Respiratory health and lung function in Chinese restaurant kitchen workers

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Abstract

Objectives To measure air pollutant concentrations in Chinese restaurant kitchens using different stove types and assess their influence on workers' respiratory health.

Methods 393 kitchen workers from 53 Chinese restaurants were surveyed over 16 months: 115 workers from 21 restaurants using only electric stoves and 278 workers from 32 restaurants using only gas stoves. Workers were interviewed about their respiratory symptoms and had their lung function tested. Concentrations of nitric oxide (NO), nitrogen dioxide (NO2), carbon monoxide (CO), carbon dioxide (CO2), methane (CH4), non-methane hydrocarbons (NMHC), total volatile organic compounds (TVOC) and fine particulate matter (PM2.5) were measured using portable monitors and air-bag sampling. Temperature and noise levels were assessed.

Results Median concentrations of NO, NO2 and CO were 7.4, 1.5 and 1.6 times higher in gas-fuelled kitchens than in electric ones and average concentrations of PM2.5 and TVOC were 81% and 78% higher, respectively. Differences were smaller for CH4 and NMHC. Electricity-run kitchens were 4.5 dBA less noisy than gas-fuelled ones. Workers using electric cookers had significantly better lung function than their gas-using counterparts and their mean FEV1 and FVC values were 5.4% and 3.8% higher, respectively, after adjustment for confounders. Wheeze, phlegm, cough and sore throat were more prevalent in workers using gas. The adjusted OR for having phlegm regularly was significantly higher.

Conclusions The poorer lung function and higher prevalence of respiratory symptoms among workers in gas-fuelled kitchens compared to those in electricity-powered kitchens may be associated with exposure to higher concentrations of toxic air pollutants generated during gas cooking.

Introduction

The relationship between indoor air pollution and health has received increasing attention over the past few decades, especially since most people live and work in indoor environments for at least 90% of their time. Cooking is an important source of pollutants in indoor air.1

Chinese cooking often involves stir-frying, whereby meat, vegetables and other ingredients are cooked together in a wok heated to high temperatures.2 Considerable amounts of cooking oils—such as peanut, canola and palm oils—are often used.3-5 This method of food preparation generates cooking fumes, which are a complex mixture of organic aerosols. Their constituents mainly include fatty acids, n-alkanes and polycyclic aromatic hydrocarbons (PAHs)—often associated with cooking meat—as well as specific compounds such as laevoglucosan, β-sitosterol and nonanal, which form a chemical profile characteristic of Chinese cooking. Organic chemicals have been shown to make up around 5–20% of the particulate matter with an aerodynamic diameter of less than 2.5 μm (PM2.5) produced during cooking.6-7

In Hong Kong, Chinese restaurants traditionally cook with a gas flame.2 The use of gas rings allows the chef to attain and control high cooking temperatures, use a round-bottomed wok, and toss ingredients while stir-frying. However, it is now known that besides the aforementioned cooking fumes, gas cooking generates particulates, nitrogen oxides, carbon dioxide (CO2), sulphur dioxide and volatile organic compounds.8-9 Most of these chemicals are hazardous to health.4,8,10-11 In poorly ventilated kitchens, carbon monoxide (CO) is also formed; this highly toxic gas deactivates haemoglobin in the blood, and poses a severe health threat as it accumulates. Furthermore, workers in gas-fuelled kitchens are exposed to high levels of noise and heat from the use of the gas stove. The excess heat produced from the open flame of a gas cooker poses a greater risk of burns.

Flat electric hot plates, previously the only alternative to gas stoves, are unable to achieve the high temperatures preferred in Chinese cooking, and are not usually suitable for this cooking style. They are thus rarely used in Chinese restaurants.
restaurant kitchens. In recent years, electric cooking appliances that utilise magnetic induction principles have become popular, as they can attain temperatures similar to those produced by gas cookers. Other claimed advantages of these induction cookers include their higher energy efficiency and quieter operation, together with reduced nitrogen dioxide emissions and lower thermal load on the environment. Our study aimed to compare the environmental and health impacts of this newer technology with the traditional methods.

