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BRIEF REPORT

Association Between Household Cooking Fumes Exposure and Lung Cancer Risk; Brief Review and Recommendation

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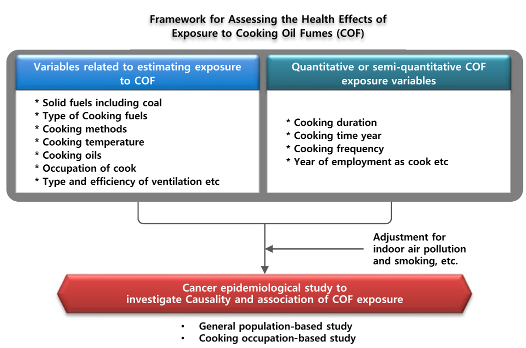
Abstract
This study aims to summarize the main findings of meta-analyses on the association between exposure to cooking fumes CF and lung cancer risk. Meta-analyses of CF exposure and lung cancer risk published up to December 2024 were collected using PubMed and Google. Studies on lung cancer risk among cooks were also included. Study type, country, sample size, exposure surrogates, and main outcomes were summarized. A total of 293 mostly case-control studies, the bulk of which were conducted in China, were pooled into 14 individual meta-analyses. All studies showed that non-use of exhaust ventilation and use of coal for cooking significantly increased the odds ratios for lung cancer, although the odds ratios (ORs) and level of significance varied among CF exposure surrogates. However, no other cooking-related variables, such as cooking method, have shown a consistent association or causal relationship with lung cancer. Future studies should differentiate among CF exposure factors, such as the use of solid fuels, cooking methods and occupational cooking, by frequency and duration to clarify sources of CF exposure, distinguish between household and occupational CF exposure, and assess associations with lung cancer and other health outcomes.

Graphical Abstract



Keywords Cooking fumes (CF) · Frying methods · Lung cancer

1 Introduction

The International Agency for Research on Cancer (IARC) has classified emissions from cooking-related activities using heating fuel such as household solid fuels, high-temperature frying, which are all referred as cooking oil fumes or cooking fumes(hereafter CF), as possibly carcinogenic to humans (Group 2 A) (IARC 2010). This classification is based on evidence that exposure to CF may increase the risk of lung cancer due to the presence of harmful compounds such as polycyclic aromatic hydrocarbons (PAHs) and aldehydes. Many factors related to cooking, including types of cooking fuels, cooking methods, cooking types and cooking environments, vary not only between countries but also within regions inside countries. In this study,

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CF refers to a broad range of fumes, not only those generated from cooking oils but also fumes produced during the cooking process from various ingredients (e.g., vegetables, fish, and meat) and from fuels. In addition, it is difficult to distinguish not only between different sources of CF exposure, but also between household CF and occupation as a cook, which complicates epidemiological studies on the effects of CF exposure on health outcomes, including cancer. The aim of this study is to summarise the results of meta-analyses on the association between household exposure to CF and lung cancer risk and to recommend strategies to improve the understanding of associations and causal relationships with lung cancer.

2 Methods

This brief review follows the PRISMA-ScR guidelines and focuses on meta-analyses and reviews of the association between exposure to CF and lung cancer risk. A literature search of PubMed, EMBASE, and the Cochrane Library was conducted up to December 2024 using the keywords"cooking oil fumes,""meta-analysis,""review,""lung cancer,""household coal use,""household cooking emission,"and"household cooking fume,"individually or in combination. Key findings from all English-language abstracts were included, even if the full article was not published in English. In addition, further publications were identified through an examination of the reference lists of the articles. As our objective was to provide a broad overview rather than a detailed systematic review., we did not conduct an in-depth analysis of overlap among primary studies included in the meta-analyses, A total of 14 meta-analyses and reviews, including three for which only the abstracts were written in English (Zhang et al. 2001; Yao and Shi 2003; Yu et al. 2016), were eventually included and summarized for this study. Relevant data was extracted from the meta-analysis studies using a standardized form, including study characteristics (e.g., study duration, number of studies analyzed, number of subjects combined), variables related to CF exposure surrogates, and effect estimates (e.g., odds ratios, relative risks). The summary of results from epidemiological studies based on general population-based designs, which compare standardized incidence or mortality rates—including lung cancer—across various standard occupational groups (SOCs), including cooking-related occupations, was excluded. In addition, surrogates for COF in this study refer to exposures related to cooking oils, cooking ingredients, cooking fuels, cooking methods, and cooking types, while excluding indoor pollutants such as ETS and heating sources unrelated to cooking.

