the exposure and both increased prevalence of respiratory symptoms and decreased PFT indices.

The proportion of individuals with normal spirogram, and restrictive, obstructive, and mixed pattern in our study was 70.5%, 6%, 8.5%, and 15%, respectively. In NIOSH study, 81% of subjects had normal spirogram; 14% had restrictive, and 5% had obstructive or mixed pattern.<sup>7,8</sup>

Although, the mean values of most pulmonary function indices were within the normal range (>80%), VC, FVC, FEV<sub>1</sub>, and PEF parameters reduced by 9%, 5%, 5%, and 4%, respectively, during a work shift. Additionally, 37% of exposed workers in our study had >5% decrement in their FEV<sub>1</sub>. This observation could not be simply overlooked as Occupational Safety and Health Administration (OSHA) recommends that declines in FEV<sub>1</sub> as little as 5% following occupational exposure to workplace contaminants should be considered clinically important.<sup>38</sup>

In conclusion, the findings of the present study provide circumstantial evidence in favor of the notion that occupational exposure to cooking fumes is associated with increased prevalence of respiratory symptoms and acute reversible decrease in lung functional capacity. To prevent developing irreversible respiratory disorders, introduction of a surveillance program for these workers is thus strongly recommended.

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**Conflicts of Interest:** None declared.

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