Many epidemiological studies on the effect of gas cooking on health have been reported. However, these studies generally targeted domestic cooking and its impact on children or housewives, rather than commercial cooking and kitchen workers. In Hong Kong, the air quality in restaurant dining areas has been assessed, but not its impact on the health of restaurant workers. There are also a few studies on the respiratory health of kitchen workers, but none for those in Chinese restaurants, where the type of cooking fumes might be substantially different from those in Western style restaurants.

In this study, we assessed the lung function of workers in Chinese restaurant kitchens that use either gas or electric induction stoves, and the prevalence of respiratory symptoms in the two groups. We also compared the concentrations of air pollutants emitted from the cooking processes and assessed the thermal environment and noise levels in these kitchens.

**Methods**

The kitchens of 53 Chinese restaurants, covering most of the districts in Hong Kong, were surveyed. Of these, 21 kitchens used electric induction stoves and 32 used conventional gas stoves. These restaurants, selected by purposive sampling, included many major establishments. Their kitchens were similar in layout, workflow and the types of food cooked. Most kitchens had four to five stoves, while the number of stoves in use at the time of measurement ranged from one to five, depending on customer demand.

**Subject characteristics**

We surveyed 395 kitchen workers, all of whom were ethnic Chinese, in the selected restaurants. Of these, 278 (70.7%) were recruited from kitchens using gas and 115 (29.3%) from kitchens using electricity. An adaptation of the American Thoracic Society (ATS) questionnaire (1978 version) was administered to the workers by a team of trained interviewers. The following information was sought: personal data (including age and gender), amount of time spent before the stove, history of cigarette smoking and exposure to environmental tobacco smoke, and prevalence of respiratory symptoms. The workers’ body heights were recorded. Two lung function parameters—forced expiratory volume in 1 s (FEV1) and forced vital capacity (FVC)—were measured by trained researchers using a portable mechanical volumetric spirometer (Model 2160; Vitalograph, Ennis, Ireland), which produced hard-copy charts of lung function tests. The correct method for performing open-circuit spirometry was first demonstrated to all subjects before the test. At least three tests of acceptable quality were carried out for each subject. Subjects whose performance did not meet test criteria were asked to repeat the test until they produced satisfactory tracings, from which results were manually read. Our procedures were in accordance with the ATS guidelines.

The tests and interviews were conducted during the workers’ breaks from 14:00 to 16:00 h, following the peak cooking activities between 12:00 and 14:00 h.

**Environmental measurements**

Air sampling was carried out in the kitchens over the entire lunchtime period, beginning shortly before cooking activities started and ending after 1–1.5 h. The following gases were assessed: CO, CO2, nitric oxide (NO), nitrogen dioxide (NO2), PM2.5, methane (CH4), non-methane hydrocarbons (NMHC) and total volatile organic compounds (TVOC).

The air sampling equipment was placed within 1 m behind the chef working at the stove, at a height of about 1 m off the ground. The following portable gas samplers were used: Dust-Trak Model 8520 (TSI, St. Paul, Minnesota, USA) for PM2.5, Model PGM-7240 (RAE Systems, San Jose, California, USA) for TVOC, and O2 Monitor Model 8554 (TSI) for the continuous monitoring of CO, CO2, temperature and humidity. The concentrations of CO2, PM2.5 and TVOC were measured continuously for 1 h, at baseline levels and during lunchtime cooking processes, which in most cases involved stir-frying.

Air samples were also collected for 10 min in air bags within 1 m from the stove, near the breathing zone of the chef, while the latter used the wok for stir-frying or deep-frying. The aim was to capture pollutant concentrations during peak cooking activity, when workers’ exposure would be maximal. The grab samples were used for the chemical analysis of CO, NO, NO2, CH4 and NMHC. Analyses were performed as follows: (i) CO was measured by non-dispersive infrared absorption spectrometry; (ii) NO and NO2 were measured by chemiluminescence; (iii) CH4 and NMHC were measured by flame ionisation techniques; and (iv) TVOC was measured by photo-ionisation methods.