3 Results

A total of 293 epidemiological studies, mostly case-control, examining exposure to CF and lung cancer risk were combined in the 14 individual meta-analyses. All studies showed that non-use of an extractor and use of coal for cooking significantly increased the odds ratios for lung cancer, although the significance varied among surrogates for CF (Table 1). Certain cooking methods such as stir-frying were partially associated with an increased risk of lung cancer.

4 Discussion

This study found that the use of extractors, coal fuel, and certain cooking methods were significantly associated with lung cancer risk in the general population, mainly from data collected in China. However, no consistent dose-response relationship with household CF exposure was observed (Table 1). For several reasons, it can be challenging to estimate past exposure to surrogates related to CF, to differentiate their health effects, and to adjust for several confounding variables from indoor pollution and individual demographic characteristics that vary among countries and cooking cultures.

Firstly, it is necessary to distinguish not only between multiple CF exposure sources (solid fuels, frying methods etc.), variability in cooking practices and ventilation conditions, but also occupation and indoor pollutants from sources other than household cooking, in order to examine the net effect on health outcomes of either CF or a specific cooking-related variable. Each of these CF exposure sources may contribute to lung cancer risk, making it difficult to isolate the effect of any single factor. (Lee and Gany 2013) There is essentially no evidence on whether CF exposure itself remains a risk factor for lung cancer in populations that do not use solid fuels and apply different cooking methods. The complexity of isolating the effects of different cooking-related factors on lung cancer risk has not been well examined.

Secondly, differences in CF exposure among cooking practices, such as cooking fuels, cooking oil types, foods cooked, cooking methods, cooking temperatures, ventilation level, and more need to be assessed in combination with frequency and duration and other appropriate variables. Cooking methods and practices vary widely from country to country, culture to culture, and even household to household. The frequency and duration of cooking varies as well. For example, many regional cuisines, particularly those that use deep-frying, frying, stir-frying, and

Table 1 Summary of meta-analyses that pooled the results of epidemiologic studies that examined the association between exposure to cooking oil fumes and the risk of lung cancer

Country	Sex of participants	Study subjects	Period	Number of studies pooled	CF exposure estimating variables and significant CF-related variables(marked as *)	Cooking job history	Key findings	Ref.
China/Taiwan/India	Both sex (LCINS)	13 case-control and 3 prospective cohort study	2012–2022	16 (13 case-control, 3 prospective cohorts)	CF, poor ventilation, no fume extractor, coal use	No	Seven case-control studies linked cooking oil fumes to an increased risk of LCINS, with two showing a reduced risk with the use of a cooker hood. Other studies found an increased risk with coal use and lack of kitchen ventilation. Poor ventilation alone (AHR = 1.49) and in combination with coal use (AHR = 2.03) further increased the risk of LCINS in a cohort study	(Bhurosy et al. 2023)
China	NI	NI	1980 to 2020	29	Years cooked (< 2000, 2000–2010 and 2010–2020), level of cooking time-years, Cooking type# (*), Cooking method $ (*).Frequent use of the pan-frying method (*)	No	The ORs for lung cancer risk from CF varied over time, with ventilation reducing the OR to 0.54. Cuisines # involving certain cooking methods had higher ORs, indicating an increased risk of lung cancer	(Zhang et al. 2022)

Table 1 (continued)

Country	Sex of participants	Study subjects	Period	Number of studies pooled	CF exposure estimating variables and significant CF-related variables(marked as *)	Cooking job history	Key findings	Ref.
China	Both sexes	Lung cancer cases (n=9411)		23 observational studies	CF(*), level of ventilation (*), cooking methods: stir frying(*) and deep frying, cooking men	No	Exposure to CF increased the risk of lung cancer in non-smoking women (OR = 1.98) and in partially smoking women (OR = 2.00). For cooking men, the pooled OR was 1.15, showing no significant increase. Poor ventilation (OR = 1.20) and stir-frying (OR = 1.89) were associated with a higher risk of lung cancer, whereas deep-frying was not	(Jia et al. 2018)
China	Both sexes	11,362 cases and 13,953 controls	1990 to 2014	28	Indoor coal use for heating and cooking(*), environmental tobacco smoke(ETS)	No	The OR for the association between indoor coal use for cooking and lung cancer risk was 1.49 (95% CI 1.33–1.67)	(Li et al. 2018)
China	Non-smoking Chinese women	Cases (n=3,5960, control (n=6,082)	1992-2009	3 case-control and 10 hospital-based studies	CF exposure(*), use of kitchen ventilation(*)	No	The pooled ORs for exposure to cooking oil fumes and not using a kitchen fan while cooking were OR 1.74 (95% CI =1.57–1.94) and 2.11 (95% CI =1.54–2.89)	(Xue et al. 2016)

