論文

烹飪油煙對男性餐館業勞工脂質過氧化傷害指標影響評估研究

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摘要

本研究嘗試評估中式餐廳的男性餐館業勞工暴露烹飪油煙中的多環芳香族碳氫化合物之內在暴露劑量與氧化傷害情形，研究對象有155位沒有吸菸習慣的男性餐飲業勞工，包括62位廚房工作人員與93位用餐區服務人員。連續採集廚房與用餐區的空氣中粒狀多環芳香族碳氫化合物2個工作天，每個工作天採集時間約12個小時，並以高效能液相層析儀分析粒狀多環芳香族碳氫化合物。以尿液中1-羥基焦腦油做為暴露烹飪油煙的內在劑量指標，並以尿液中丙二醛作為氧化傷害指標。在調整主要個人變項後，以多變項線性迴歸模式評估尿液中1-羥基焦腦油與尿液中丙二醛之相關性。

廚房的空氣中粒狀多環芳香族碳氫化合物總和濃度（中位數：24.7 ng/m^3）顯著高於用餐區的濃度（中位數：4.6 ng/m^3）。廚房工作人員的尿液中丙二醛與1-羥基焦腦油濃度分別為344.2±243.7 µmol/mol creatinine 與6.0±8.0 µmol/mol creatinine，顯著高於用餐區服務人員的尿液中丙二醛與1-羥基焦腦油濃度：244.2±164.4 µmol/mol creatinine 與2.4±4.3 µmol/mol creatinine。勞工尿液中1-羥基焦腦油與廚房工作顯著相關 (p <0.05)。勞工尿液中丙二醛濃度與其尿液中1-羥基焦腦油濃度顯著相關(p <0.001)，勞工尿液中丙二醛濃度並與其每天工作時數顯著相關(p <0.05)。此研究的尿液中丙二醛濃度與尿液中1-羥基焦腦油反應出中式餐廳勞工之職業性烹飪油煙中的多環芳香族碳氫化合物暴露與氧化傷害情形。

關鍵字：烹飪油煙、1-羥基焦腦油、丙二醛、多環芳香族碳氫化合物、餐館業勞工

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Research Articles

Biomarkers of Lipid Peroxidation of Exposure to Cooking Oil Fumes on Male Restaurant Workers

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Abstract

This study attempted to assess the internal dose and oxidative stress in male restaurant workers exposed to polycyclic aromatic hydrocarbons (PAHs) from cooking oil fumes (COFs) in Chinese restaurants. The study participants included 155 non-smoking male restaurant workers, 62 kitchen staff and 93 service staff in Chinese restaurants in Taiwan. Airborne particulate PAHs were monitored in kitchens and dining areas for two consecutive workdays, measured over a 12 hour period on each workday, then identified via HPLC chromatograph. Urinary 1-hydroxypyrene (1-OHP) were used to provide an internal dose of COFs exposure, and urinary malondialdehyde (MDA) was adopted as an oxidative stress marker. Multiple regression models were used to assess the relationship between MDA and 1-OHP levels, after adjusting for key personal covariates.

Summed particulate PAHs levels in kitchens (median: 24.7 ng/m^3) were significantly higher than those in dining areas (median: 4.6 ng/m^3). For non-smoker kitchen staff, mean MDA and 1-OHP levels were 344.2 ± 243.7 μmol/mol creatinine and 6.0 ± 8.0 μmol/mol creatinine, respectively. These levels were significantly higher than those for non-smoker service staff: 244.2 ± 164.4 μmol/mol creatinine and 2.4 ± 4.3 μmol/mol creatinine, respectively. Worker urinary 1-OHP levels were significantly associated with work in kitchens (p <0.05). Furthermore, worker urinary MDA levels were significantly associated with their urinary 1-OHP levels (p <0.001) and work hours per day (p<0.05).The findings indicate that urinary 1-OHP and MDA reflect occupational PAHs from COFs exposure and oxidative stress in Chinese restaurants.