The wet bulb globe temperature (WBGT), an index of thermal stress, was measured on-site with a portable heat stress monitor (Model HS-S700; Metrosronics, Oconomowoc, Wisconsin, USA). Noise levels were measured with a sound level meter (Model NL-14; RION, Tokyo, Japan). Both meters were placed within 1 m behind the chef at the stove. The measurements primarily reflected the noise generated by cooking. Other noisy activities, such as manual dishwashing, were usually done about 5–6 m away from the measurement site. Values were expressed as equivalent A-weighted sound pressure levels (LWA).

Sound measurements were taken over varying time periods, depending on the length of time available for sampling. This ranged from around 15 min to more than 1 h. However, only three measurements were as short as 15 min and most were 1 h or more.

**Statistical methods**

Parameters measured in the environmental survey were expressed for each kitchen type by their mean values and standard deviations (SDs) for symmetrically distributed variables, or by median values and quartiles for those asymmetrically distributed. Comparisons of the mean or median values of the air pollutant concentrations, WBGT and noise levels were made using either an independent samples t test, or a non-parametric Mann–Whitney U test, respectively. Comparisons of lung function parameters were made using analyses of covariance (ANCOVA), adjusting for age, gender, height and exposure to cigarette smoke as confounders. The mean FVC and FEV1 were adjusted by equalising the value of each confounder between workers in the two groups. ORs for respiratory symptoms were obtained using binary logistic regression models, and were adjusted in the same manner for age, gender, height, cigarette smoking, exposure to second-hand smoke and exposure to the stove. Statistical analyses were performed using SPSS 15.0 for Windows.
RESULTS

Environmental assessment in the kitchens

The median or mean concentrations of all eight air pollutants were substantially higher in kitchens using gas-fuelled stoves than in those using electric induction cookers. In kitchens using gas, the median concentrations of PM_{2.5}, CO, NO, NO_{2}, TVOC and CH_{4} were 0.281 mg/m^{3}, 1.66 ppm, 86.2 ppb, 40.2 ppb, 402 ppb and 2.88 ppm, respectively. In kitchens using electricity, the corresponding values were 0.155 mg/m^{3}, 1.04 ppm, 11.6 ppb, 26.2 ppb, 226 ppb and 2.58 ppm, respectively. The differences in concentrations between gas- and electricity-run kitchens were highly significant (p<0.001) for all of these pollutants, except for PM_{2.5} (p=0.172) and TVOC (p=0.056), with the latter showing borderline significance.

The mean concentrations of CO_{2} and NMHC were 768 ppm and 0.754 ppm, respectively, in gas-using kitchens, while their corresponding values in electric kitchens were 596 ppm and 0.682 ppm. When compared, the concentration differences were significant for CO_{2} (p=0.005) but not for NMHC (p=0.425).

Figure 1 shows the average concentrations in the two types of Chinese restaurant kitchen of the four air pollutants thought to have the greatest health impact.

The median concentration of CO was 60% higher in kitchens using gas than in those running on electricity. Similarly, the median NO and NO_{2} concentrations in gas-fuelled kitchens were 7.4 times and 1.5 times higher, respectively, than in those using electricity. Both PM_{2.5} and TVOC, which could originate from gas fuel or cooking fumes, were 81% and 78% higher, respectively, in gas-burning kitchens than those using electricity. Median concentrations of CH_{4} and mean concentrations of NMHC were about 12% and 11% higher, respectively, while the mean concentration of CO_{2} was 29% higher in gas-burning kitchens than in electric kitchens. Box 1 shows reference exposure units for comparison.

Figure 1 also shows the mean temperature and noise level in each type of restaurant kitchen. Those using electricity had a significantly cooler and quieter environment compared to gas kitchens (p<0.001 for both parameters); the mean WBGT was 22.5°C and 26.8°C, respectively, while the sound levels were 79.8 dBA and 88.8 dBA, respectively. When data from the three kitchens where noise was measured for only 15 min were excluded, the mean sound levels were very similar with levels being 79.9 dBA in electric kitchens and 88.9 dBA in gas-fuelled kitchens.

