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## Incense use and respiratory tract carcinomas: a prospective cohort study

Jeppe T. Friberg, MD, PhD<sup>1,2</sup>, Jian-Min Yuan, MD, PhD<sup>1</sup>, Renwei Wang, MD, MS<sup>1</sup>, Woon-Puay Koh, MBBS, PhD<sup>3</sup>, Hin-Peng Lee, MBBS<sup>3</sup>, and Mimi C. Yu, PhD<sup>1</sup>

<sup>1</sup> The Cancer Center, University of Minnesota, Minneapolis, 55455 MN, USA

<sup>2</sup> Department of Epidemiology Research, Danish Epidemiology Science Centre, Statens Serum Institute, 2300 Copenhagen, Denmark

<sup>3</sup> Department of Community, Occupational and Family Medicine, Yong Loo Lin School of Medicine, National University of Singapore, 117597 Singapore

### Abstract

**Background**—Incense use is an integral part of daily life in large parts of Asia. The burning of incense is a powerful producer of particulate matter and the smoke contains a multitude of well-characterized carcinogens. However, no convincing association has been reported between the exposure to incense smoke and cancer development. We therefore analyzed the relationship between incense use and the risk of respiratory tract carcinomas in a prospective cohort study.

**Methods**—In 1993-1998 a population-based cohort of 61,320 Singapore Chinese who were free of cancer and aged 45-74 years, completed a comprehensive interview on living conditions, dietary and lifestyle factors. By linkage to population-based registries, the cohort was followed through 2005 and cancer occurrence determined. The relative risk for these cancers associated with incense use was estimated using a Cox proportional hazards model.

**Results**—A total of 325 upper respiratory tract carcinomas (UPT) and 821 lung carcinomas were observed during follow-up. Incense use was associated with a significantly increased risk of UPT carcinomas other than nasopharyngeal, whereas no overall effect was observed on lung cancer. Duration and intensity of incense use were associated with an increased risk of squamous cell carcinomas in the entire respiratory tract ( $p$  for trend=0.004), while there was no significant association between incense use and non-squamous cell carcinomas. The relative risk of squamous cell carcinomas among long-term incense users was 1.8 (95% CI, 1.2-2.6;  $p=0.004$ ) in the entire respiratory tract.

**Conclusion**—The study indicates that long term use of incense is associated with an increased risk of squamous cell carcinoma of the respiratory tract.

### Keywords

Incense; carcinoma; respiratory tract; Chinese

### Introduction

The burning of incense is an integral part of daily life in large parts of Asia, and in addition to use in places of worship, approximately half of populations across South-East Asia burn

incense at home on a daily basis (1-4). The incense used in Asian countries is made of plant material mixed with essential oils, and forms a combustible mixture which releases fragrant smoke upon burning. The burning of incense is a powerful producer of particulate matter (5; 6), and since the late sixties incense smoke has been known to contain a multitude of possible carcinogens, including polyaromatic hydrocarbons (PAHs), carbonyls and benzene (7-11). Consistent with this, incense smoke condensates have been found to have mutagenic and genotoxic activity, and the genotoxicity of certain incense smoke condensates in mammalian cells is higher than that of tobacco smoke condensate (12;13).

Incense smoke has been proposed to be associated with cancer development (7), and reports have linked incense use at home to childhood leukemia and brain tumors (14;15). As inhalation is the route of exposure, the influence of incense smoke on the risk of lung cancer has been investigated in a number of case-control studies. Results from these studies are inconsistent. An increased risk of lung cancer associated with daily use of incense has been reported in some studies (3;16), while others have found no associations (17-19). The possible association of incense use and other respiratory tract cancers have not been investigated.

Incense is sold without a warning label, and given the high prevalence of use and the often involuntary nature of the exposure, clarifying the role of incense smoke as a carcinogen is important from a public health perspective. In this report, we describe the associations between exposure to incense and the whole spectrum of respiratory tract carcinomas in a large prospective cohort of Singapore Chinese.