Keywords: Cooking oil fumes, 1-hydroxypyrene, Malondialdehyde, Polycyclic aromatic hydrocarbons, Restaurant workers

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INTRODUCTION

Cooking oil fumes (COFs) are created and released into the environment when food is fried, stir-fried or grilled using cooking oil at high temperatures. The degradation of sugar and fat, and the pyrolysis of proteins and amino acids during high temperature treatment of food can produce harmful degraded materials [1] such as polycyclic aromatic hydrocarbons (PAHs) [2], aromatic amines [3], nitro-polycyclic aromatic hydrocarbons (NPAHs) [4], benzene [5], and aldehydes [6-7]. Traditional Chinese cooking makes especially frequent use of stir frying and deep frying which generates significant amount of COFs [8].

Because the adverse health effects of COFs are related to long-term exposure, a biological monitoring approach, reflecting the integrated internal dose of an individual, is the preferred approach for assessing occupational exposure to COFs. One indicator of COFs exposure for restaurant workers is metabolites of PAHs, such as 1-hydroxypyrene (1-OHP). Studies have identified urinary 1-OHP as a good biological marker of PAHs exposure in firefighters [9], iron foundry workers [10], and coke oven workers [11-12]. The half-life of urinary 1-OHP excretion ranges from 6h to 35 h [13]. This study investigates whether urinary 1-OHP and work in kitchens are good indicators of COFs exposure in workers in Chinese restaurants.

Exposure to COFs increasing the induction of lipid peroxidation of lung epithelial cells and oxidative stress has been reported in an in vitro [8], and a cross-sectional study [14], respectively. Notably, two studies conducted in Western countries identified increased risk of lung cancer in male restaurant cooks, even after adjusting for tobacco use [15-16]. Oxidative stress is defined as a disequilibrium in pro-oxidant and anti-oxidant systems in intact cells resulting from oxygen- using metabolic reactions. Oxidative stress implies that cells contain intact pro-oxidant and anti-oxidant systems that continuously generate and detoxify oxidants during normal aerobic metabolism. Lipid peroxidation is a type of oxidative stress and can be defined as the oxidative deterioration of lipids containing carbon-carbon double bonds. Plasma malondialdehyde (MDA) is a biological marker of lipid peroxidation resulting from oxidative stress [17]. Previous studies have demonstrated relationships between lipid peroxidation and atherosclerosis [18], aging [19], rheumatoid arthritis [20], diabetes mellitus [21], and cancer [22]. Studies also demonstrated that MDA, a stable aldehydic product of lipid peroxidation contained in biological samples such as urine, hair or blood, can reflect global oxidative status in the human body [23-24]. The half-life of induced MDA was about 21 hours [25]. This study assesses internal dose using urinary 1-OHP and oxidative stress using urinary MDA in male restaurant workers exposed to PAHs from COFs in Chinese restaurants.

METHODS

1. Study subjects

Originally, 198 non-smoking male restaurant workers employed for at least 1 year in 19 Chinese restaurants in Taiwan and still working there during 2005 were recruited via two trade unions to participate in a questionnaire survey and health check-up. A sample of 155 restaurant workers who completed both the questionnaire survey and health check was then recruited (Response rate = 78%). The 43 non-participating workers could not attend pre-arranged health check-ups owing to work commitments. Trained interviewers interviewed the participants between July 2005 and December 2005 and collected data including age, work experience, main cooking methods used, height, weight, employment in kitchen work versus some other restaurant employment, and health condition and life style data including smoking, cooking at home, secondhand smoke exposure, and use of respiratory protection devices via questionnaire survey. The variables of smoking, cooking at home, and secondhand smoke exposure were defined as engaging in the relevant behavior on at least four days each week. Subjects who reported smelling cigarette smoke in any time at any place was counted as having been exposed to secondhand smoke that day.