Characteristics of the subjects

Overall, 393 kitchen workers were interviewed, comprising 115 staff from restaurants using electric stoves and 278 from those using gas cookers. A total of 283 workers (72%) spent some of their working time at the stove (ranging from 0.25 h to more than 10 h) and were defined as ‘stove-exposed’. The remaining 110 workers, who reported that they did not spend any time before the stove, were classified as ‘not stove-exposed’.

Table 1 summarises the kitchen workers’ demographic data, including their age, height and gender. Also displayed are their exposures to restaurant stoves and cigarette smoke. Most of the workers were male, with an average age of about 40 years.
Nearly half of them were smokers. The characteristics of the workers were fairly similar between the two groups. Out of all 393 workers, 44.3% were cooks and barbecuers, who were responsible for most of the cooking and meat-roasting, respectively. They were the most likely to be exposed to cooking fumes, with 97.1% of workers in this group reported as stove-exposed. Other workers included dim-sum makers (23.9%), of whom 80.9% were stove-exposed; food preparers (18.6%), primarily in charge of cutting and chopping raw food, of whom 39.7% were stove-exposed; and other kitchen staff (13.2%), including cleaners, dishwashers, runners and handymen, of whom just 17.3% were stove-exposed. Exposure to the stove and hence to cooking fumes was much higher for workers responsible for cooking and food preparation than for auxiliary staff.

Lung function of the subjects

Table 2 details the mean FVC and FEV₁ of the two types of kitchen workers stratified by stove exposure. The cooks, barbecuers and dim-sum makers jointly comprised 86.6% of the stove-exposed workers. After adjusting for age, gender, body height and cigarette smoking, the FEV₁ of workers in electricity-run kitchens was significantly higher than that of workers in gas-fuelled kitchens, while FVC was only marginally higher in the former group. The differences in FEV₁ and FVC between the two kitchen types were larger and statistically significant among stove-exposed workers, but were smaller and insignificant among the non-exposed workers.

Irrespective of stove exposure, we also compared the adjusted mean FEV₁ and FVC of all workers by their job titles, and found a consistent pattern of better lung function among workers in kitchens using electricity than among those in gas-fuelled kitchens. However, the differences did not reach statistical significance except in the group consisting of cleaners, dishwashers, runners and handymen combined.

The adjusted lung functions of the stove-exposed workers were uniformly higher than those of the non-exposed workers, by about 0.4 litres for FEV₁ and up to 0.5 litres for FVC in both kitchen groups. To determine whether the differences were caused by an uneven distribution of gender, we compared the lung functions of only the male workers. As before, the lung functions of stove-exposed workers in gas-fuelled kitchens were significantly worse than those in electric kitchens, while for the non-exposed group, the differences were not significant. For male workers of both kitchen types, the stove-exposed workers still showed better lung function than their non-exposed counterparts, but the differences were much smaller, by about 0.1–0.2 litres for FEV₁ and FVC in both kitchen groups.

Table 1 Characteristics of kitchen workers by fuel use

<table>
<thead>
<tr>
<th>Worker characteristics</th>
<th>Kitchens using electricity (n = 115)</th>
<th>Kitchens using gas (n = 278)</th>
<th>Crude p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>41.4 (11.1)</td>
<td>39.6 (11.0)</td>
<td>0.144</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.8 (7.4)</td>
<td>167.8 (8.0)</td>
<td>0.191</td>
</tr>
<tr>
<td>No. of male workers</td>
<td>99 (86.1%)</td>
<td>245 (88.1%)</td>
<td>0.577</td>
</tr>
<tr>
<td>Stove exposure</td>
<td>82 (71.3%)</td>
<td>201 (72.3%)</td>
<td>0.841</td>
</tr>
<tr>
<td>First-hand smoke exposure</td>
<td>0.851</td>
<td>0.835</td>
<td></td>
</tr>
<tr>
<td>Non-smoker</td>
<td>44 (38.3%)</td>
<td>108 (38.8%)</td>
<td></td>
</tr>
<tr>
<td>Ex-smoker</td>
<td>16 (12.9%)</td>
<td>33 (11.9%)</td>
<td></td>
</tr>
<tr>
<td>Current smoker</td>
<td>54 (47.0%)</td>
<td>135 (48.6%)</td>
<td></td>
</tr>
<tr>
<td>Second-hand smoke exposure</td>
<td>22 (19.1%)</td>
<td>71 (25.7%)</td>
<td>0.049</td>
</tr>
</tbody>
</table>

Numbers in parentheses denote standard deviations or percentages. The Student t test was used for continuous variables, and the \( \chi^2 \) test was used for categorical variables.