## Materials and methods

### Participants

In 1993 a population-based cohort study among middle-aged and older ethnic Chinese men and women of the Hokkien or Cantonese dialect group was initiated in Singapore. The main focus of the Singapore Chinese Health Study was on the role of diet and nutrition in cancer aetiology. During 1993-1998 a total of 63,257 individuals aged 45-74 years were enrolled. As 1,937 individuals had a history of cancer prior to enrolment, these individuals were excluded from the analysis. Thus, the final cohort consisted of 61,320 individuals. The study was approved by the Institutional Review Boards of the National University of Singapore and the University of Minnesota.

At recruitment a face-to-face interview was conducted by a trained interviewer using a structured questionnaire to obtain information on demographics, physical activity, use of tobacco and alcohol, menstrual and reproductive histories (for women only), medical history, occupational exposures to inhalants, and use of incense. The questionnaire also included a validated, semiquantitative food frequency section, listing 165 food items (20).

Questions concerning use of incense covered ever use of incense (no, yes), number of years of incense burning (10 years or less, 11-20, 21-30, 31-40, 41+ years), current frequency of burning (never, a few times per year, a few times per month, a few times per week, daily), placement of the main altar (subject's bedroom, other bedroom, living room, dining room, kitchen) and intensity of burning (during the night only, during the day only, intermittently during the day, at all times). In our study population placement of the main altar was predominantly in the living room (91.9%), while placement in the bedroom was very rare (0.4%). Therefore, we considered the level of incense exposure to be 'low' if incense was burned "only during the night" or "intermittently during the day"; incense use "during the day only" or "at all times" were considered to relate to high exposure levels. In Singapore Chinese homes, the common types of incense used are the coils and joss sticks; use of incense ropes, smudge bundles and

powder are negligible. The study questionnaire did not solicit information on the specific types of incense used.

### Identification of cancer patients

In Singapore all individuals are provided with a unique personal identifier, the National Registration Identity Card (NRIC) number. Using the NRIC number, follow-up of the cohort has been achieved via regular linkage of the cohort database with the respective databases at the Singapore Registry of Births and Deaths and the nationwide Singapore Cancer Registry. Since its inception in 1968, the Singapore Cancer Registry has been part of the IARC (International Agency for Research on Cancer) Cancer Incidence in Five Continents serial publications, attesting to its level of completeness and rigor in cancer reporting (21;22). To date, only 17 subjects (0.03%) were lost to follow-up due to migration out of Singapore.

The group of carcinomas of the upper respiratory tract in Southern Chinese constitutes two carcinoma types with different etiology. Nasopharyngeal carcinomas (NPC) are predominantly undifferentiated carcinomas, and major risk factors include Epstein-Barr virus, a genetic predisposition and different types of preserved foods (23). Carcinomas at other sites of the upper respiratory tract are primarily differentiated squamous cell carcinomas, and mainly associated with smoking and alcohol consumption (24). Therefore, we analyzed the two groups of cancers separately. The ICD-O code for NPC was C11 while the other upper respiratory tract cancers included the nasal (C30), sinuses (C31), oropharynx (C01-C06, C09-C10, C12-C14) and laryngeal regions (C32). Lower respiratory tract cancers consisted of lung cancers (C33-C34). We restricted cases to the histologically verified carcinomas defined by ICD-O histology codes 801-872. For patients with multiple primary cancers in the respiratory tract, only his/her earliest cancer was considered during the analysis when multiple cancer sites (e.g., upper respiratory tract carcinomas) were grouped together.

A total of 1,304 respiratory tract cancers were diagnosed in the cohort by the end of follow-up for the present analysis, which is December 31, 2005. Among these cases, 1,191 (91.3%) were diagnosed histologically and their diagnoses were confirmed via manual review of pathology reports by a medically trained research staff. Non-carcinoma cases were excluded and the final analyses included 1,146 cases of histologically verified invasive carcinomas within ICD-O histology codes 801-872.