Based on job titles, the 155 restaurant workers were divided into two groups. Kitchen staff included chefs, sous chefs, sauce chefs, executive chefs, and assistant cooks, all of whom were relatively close to COFs exposure in restaurants. Service staff included reception staff, cashiers, waiters, and valets, who had relatively low COFs exposure in restaurants. Spot urine samples from the subjects were collected post-workshift during the weekend. All participants were asked to wash their hands before urine collection to avoid contamination. The Institute Review Board of National Health Research Institutes in Taiwan approved this study. All subjects provided informed consent.

2. Exposure measurement

Daily area monitoring was conducted for particulate PAHs in kitchens and dining areas over two continuous days in all 19 Chinese restaurants in this study. Particulate PAHs in the workplace were sampled via IOM (Institute of Occupational Medicine, England) samplers with glass fiber filters (diameter: 25mm, pore size: 0.7 μm) at a flow rate of 2.0 L/min. The samplers were placed near the breathing zone of the workers. Duplicate samples were obtained for each sampling location. Airborne particulate PAHs were monitored in the kitchen and dining areas over two consecutive workdays, measured for 12 hours on each workday, then analyzed by high performance liquid chromatograph (HPLC). Five PAH species, including pyrene, benzo(k)fluroranhene (BkF), benzo(a)pyrene (BaP), benzo(ghi)perylene (Bghip), and dibenzo(a,e)pyrene (DBaeP) were quantified via HPLC chromatograph. Each sample collected was extracted using 2mL n-hexane in an ultrasonic bath for 20 minutes and 4 mL 5% NaOH was added before centrifuging at 3000 rpm for 20 minutes. Subsequently, dimethyl sulfate (DMS) was added to a 1.5 mL suspension solution and condensed via nitrogen gas (N_2). PAH content in the final solution was determined by a Shimadzu system HPLC (Japan) with a system controller (SCL-10A) and a fluorescent detector (RF-10AXL) equipped with a semi-micro column (Kaseisorb LC ODS-60-5, 4.6 mm × 250 mm). The mobile phase comprised CH3CN/H2O (9:1) solution with flow rate of 1.0 mL/min. The detection limits were determined via seven repeated analyses of the lowest standards for each PAH specie. The coefficient variation for these repeated analyses was less than 2% for all five PAHs. The detection limits were 0.28 pg for pyrene, 0.72 pg for BkF, 0.28 pg for BaP, 0.63 pg for Bghip , and 0.43 pg for DBaeP, respectively.

3. Urinary 1-OHP and MDA

Urinary 1-OHP was analyzed via HPLC using a fluorescent detector. The detection limit was found to be approximately 0.1 μg/L based on seven repeated analyses of 1-OHP at 15.0 μg/L, and the variation in the coefficients of repeated analyses for urinary 1-OHP was less than 10%. Urinary MDA concentration was measured with a HPLC (JASCO Model 980-PU, Toyoko, Japan) using a C18 column and ultraviolet-visible detector at 532 nm (JASCO UV-975, Toyoko, Japan). The mobile phase comprised methanol/potassium phosphate (9:11) buffer and the flow rate was 1.2 ml/min. The within-run and run-to-run precisions of MDA in urine were assessed. The samples were analyzed for MDA based on thiobarbituric acid (TBA) reaction, with HPLC separation of the MDA $(TBA)_2$ adduct, using tetraethoxypropane as a standard. A detection limit of 0.06μg/L was obtained from seven repeated analyses of deionized water and the coefficients variation of repeated analyses was less than 10%. The urinary 1-OHP and MDA levels of each individual were corrected according to the urine creatinine values, which were measured using an automated method based on Jaffe reaction [26].