Prevalence and risk factors for respiratory symptoms

The crude prevalence of most respiratory symptoms was higher among workers in gas kitchens than in electric kitchens (table 3). Using workers in electricity-run kitchens as the reference group, the adjusted ORs for workers in gas-fuelled kitchens were higher than unity for the following symptoms: cough, phlegm, wheeze, eye pain, runny nose and sore throat. However, the differences were not statistically significant, except for having regular phlegm (OR 2.70, 95% CI 1.01 to 7.23).

When the symptoms were analysed by risk factor, phlegm in the past month was significantly associated with the stove-exposed workers (OR 2.98, 95% CI 1.12 to 7.70) and current smokers (OR 4.10, 95% CI 1.69 to 9.95). For the other symptoms, the ORs for stove exposure were above unity (except for watery eyes and frequent wheezing), ranging from 1.50 to 2.94, but these were statistically insignificant. The significant risk factors were current smoking for cough in the past month (OR 2.80), and passive smoking for frequent wheezing (OR 5.75).

DISCUSSION

Gas cooking has been shown to be associated with a decrease in lung function and a higher prevalence of respiratory symptoms, often following a dose-response relationship. However, previous studies tended to focus on the domestic use of gas stoves, even though household exposure is probably much lower than occupational exposure in terms of frequency and concentration. Our paper is unique in examining the effects of using not only gas stoves but also electric magnetic induction cookers, on the respiratory health of kitchen staff in Chinese restaurants.

In this study, we assessed the kitchen environment of 53 Chinese restaurants around Hong Kong. We measured the concentrations of eight air pollutants—most of which, apart from CO₂ and CH₄, are toxic to humans by inhalation—as well as heat and noise levels. We also administered questionnaires to 593 kitchen workers from these restaurants, and performed lung function tests on them following the luncheon peak in cooking activity.

The levels of all eight air pollutants were higher in kitchens using gas stoves than in those with electric induction cookers.
The median concentrations of the toxic air pollutants CO, NO, NO\textsubscript{2}, PM\textsubscript{2.5} and TVOC were 60–700\% higher in gas-fuelled kitchens than in electricity-run kitchens. This finding agrees with our expectations, since most of these pollutants are by-products generated by fuel combustion, although some are also produced in the cooking process itself. For CH\textsubscript{4}, NMHC and CO\textsubscript{2}, the median or mean concentrations in gas kitchens were also higher by 11–29\%. Studies elsewhere, such as in the USA and Germany, have cited cooking on gas stoves as a source of indoor air pollutants, particularly NO\textsubscript{2}.\textsuperscript{18,19} The fine particulate matter, containing a mixture of non-volatile and semi-volatile organic compounds, is often produced by the processes of burning and frying. It is harmful to health, and contributes to respiratory and cardiovascular diseases.\textsuperscript{19,20} The median PM\textsubscript{2.5} concentration was much higher in kitchens using gas than in those using electricity. This agreed with laboratory-based experiments that measured particulate concentrations generated while using gas and electric cookers.\textsuperscript{1}

Total volatile organic compounds are products of cooking and are formed in all kitchens, regardless of fuel type. The concentrations of TVOC were higher in gas-fuelled kitchens than in electric kitchens, probably due to the presence of an open flame. Many compounds in this group are irritants or even carcinogens.\textsuperscript{21,22} CH\textsubscript{4}, NMHC and CO are ingredients of the gas fuel used in Hong Kong, and their presence in gas stoves as a source of gaseous hydrocarbons in electric kitchens would represent background levels.