### Statistical analysis

Person-years of follow-up for each cohort member were counted from the date of interview to the date of cancer diagnosis or death, or December 31, 2005, whichever occurred first. Hazard ratios (HRs) and their corresponding 95% confidence intervals (CIs) of respiratory tract cancers associated with various exposure variables were estimated using Cox proportional hazards regression models that also included following covariates: age at recruitment, year of interview, gender, dialect group (Hokkien, Cantonese), level of education (no formal education, primary school, secondary school or higher), body mass index (<20, 20-24, 24-28, 28+ kg/m<sup>2</sup>), number of cigarettes smoked per day (never, 1-12, 13-22, 23+ cigarettes), years of smoking (never, 1-19, 20-39, 40+ years), time since smoking cessation (never, 20+, 5-19, 1-4, <1 years, current smoker), frequency of alcohol intake (nondrinker/monthly, weekly, daily drinker), dietary intakes of isothiocyanates, beta-cryptoxanthin, lycopene, lutein, summed Chinese-style preserved foods (all in quartiles), and for women, parity (nulliparous, 1-2, 3-4, 5+ livebirths) (23;25;26). We performed statistical testing for linear trend of disease risk with levels of exposure using ordinal scores for 3 or more or 4 levels of incense use. The proportionality

$$\frac{\sum_{i=0}^k (P_i)(OR_{i-1})}{1 + \sum_{i=0}^k (P_i)(OR_{i-1})}$$

assumption was tested and found to be satisfied. We used the formula, described in Rockhill et al. (27) to calculate the population attributable risk (PAR) fraction. This formula allows for the use of multiple levels of the exposure under study in the estimation of the population attributable risk.

Statistical computing was done using SAS version 9.1 (SAS Institute Inc, Cary, NC). All *P* values quoted are two-sided. *P* values less than 0.05 was considered statistically significant.

## Results

A total of 1,146 cases of histologically verified carcinoma of the respiratory tract were observed among the cohort participants by the end of follow-up for the present analysis, i.e. December 31, 2005 (Table 2). They constituted 10 nasal/sinus, 20 tongue, 29 mouth, 12 other oropharynx, 14 hypopharynx, 1 unspecified pharyngeal, 175 nasopharyngeal, 64 laryngeal and 821 lung carcinomas. Most (89%) nasopharyngeal carcinomas were undifferentiated carcinomas, while non-NPC, upper respiratory tract carcinomas were predominantly squamous cell carcinomas (88%). There were more adenocarcinomas (42%) than squamous cell carcinomas (24%) of the lung in Singapore Chinese.

### Incense use

The frequency of current incense use was similar in men (77.5%) and women (76.5%) (Table 1). People at different ages reported similar frequencies of current incense use, but use was more frequent among Hokkien (80.0%) than Cantonese (73.4%) subjects. Frequency of incense use was inversely related to level of education ( $p < 0.001$ ). Ever smokers reported use of incense more frequently (83.5%) than never smokers (75.2%). Among current users, most (92.7%) used it daily or had used it for more than 40 years (83.9%).

Table 3 shows the associations between incense use and risk of three groups of respiratory tract carcinomas. Compared to never users, current use of incense was not associated with an increased risk of NPC or lung carcinoma. In contrast, incense use was associated with an increased risk of carcinoma of the upper respiratory tract other than the nasopharynx. The incense-cancer risk association was dose-dependent, with high risk for long-term ( $P$  for trend = 0.04) and frequent use ( $P$  for trend = 0.02). Compared with non-users, daily users with more than 40 years of incense exposure had a statistically significant 70% increase in risk of non-NPC upper respiratory tract carcinoma (95% CI = 1.0-2.8,  $P = 0.04$ ). Individuals who used incense during the day or 'at all times' had a relative risk of 2.1 (95% CI = 1.1-3.8,  $P = 0.02$ ).