Table 1 (continued)

Country	Sex of participants	Study subjects	Period	Number of studies pooled	CF exposure estimating variables and significant CF-related variables(marked as *)	Cooking job history	Key findings	Ref.
China	Non-smoking Chinese women	Cases (n=11,946), control (n=12,596)	1995 to 2014	24 case-control studies	Kitchen smog while cooking(*), Position of kitchen(*), Frequency of deep frying per week(*)	No	The pooled ORs (95% CI) were as follows: kitchen smog during cooking, 2.21 (1.27–2.96); kitchen location, 1.76 (1.48–2.09); and frequency of frying per week, 2.24 (1.61–3.12)	(Yu et al. 2016)
Immigrants in US; China/Taiwan/ Hong Kong/ Singapore/British Columbia/UK/ Finland/Norway	Both sexes	NI	NI	22 case-control and 7 ecological studies	Job history related to cooking(*), frequent cooking(*), eye irritation during cooking(*),lack of a fume extractor(*), lack of a separated kitchen(*), cooking dish-years(*)	Included in five case-control studies	Two studies found an association between exposure to CF and the risk of lung cancer, In addition, five epidemiologic studies reported an increased risk of oxidative DNA stress and/or lung cancer associated with cooking-related occupations	(Lee and Gany 2013)
Europe/Canada/ New Zealand/ China	Both sexes	13,176 lung cancer cases and 16,129 controls		16 case-control studies	Lifetime work histories, ever worked as a cook or kitchen worker, working hours	Included	Cooking occupations showed an increased risk of lung cancer before adjustment for smoking (OR 1.20), but no association after adjustment (OR 1.01, 95% CI 0.86–1.20). No significant association was found between working hours and lung cancer risk	(Bigert et al. 2015)

Table 1 (continued)

Country	Sex of participants	Study subjects	Period	Number of studies pooled	CF exposure estimating variables and significant CF-related variables(marked as *)	Cooking job history	Key findings	Ref.
China, Hong Kong, Thailand	Both sexes	912 cases; 1,063 controls		6	Coal, charcoal and wood use for heating and cooking(*)	No	Four studies found that the use of coal for heating and cooking was associated with an increased risk of lung cancer (OR 1.64, 95% CI 1.25–2.14)	(Hosgood III et al., 2007)
China	Both sexes	5563 cases and 8484 controls	1995–2004	27 case-control studies (19 in English and 8 in Chinese)	Coal use for heating and cooking(*), Indoor air pollution(*), environmental tobacco smoke(*)	No	For household coal use for heating and cooking, the pooled ORs are 1.83 (95% CI: 0.62–5.41) and 2.66 (1.39–5.07) for women and both sexes, respectively. For indoor coal dust exposure, the OR values are 2.52 (95% CI: 1.94–3.28)	(Zhao et al. 2006)
China	Both sexes	Cases (n= 5,600), controls (n=6,892)	1990 to 2001	41	Ventilation in kitchen(*), coal ever used in life(*),environmental tobacco smoke(*)	No	The pooled ORs were 3.20 for indoor exposure to coal, 2.72 for indoor exposure to CF, 2.13 for poor kitchen ventilation, and 1.50 for ever using coal in life	(Yao and Shi 2003)
China	Non-smoking Chinese women	Case (n=1,115)-control (n=1,520)	1990 to 1999	7 case-control studies	Indoor CF and coal pollution(*)	No	The pooled OR values for indoor CF pollution and coal pollution were 2.52 and 1.42, respectively	(Zhang et al. 2001)

Table 1 (continued)

Country	Sex of participants	Study subjects	Period	Number of studies pooled	CF exposure estimating variables and significant CF-related variables(marked as *)	Cooking job history	Key findings	Ref.
China	Both sexes	NI	1982-1994	9 case-control studies	Frequency of stir-frying, frying, or deep-frying(*), Age started cooking(*), kitchen layout (separation)(*), fume extractors(*), number of meals at home/day, area of window	No	Consistent positive associations between lung cancer risk and a variety of indices of exposure to indoor air pollution from Chinese-style cooking	(Zhong et al. 1999)
Africa, Europe, China and Taiwan	Both sexes	10,142 cases and 13,416 controls	1981-2004	25 case-control studies	The frequency of stir-frying, frying, or deep-frying(*), age started cooking(*), kitchen layout(separation)(*), the use of fume extractors(*)		Household coal use was associated with lung cancer risk among all studies throughout the world [OR = 2.15; 95% CI = 1.612.89, N(studies) = 25], and particularly among those studies carried out in mainland China and Taiwan (OR = 2.27; 95% CI = 1.653.12, N(studies) = 20)	(Hosgood III et al., 2011).
Total				293				