In kitchens that used gas, noise was generated during cooking by the air blower used to supply more oxygen to the burner. The mean noise level of 88.3 dbA was 9 dbA higher than that found in kitchens using electricity, implying an almost eightfold increase in sound intensity. Although this average level was greater than the NIOSH REL (85 dbA), owing to the periodic nature of cooking activity in restaurant kitchens, the time-weighted average (TWA) of the L\textsubscript{eq} may not necessarily exceed the limit when measured over an 8 h interval. Nevertheless, even if the noise thus generated did not damage hearing, it could still have given rise to psychological stress among kitchen workers. As noise measurements were taken about 1 m away from the chefs doing the cooking, their exposure might have been underestimated.

Temperatures were much higher in gas kitchens than in electric ones. As WBGT is a measure of overall thermal stress, taking radiant heat and humidity into account, the mean WBGT in gas-fuelled kitchens was more likely to induce heat stress among workers.\textsuperscript{23} Overall, the working environment in kitchens using induction cookers was more comfortable, and possibly safer, than in kitchens with gas stoves.

Despite the observed differences between the air pollutant levels in the two types of kitchen, most of these concentrations were much lower than the recommended occupational exposure levels, and probably contributed little to the prevalence of the workers’ respiratory symptoms only the temperature and noise levels approached the exposure levels considered to cause harm or discomfort to workers. The concentration of PM\textsubscript{2.5} appeared high, however, when compared to environmental exposure standards. For 24 h concentrations of PM\textsubscript{2.5}, the WHO set its 2005 air quality guideline (AQG) at 20 \textmu g/m\textsuperscript{3}, which is much lower than our measured concentrations of 0.155 and 0.281 mg/m\textsuperscript{3} (or 155 and 281 \textmu g/m\textsuperscript{3}) for electric and gas kitchens, respectively.

Although PM\textsubscript{2.5} has been implicated in many adverse health outcomes, we do not know to what extent the other gaseous pollutants may have affected the health of the workers in our study. As with most epidemiological studies on air pollution, the effects on health of individual pollutants cannot be readily separated. Rather, different combinations of air pollutants were probably responsible for the observed differences in health outcomes. Since the pollutant levels were much lower than their recommended limits, particularly for pollutants such as NO and NO\textsubscript{2}, the clinical effects of exposure are uncertain.

In the health survey, both the crude and adjusted lung function parameters (FEV\textsubscript{1} and FVC) were better among those working in kitchens using electricity compared to those in gas-fuelled kitchens. This finding agreed with other studies, some of

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**Table 2 Lung function in kitchen workers by fuel use and stove exposure**

<table>
<thead>
<tr>
<th>Stove exposure</th>
<th>Lung function parameter</th>
<th>Kitchens using electricity, E (n=115)</th>
<th>Kitchens using gas, G (n=278)</th>
<th>Percentage difference (%)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes (n=283)</td>
<td>FVC</td>
<td>3.40 (0.06)</td>
<td>3.25 (0.04)</td>
<td>4.62</td>
<td>0.038</td>
</tr>
<tr>
<td></td>
<td>FEV\textsubscript{1}</td>
<td>2.85 (0.05)</td>
<td>2.70 (0.04)</td>
<td>5.56</td>
<td>0.017</td>
</tr>
<tr>
<td>No (n=110)</td>
<td>FVC</td>
<td>2.99 (0.10)</td>
<td>2.89 (0.07)</td>
<td>1.74</td>
<td>0.890</td>
</tr>
<tr>
<td></td>
<td>FEV\textsubscript{1}</td>
<td>2.44 (0.09)</td>
<td>2.33 (0.07)</td>
<td>4.72</td>
<td>0.364</td>
</tr>
<tr>
<td>Both groups (n=393)</td>
<td>FVC</td>
<td>3.27 (0.05)</td>
<td>3.15 (0.03)</td>
<td>3.81</td>
<td>0.050</td>
</tr>
<tr>
<td></td>
<td>FEV\textsubscript{1}</td>
<td>2.74 (0.05)</td>
<td>2.60 (0.03)</td>
<td>5.38</td>
<td>0.017</td>
</tr>
</tbody>
</table>

Analysis of covariance was used, adjusting for age, gender, height, the smoking habits of the workers and their family members, and, for stove-exposed and non-exposed groups combined, stove exposure. Numbers in parentheses denote standard errors.