### Incense use and smoking

A dose-dependent, increased risk of non-NPC upper respiratory tract carcinomas was present in both never and ever smokers, but the association was only statistically significant among never smokers ( $P$  for trend = 0.04) (Table 4). Among never smokers, a three-fold increased risk was observed for individuals who used incense during the day or at all times. Incense use was unrelated to risk of NPC or lung carcinoma irrespective of cigarette smoking status.

### Incense use and histological subtypes

Table 5 shows the relationship between incense use and risk of upper and lower respiratory tract carcinomas stratified by histological subtypes. Risk of squamous cell carcinoma of the entire respiratory tract significantly increased with increasing use of incense ( $P$  for trend = 0.004); compared with non users of incense at recruitment, low- and high-intensity users had

hazard ratios of 1.2 (95% CI = 0.9-1.6; P=0.31) and 1.8 (95% CI = 1.2-2.6; P=0.004), respectively. The gender-specific hazard ratios for low- and high-intensity current use of incense were 1.8 (95% CI, 0.7-4.3) and 2.7 (95% CI, 0.9-7.6) in women, and 1.1 (95% CI, 0.8-1.5) and 1.6 (95% CI, 1.0-2.4) in men. The increased risk of squamous cell carcinomas was observed in both the upper (P for trend = 0.049) and lower respiratory tract (P for trend = 0.03). The risk of non-squamous cell carcinomas of the entire and the upper respiratory tract was not influenced by the level of incense use. However, limiting the analysis to lower respiratory tract carcinomas only revealed a trend towards lower risk of non-squamous cell carcinomas associated with increasing incense use.

The frequencies of deep- or stir-fried foods being eaten at home were not associated with the risk of respiratory tract carcinoma in men or women studied either stratified by site or histological type (data not shown). Using the algorithm described earlier, the population attributable risk (PAR) of incense use on squamous cell carcinoma in the whole respiratory tract in the study population was 18%, while the PAR of non-NPC upper respiratory tract carcinomas was 31%.

## Discussion

The present study is the first prospective study addressing use of incense and cancer risk, and the results indicate an association between long-term incense use and development of squamous cell carcinomas of the respiratory tract.

Traditional incense burning produces a considerable amount of smoke, and indoor concentrations of particulate matter during incense burning have been found to far exceed outdoor air quality standards (28). The smoke contains a multitude of harmful constituents, including polycyclic aromatic hydrocarbons (PAHs), benzene and carbonyls, and incense is found to be the major contributor to PAHs in Hong Kong homes (29). While the carcinogenic properties of incense smoke is well-established (7-11), no epidemiological studies have so far succeeded in establishing an association between use of incense and risk of cancer in the respiratory tract. Upper respiratory tract cancers have not been studied, but a number of case-control studies in Chinese populations investigating the effect of incense burning on the risk of lung cancer have produced conflicting results. Some studies found that incense burning was associated with an increased risk of lung cancer in women (3;16;18), while other studies either have reported lack of an overall association or an inverse association between incense burning and adenocarcinoma of the lung (17;19).

We found the influence of incense on the risk of cancer to be dependent on the histological subtype, and that use of incense seemed to increase the risk of squamous cell carcinomas of the respiratory tract in a dose-dependent manner. The influence was most pronounced for carcinomas of the upper respiratory tract, which is consistent with studies showing that particulate matter from incense burning to a large degree deposits in the upper airways (30). Incense use not only seem to add to the increased risk of upper respiratory tract squamous cell carcinoma in smokers, but the considerably increased risk in never smokers points to an independent effect of incense smoke.

Nasopharyngeal carcinoma (NPC) is rare in most populations, but the undifferentiated type is prevalent in areas of South East Asia, North Africa and among Inuit in the Arctic (23). The pathogenesis of NPC differ substantially from that of other pharyngeal carcinomas, and undifferentiated NPC is believed to be the result of environmental factors, among these Epstein-Barr virus and preserved foods, acting on genetically susceptible individuals (31). A single study have found a higher risk of NPC among individuals with a burning alter at home (32), while other studies have found no association between incense exposure and risk of NPC

(33;34). In contrast to the noticeable effect on non-NPC upper respiratory tract carcinomas, use of incense did not influence the risk of NPC in our study. This finding is consistent with the overall evidence based on a large number of studies that undifferentiated NPC is only marginally affected by smoking, and not affected at all by environmental tobacco smoke (23; 35;36).