4. Statistical methods

Student t and Chi-Square statistics were used to compare personal covariates, urinary MDA, and 1-OHP between kitchen and service staff. Furthermore, non-parametric tests with Mann-Whitney U test were used to compare differences in workplace PAHs levels between kitchen and service staff. Urinary MDA and 1-OHP concentrations were log-transformed to normalize their distributions prior to regression analysis. All data from 154 non-smoking restaurant workers were then included in multiple linear regression models to identify significant predictors of non-smoker worker urinary MDA and 1-OHP concentrations, respectively. The level of statistical significance was set to $\alpha=0.05$ for all tests. All data was analyzed using the SAS Version 9.1.

RESULTS

The kitchen staff averaged 4.1 ± 2.3 cooking hours in the workplace per day. Table 1 lists comparisons of personal characteristics, work experience, and health behavior between kitchen and service staffs. Deep frying, stir frying, grilling, steaming, and stewing were the five main cooking methods used by kitchen staff in the surveyed Chinese restaurants. The main cooking methods used by restaurant workers at home were steaming and stewing, neither of which generate significant amounts of COFs. These restaurant workers do not deep fry, stir fry or grill foods at home because they are aware of the hazards of COFs as a result of having attended government training programs, and thus are exposed to few or no COFs. There were no significant differences in height, weight, BMI, working years, work days per week and exposure to secondhand smoke between the kitchen and the service staff. None of the 155 restaurant workers wore respiratory protection devices such as masks during the work period.

Table 2 lists particulate PAHs levels in the kitchens and dining areas of 19 Chinese restaurants. The median levels of pyrene, benzo(k)fluroranhene (BkF), benzo(a)pyrene (BaP), benzo(ghi)perylene (Bghip), and dibenzo(a,e)pyrene in the kitchens were significantly higher than those in dining areas. The median levels of summed PAHs in the kitchens were also significantly higher than those in dining areas.

Table 3 lists urinary MDA and 1-OHP together with job title. The non-smoking kitchen staff, mean MDA and 1-OHP levels were 344.2 ± 243.7 μmol/mol creatinine and 6.0 ± 8.0 μmol/mol creatinine, respectively, and thus were significantly higher than for non-smoker service staff: 244.2 ± 164.4 μmol/mol creatinine and 2.4 ± 4.3 μmol/mol creatinine, respectively.

Table 1 Comparison of personal characteristics, work experience, health behavior between kitchen and service staffs of 155 non-smoking male restaurant workers

	Service staff (n=62)	Kitchen staff (n=93)	***P***
Personal characteristics (Mean ± SD)			
Age (years)	35.4 ± 12.3	39.4 ± 10.9*	**0.022**
Height (cm)	167.9 ± 6.3	167.0 ± 6.5	**0.343**
Weight (kg)	69.6 ± 10.5	71.3 ± 11.6	**0.194**
Body mass index (kg/m^2)	24.6 ± 3.2	25.7 ± 3.7	**0.353**
Work experience (Mean ± SD)			
Working years	12.2 ± 11.1	15.0 ± 9.9	**0.065**
Work days per week	5.3 ± 0.4	5.4 ± 0.3	**0.115**
Work hours per day	8.5 ± 1.8	9.1 ± 2.5*	**0.043**
Cooking hours at work per day	0.0 ± 0.0	4.1± 2.3	—
Main cooking methods at work (N (%)$^{\#}$)			
Deep fry	0 (0.0%)	97 (56.7%)	—
Stir fry	0 (0.0%)	120 (70.2%)	—
Grill	0 (0.0%)	73 (42.7%)	—
Steam	0 (0.0%)	95 (55.36)	—
tew	0 (0.0%)	95 (55.36)	—
Health behavior (N (%)$^{\#}$)			
Cooking at home (≥ 4 days per week)	4 (6.6 %)	34 (36.6%)†	**<0.001**
Secondhand smoke exposure (≥ 4 days per week)	24 (38.7%)	74 (43.3%)	**0.263**

SD: standard deviation
* Kitchen staff differ significantly from service staff at *p* <0.05 by Student t test.
Kitchen staff differ significantly from service staff at *p* <0.001 by Chi-Square test.
$^{\#}$ (N (%) represents the percentage for the main cooking methods at work or health behavior among service staff or kitchen staff.