FEV\textsubscript{1}, forced expiratory volume in 1 s; FVC, forced vital capacity.

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**Table 3 Prevalence of respiratory symptoms in kitchen workers**

<table>
<thead>
<tr>
<th>Respiratory symptom</th>
<th>Kitchens using electricity (n=115)</th>
<th>Kitchens using gas (n=278)</th>
<th>Adjusted* OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough in the past month</td>
<td>11 (9.6%)</td>
<td>31 (11.2%)</td>
<td>1.11 (0.52 to 2.38)</td>
</tr>
<tr>
<td>Regular cough</td>
<td>8 (7.0%)</td>
<td>18 (6.5%)</td>
<td>1.34 (0.54 to 3.36)</td>
</tr>
<tr>
<td>Cough in the morning</td>
<td>5 (4.3%)</td>
<td>16 (5.8%)</td>
<td>1.15 (0.39 to 3.42)</td>
</tr>
<tr>
<td>Phlegm in the past month</td>
<td>14 (12.2%)</td>
<td>43 (15.5%)</td>
<td>1.48 (0.64 to 2.64)</td>
</tr>
<tr>
<td>Regular phlegm</td>
<td>7 (6.1%)</td>
<td>25 (9.0%)</td>
<td>2.70 (1.01 to 7.23)</td>
</tr>
<tr>
<td>Phlegm in the morning</td>
<td>10 (8.7%)</td>
<td>24 (8.6%)</td>
<td>1.10 (0.52 to 2.77)</td>
</tr>
<tr>
<td>Phlegm at other times</td>
<td>8 (7.0%)</td>
<td>23 (8.3%)</td>
<td>1.08 (0.44 to 2.64)</td>
</tr>
<tr>
<td>Wheeze (with cold)</td>
<td>7 (6.1%)</td>
<td>24 (8.6%)</td>
<td>1.46 (0.46 to 2.87)</td>
</tr>
<tr>
<td>Wheeze (without cold)</td>
<td>2 (1.7%)</td>
<td>10 (3.6%)</td>
<td>1.57 (0.31 to 7.91)</td>
</tr>
<tr>
<td>Frequent wheeze</td>
<td>1 (0.9%)</td>
<td>9 (3.2%)</td>
<td>1.34 (0.41 to 28.85)</td>
</tr>
<tr>
<td>Disabled by wheeze</td>
<td>1 (0.9%)</td>
<td>10 (3.6%)</td>
<td>2.59 (0.30 to 22.50)</td>
</tr>
<tr>
<td>Breathlessness while walking up slope</td>
<td>45 (39.1%)</td>
<td>94 (33.8%)</td>
<td>1.24 (0.58 to 2.69)</td>
</tr>
</tbody>
</table>

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*Binary logistic regression was used, adjusting for age, gender, height, the smoking habits of the workers and their family members, and stove exposure.
which have established a dose–response relationship between lung function and cooking with gas, albeit in domestic situations.\textsuperscript{3 12 23} We used the adjusted results in our comparison, since lung function parameters vary with gender, height, age and smoking. The differences were statistically significant. The same trend was mostly consistent, although not necessarily significant, when comparing the gas and electricity groups by the same job types (eg, dim-sum makers). The lack of significance may have been due to the much smaller numbers of subjects found in each job category.

Stove-exposed workers, defined as those who have spent time in front of the stove in the course of their duties, included almost all of the cooks, and most of the dim-sum makers and barbecuers. A smaller but still substantial fraction of food preparers were also classified as stove-exposed, presumably whenever their jobs required them to assist the senior cooks. Other kitchen staff had much lower rates of stove exposure as their work did not require them to be near a stove for long, continuous periods. A comparison of lung function between stove-exposed and non-exposed workers, irrespective of the type of job or kitchen, showed a higher mean FEV\(_1\) and FVC in the former group. This unexpected result could be due to unidentified confounders, such as body weight. Systematic differences between the build of the stove exposed and the non-exposed workers is a possible explanation. The former group consisted mostly of cooks and barbecuers, who tended to be more heavily built than the latter, who were mostly cleaners and handymen. When the data on only male workers were analysed, the difference became much smaller, implying that gender was under-adjusted for in our original model.