We also did not observe any influence of incense on the overall risk of lung carcinoma. This may represent a true lack of influence of incense smoke on the risk of lung cancer. However, when stratified by histological subtypes, incense was associated with risk of squamous cell carcinomas of the lung, but not with risk of non-squamous cell carcinomas (majority of them are adenocarcinoma). The association with squamous cell carcinomas of the lung is consistent with the observed association between incense and non-NPC carcinomas in the upper respiratory tract, the majority of which are squamous cell carcinomas. The reason for a possible differential association between incense and histological subtype is unknown. Tobacco-specific nitrosamines have been found to induce mainly adenomas and adenocarcinomas in rodents, whereas polycyclic aromatic hydrocarbons (PAH) such as benzopyrene primarily induce squamous cell carcinoma (37). While incense is known to be a significant contributor of PAH, the amount of nitrosamines in incense smoke needs to be determined.

The risk of squamous cell carcinomas associated with incense use was higher among women compared to men, which is consistent with Chinese women spending more time at home. Exposure to oil vapors from high temperature wok cooking has been postulated to be a risk factor for lung cancer in Chinese women, especially among never smokers (38). We did not specifically ask women about their cooking practices and frequencies of wok frying during the baseline interview. Frequency of consuming deep- or stir-fried foods at home could be viewed as a crude surrogate marker for exposure to cooking fumes in women of our study cohort. We did not observe any association between consumption of deep- or stir-fry foods and risk of respiratory tract cancer by subsite, gender or histological subtype. Coal burning is another indoor air pollutant linked to risk of lung cancer in Chinese (38). This latter exposure is irrelevant in Singapore, a city-state one degree north of the equator.

Environmental tobacco smoke (ETS) has been associated with an increased risk of lung cancer (39), but information on baseline ETS exposure is unavailable in our cohort study. Thus, there is a legitimate concern that ETS may influence our observed incense-cancer associations. We think this is an unlikely scenario, given that ETS has been shown to exert comparable effects on non-squamous cell carcinomas and squamous cell carcinomas of the lung (39). It is interesting to note that incense burning can potentially generate much higher quantities of particulate matter than side-stream cigarette smoke (40).

The importance of incense use as a risk factor for respiratory tract carcinomas extends beyond the Chinese populations. Incense is used on a daily basis in both temples and homes in many non-Chinese, Asian communities, including those in Southeast Asia and the Indian subcontinent. Regular use also has been reported in the West. Among non-Asian, minority women in New York, 28% reported burning incense during pregnancy, which was identified as a significant source of exposure to polyaromatic hydrocarbons in this group (41). The present study suggests that incense use was associated with one-third of upper respiratory tract cancers other than NPC occurring among Singapore Chinese. The cancer burden associated with incense burning may be more significant in other Asian populations with a higher underlying rate of non-NPC pharyngeal cancer, such as Asian Indians whose rate is 3-4 times higher than the Singapore Chinese (21).

One limitation of our study is the relatively low proportion of individuals that had never been exposed to incense. Nonetheless, we were able to observe a dose-dependent, statistically

significant association between incense exposure and upper respiratory tract carcinomas. Another limitation of our study is that we measured subject's use of incense with history of use at baseline only, which could result in misclassification of subjects in term of incense use over lifetime. However, given the prospective nature of the study, such misclassification, if ever occurred, would be more likely to be non-differential, which could lead to attenuating, but rather than creating, the observed positive association between incense use and cancer risk. Moreover, it would be ever more difficult to imagine such misclassification would result in a spurious relation for incense use with squamous cell carcinomas but not with adenocarcinoma.