LCINS Lung cancer in never-smokers, *AHR* Adjusted hazard ratio, *CF* Cooking fumes, *OR* Adjusted odds ratio; *CI* confidence intervals, *NI* No Information

[$]Cooking methods; deep-frying, quick-frying, stir-frying and pan-frying

[#]Cooking types: Liao cuisine, Fujian cuisine, Shanghai cuisine, Jingdong cuisine and Shaanxi cuisine had ORs (95% confidence interval) of 1.91 (95 % CI 1.62, 2.25), 2.38 (95 % CI 1.80, 3.16), 1.56 (95 % CI 1.29, 1.89), 2.58(95 % CI 1.63, 4.09) and 1.57 (95 % CI 1.16, 2.11), respectively pan-frying, had higher ORs, indicating that these cooking methods are associated with an increased risk of lung cancer. Stir-frying (OR = 1.89, 95% CI 1.23, 2.90, I2 = 66%) was associated with an increased risk of lung cancer, whereas deep-frying (OR = 1.41, 95% CI 0.87, 2.29, I2 = 5%) was not (Jia et al. 2018).

Thirdly, the distinction between occupational and household CF exposures, which have different exposure and health risk profiles, needs to be evaluated. Few previous epidemiologic studies have compared the effect of specific occupational exposures to CF classified by job characteristics by type of cooking job, on the risk of respiratory health outcomes, including lung cancer. As reviewed in the summary of meta-analysis study results (Table 1), studies did not fully distinguish CF exposure between occupational and household cooking. Evidence is still lacking for groups of cooks with similar cooking styles, beyond simply the general population who are regularly and intermittently exposed to CF. Most studies investigating the cancer risk associated with cooking are based on general population-based designs that compare standardized incidence or mortality rates, including lung cancer, across various SOC (Xu et al. 2024; Jang et al. 2025). However, general population-based studies are limited in their ability to examine the specific occupational risk factors for lung cancer among cooks, such as employment duration, type of cooking job, type of commercial restaurant, and the frequency and intensity of exposure to cooking fumes.

Finally, the causal relationship between CF and health outcomes should be examined based on the retrospective CF exposure assessment method using multiple CF exposure surrogates stratified by frequency and duration. In a study examining the associations of cooking habits and exposure to cooking fumes in 1,302 lung cancer cases and 1,302 matched healthy controls in Taiwan during 2002-2010, a dose-response association between cooking fume exposure and lung cancer was reported (odds ratios of 1, 1.63, 1.67, 2.14, and 3.17 across increasing levels of cooking time-years (Chen et al. 2020)). To investigate the causal relationship between CF and health outcomes, the frequency and duration by cooking year, cooking method, and cooking oil type should be classified and investigated in epidemiologic studies. It also remains challenging to differentiate the individual contributions of various indoor kitchen pollutants—such as COF, ETS, solid fuel use, and other exposures—to lung cancer risk.

The main limitation of this brief communication is the potential for overlap among the 14 meta-analyses, as they are likely to include the same primary studies, although a consistent association was found between cooking coal use, extractor use, and lung cancer risk. No in-depth quantification of the overlap among primary studies included in the identified meta-analyses—which could impact the accuracy and strength of the summarized findings—was conducted. Summarizing the results of multiple meta-analyses is challenging due to overlapping studies, methodological variability and different inclusion criteria, which can lead to redundancy and inconsistencies. The strength of this communication lies in its recommendation to differentiate variables related to CF and to investigate their causal relationship with health outcomes, including lung cancer (see graphical abstract).

In conclusion, future studies should differentiate different types of CF exposure sources, such as cooking fuels, cooking methods and occupational cooking, etc., by frequency and duration in order to clarify sources of CF exposure, distinguish between household and occupational CF exposure, and assess associations with lung cancer and other health outcomes.

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Data Availability Not applicable. Qualitative information used in the manuscript is available in the literature cited.

Declarations

Conflict of Interest All authors have no potential conflicts of interest and meet the criteria for authorship. We fully understand the privilege and responsibility of authorship in scientific publications.

Ethical Approval Not applicable.

Consent to Participate Not applicable.

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