A reduced FEV\(_1\) denotes large airway obstruction. This can be induced by short-term exposure to noxious fumes, and may be reversible after the exposure stops. Lung function was measured shortly after the workers completed their shift. The percentage difference in FEV\(_1\) between the gas and electric groups was 5.6% among the stove-exposed workers, which was larger than the 4.6% difference in FVC. This suggested that exposure to pollutants generated by gas stoves produced larger short-term reductions in lung function than did those from electric stoves. The greater disparity in FEV\(_1\) corroborates the fact that FEV\(_1\) is affected by both short- and long-term exposure to air pollutants, whereas FVC is affected mainly by long-term exposure.

With the exception of regular phlegm, there were no statistically significant differences in the prevalence of respiratory symptoms, although these were generally more common in workers in gas-fuelled kitchens. One possible explanation could be that the length of time since kitchens first started using electricity for cooking had been rather short with the median length being only 5 months. Workers in electric kitchens had previously been exposed to traditional gas-fuelled kitchen environments prior to the installation of the induction cookers. This might have accounted for the failure to detect a significant reduction in the prevalence rates of respiratory symptoms. It is also probable that lung function testing is a more sensitive and objective indicator of respiratory health than the reporting of symptoms via questionnaire, which can be influenced by recall bias.

While both active and passive smoking are well-known risk factors for respiratory illnesses, the finding that stove exposure is also a risk factor suggests that air pollutants generated by cooking can indeed contribute to respiratory symptoms in restaurant workers. Similar results have been obtained in studies that investigated wheezing in childhood in conjunction with exposure to NO\(_2\), gas cooking and cigarette smoke.\textsuperscript{11 13 24}

The strength of this research is that it is one of very few studies on the health of Chinese restaurant kitchen workers and their environment. It is also unique in evaluating air pollutants generated by gas cooking and induction cooking in Chinese restaurants. The numbers of subjects and restaurants studied were large, and the health survey was conducted using standard methodology and a validated questionnaire. The occupational hygiene assessment of the kitchen environments was carried out using reliable methods.

Limitations included the use of a convenient sample of restaurants. We note, however, that these restaurants were fairly typical of Chinese restaurants in Hong Kong. Most kitchens were similar in terms of their size, layout, ventilation, methods of cooking and the types of food served. All of the kitchens used local exhaust ventilation hoods over their stoves, and all but one were air-conditioned. Artificial ventilation prevailed over natural ventilation; hence, the effects of outdoor temperatures and exterior windows and doors on our results were probably insignificant.

The number of stoves in operation and the duration of their use varied widely within each restaurant, depending on customer demand. It was therefore impractical for us to determine the number of stove-hours used in each kitchen. Ventilation measurements were not approved by restaurant management since they would have affected the normal operation of the kitchens. As both stove use and ventilation rates affect air pollutant levels, this is the major limitation of our study.

Surveys of gas- and electricity-using kitchens were evenly distributed throughout the hot and cold seasons, over a period of 16 months. Hence, we believe that differences in the prevalence of respiratory symptoms between workers in the two types of kitchen were unlikely to be confounded by season, a factor not included in our analysis.

CONCLUSIONS

This study conclusively demonstrated that air pollutant concentrations in kitchens using electric induction cookers were much lower than in those using gas-fuelled stoves for cooking. In particular, the concentrations of toxic gases, such as CO, NO and NO\(_2\), were much higher in gas-fuelled kitchens compared to those using electricity. Gas-fuelled kitchens were also hotter and noisier than their electricity-run counterparts.

There is little difference in the prevalence of respiratory symptoms, but there are significant reductions in FVC and FEV\(_1\) among the kitchen workers in gas-fuelled kitchens. Our findings suggest that induction cooking improves the work environment of Chinese restaurant kitchens and may be beneficial for the lung function of their workers, particularly those working at the stoves.

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