Table 2 Comparisons of particulate PAHs levels (median(IQR)) between kitchens and dining areas in 19 Chinese restaurants

PAHs	Dining areas (n=76)	Kitchens (n=76)	***P***
Pyrene (ng/m^3)	**0.3 (0.8)**	**3.5 (4.7)***	**<0.001**
Benzo(k)fluroranhene (ng/m^3)	**0.3 (0.6)**	**1.8 (1.9)***	**<0.001**
Benzo(a)pyrene (ng/m^3)	**1.1 (1.2)**	**5.9 (11.9)***	**<0.001**
Benzo(ghi)perylene (ng/m^3)	**0.8 (1.3)**	**5.6 (7.7)***	**<0.001**
Dibenzo(a,e)pyrene (ng/m^3)	**1.9 (2.2)**	**8.9 (13.8)***	**<0.001**
Summed PAHs a (ng/m^3)	**4.6 (5.3)**	**24.7 (26.7)***	**<0.001**

[a] Summed PAHs : Sum of pyrene, benzo(k)fluroranhene, benzo(a)pyrene, benzo(ghi)perylene, and dibenzo(a,e)pyrene
* Kitchen staff differ significantly from service staff at *p* <0.05 by using Mann-Whitney U test.

Table 3 Comparison of urinary MDA and 8-OHdG levels between kitchen and service staff

Marker	Service staff (n=62)	Kitchen staff (n=93)	***P***
MDA (mol/mol creatinine)	**244.2 ± 164.4 (213.9, 194.8)**	**344.2 ± 243.7(303.5, 279.7) ***	**0.003**
1-OHP (mol/mol creatinine)	**2.4 ± 4.3 (0.5, 2.9)**	**6.0 ± 8.0 (2.0, 8.6)***	**0.002**

*** Kitchen staff differ significantly from service staff at *p* <0.05 by Student t test.**

Table 4 lists the results of multiple linear regression models for urinary 1-OHP and MDA in non-smoking restaurant workers. Work in kitchen was found to be a significant and positive predictor of urinary 1-OHP levels, after adjusting for other covariates (r=0.335, *p*=0.033). Kitchen staff urinary 1-OHP levels were increased compared to service staff. Work years, work days per week, and work hours per day were all marginally significant predictors of urinary 1-OHP ($0.05<p<0.1$). Cooking at home, secondhand smoke, age, and BMI were not significant predictors of urinary 1-OHP levels for restaurant workers. Table 4 also lists predictors of urinary MDA levels for restaurant workers based on multiple linear regression analyses. This study found urinary excretion of 1-OHP and work hours per day to be main predictors of MDA in urine for all workers, after controlling other covariates (r=0.453, *p*<0.001). An increase in urinary 1-OHP was associated with an increase in urinary MDA (*p*<0.001). A 10-fold increase in urinary 1-OHP was associated with a 1.16-fold increase in urinary MDA ($10^{([0.065]*\log10[10])}$ = 1.91). Meanwhile, an increase in work hours per day was associated with an increase in urinary MDA (*p*<0.05). Work in kitchens, work years, work days per week, cooking at home, secondhand smoke, age, and BMI were not significant predictors of urinary MDA (*p*>0.1).

Table 4 Multiple linear regression analysis: Predictors of urinary 1-hydroxypyrene (1-OHP) and malondialdehyde (MDA) levels in 155 non-smoking restaurant workers

	Log_{10} 1-OHP (μmol/mol creatinine)	Log10 MDA (μmol/mol creatinine)
Predictors	Regression coefficient (95% Confidence interval)	Regression coefficient (95% Confidence interval)
Work in kitchens (kitchen vs. service staff)	0.494 (0.160 to 0.827)*	0.090 (-0.022 to 0.203)
Cooking at home (Yes vs. no)	0.34 (-0.238 to 0.507)	0.034 (-0.087 to 0.156)
Secondhand smoke exposure (Yes vs. no)	0.185 (-0.128 to 0.497)	0.082 (-0.020 to 0.185)
Work years (years)	0.016 (-0.002 to 0.034)	0.003 (-0.001 to 0.009)
Work days per week (days)	0.484 (-0.003 to 0.971)	0.005 (-0.157 to 0.166)
Work hours per day (hours)	0.068 (-0.003 to 0.138)	0.025 (0.001 to 0.048)*
Age (years)	-0.002 (-0.019 to 0.015)	<0.001 (-0.006 to 0.005)
BMI (kg/m^2)	-0.007 (-0.053 to 0.039)	<0.001 (-0.016 to 0.014)
Log_{10} 1-OHP (μmol/mol creatinine)	−	0.065 (0.032 to 0.111)**

* $p < 0.05$
** $p < 0.001$

DISCUSSION

Particulate PAH levels in Chinese restaurants demonstrated that kitchen staff being a high exposure group and service staff being a low exposure grouping terms of COF exposure. Since restaurant workers did not wear respiratory protection devices while working they were faced high risk of PAH exposure from COFs. Although the average levels of BaP in air of kitchens were both below permissible exposure limit of US Occupational Safety and Health Administration (OSHA) Standards: 0.2 mg/m^3 [27]. Epidemiologic studies indicate an increase in incidence of cancer among workers exposed to PAHs, even when the exposure of BaP was below 0.2 mg/m^3 [28-29].

This study used urinary MDA as a biomarker of oxidative stress, and used urinary 1-OHP and work experience as indicators of COFs exposure to assess the influence of COFs on oxidative stress in Chinese restaurant workers. The linear multiple regression models were only analyze the non-smokers owing to the strong effects of cigarette smoking on PAHs uptake. Notably, cigarette smoking influences urinary 1-OHP levels in restaurant workers. Cooking at home is not a significant predictor of urinary 1-OHP levels. Cooking methods frequently used in restaurant kitchens included deep frying, stir frying and grilling, all of which generate significant quantities of COFs [8,30]. In contrast, the main cooking methods used at home by restaurant workers were steaming and stewing, neither of which generate significant amounts of COFs. The reason why these restaurant workers do no deep fry, stir fry or grill foods at home may be that they realize the hazards of COFs as a result of having attended government training programs, and thus use little or no. On the other hand, home cooking for a few minutes versus work cooking for hours may be the other reason that home cooking is not a significant predictor for COFs exposure. The likelihood of secondhand smoke exposure at work is small, because all 19 of the surveyed restaurants were designate as non-smoking areas, including both the kitchen and dining areas. Restaurant workers who smoked thus usually did so outdoors or in designated smoking areas. Secondhand smoke exposure did not significantly influence urinary 1-OHP levels because our definition tended to overestimate workers' secondhand smoke exposure. This finding agrees with a previous study on urinary 1-OHP of police officers [31].

This study also found, using MDA as an indicator, that oxidative stress in restaurant workers is positively associated with urinary 1-OHP levels and work hours per day. Urinary 1-OHP thus was a good exposure biomarker for urinary MDA or oxidative stress.

One limitation of this study was the lack of PAHs exposure data for non-occupational settings, such as from vehicle traffic emissions. However, the restaurant workers spent more than 10 hours in the restaurants each day, including work and rest periods, compared to less than 1 hour in traffic daily. The contribution of traffic sources to the PAHs exposure of restaurant workers is believed to be limited. The lack of information regarding individual susceptibility to COFs exposure in our subjects is another limitation of this study. However, we believe that the lack of such personal data will create information bias in our work. Regardless of this limitation, this study concluded that 1-OHP was a good predictor of urinary MDA in male workers in Chinese restaurants.

CONCLUSION

IThe study findings indicate that urinary 1-OHP and MDA reflect occupational PAHs from COFs and oxidative stress in male workers in Chinese restaurants.

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