Despite these limitations, the present study represents the first prospective investigation on incense and cancer risk, and results indicate that incense use is associated with increased risk of squamous cell carcinomas in the respiratory tract, especially in the upper part. This association is consistent with a large number of studies identifying carcinogens in incense smoke, and given the widespread and sometimes involuntary exposure to smoke of burning incense, these findings carry significant public health implications. Besides initiatives to reduce incense smoke exposure, future studies should be undertaken to identify the least harmful types of incense.

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**Table 1**  
**Characteristics of the study population, Singapore Chinese Health Study 1993-2005**

|                            | Use of incense   |                       |
|----------------------------|------------------|-----------------------|
|                            | Current user (%) | Non-current user (%)* |
| <b>Gender</b>              |                  |                       |
| Women                      | 26,037 (76.5)    | 7,991 (23.5)          |
| Men                        | 21,142 (77.5)    | 6,150 (22.5)          |
| <b>Age at interview</b>    |                  |                       |
| 43-49 years                | 11,636 (75.0)    | 3,870 (25.0)          |
| 50-59 years                | 19,026 (77.8)    | 5,415 (22.2)          |
| 60-69 years                | 13,113 (77.6)    | 3,781 (22.4)          |
| 70+ years                  | 3,404 (76.0)     | 1,075 (24.0)          |
| <b>Dialect group</b>       |                  |                       |
| Cantonese                  | 20,797 (73.4)    | 7,528 (26.6)          |
| Hokkien                    | 26,382 (80.0)    | 6,613 (20.0)          |
| <b>Educational level</b>   |                  |                       |
| No formal education        | 14,445 (86.7)    | 2,216 (13.3)          |
| Primary school             | 22,341 (82.1)    | 4,882 (17.9)          |
| Secondary school or higher | 10,393 (59.6)    | 7,043 (40.4)          |
| <b>Smoking status</b>      |                  |                       |
| Never                      | 32,004 (75.2)    | 10,579 (24.8)         |
| Ex smokers                 | 5,108 (76.5)     | 1,572 (23.5)          |
| Current smokers            | 10,067 (83.5)    | 1,990 (16.5)          |
| <b>Alcohol consumption</b> |                  |                       |
| Never                      | 38,169 (76.9)    | 11,480 (23.1)         |
| Monthly                    | 3,426 (76.2)     | 1,068 (23.8)          |
| Weekly/Daily               | 5,584 (77.8)     | 1,593 (22.2)          |

\* Included both never users and former users over lifetime.

**Table 2**  
**Characteristics of patients with histologically confirmed respiratory tract carcinomas, Singapore Chinese Health Study 1993-2005**

|                                      | Upper respiratory tract  |                              | Lower respiratory tract |
|--------------------------------------|--------------------------|------------------------------|-------------------------|
|                                      | Nasopharyngeal carcinoma | Non-nasopharyngeal carcinoma |                         |
| <b>Number of cases</b>               | 175                      | 150                          | 821                     |
| <b>Proportion of males</b>           | 68.6%                    | 83.3%                        | 70.0%                   |
| <b>Mean age at diagnosis (years)</b> | 59.1                     | 66.7                         | 68.2                    |
| <b>Histological subtype</b>          |                          |                              |                         |
| Squamous cell carcinoma              | 5 (2.9%)                 | 132 (88.0%)                  | 195 (23.8%)             |
| Undifferentiated carcinoma           | 155 (88.6%)              | 4 (2.7%)                     | 14 (1.7%)               |
| Adenocarcinoma                       | 2 (1.1%)                 | 5 (3.3%)                     | 342 (41.7%)             |
| Small cell carcinoma                 | 0                        | 0 (0.7%)                     | 97 (11.8%)              |
| Other or unspecified carcinoma       | 13 (7.4%)                | 9 (6.0%)                     | 173 (21.1%)             |

**Table 3**  
**Hazards ratio (HR) of respiratory tract carcinomas by incense use, Singapore Chinese Health Study 1993-2005**

|  | Upper respiratory tract        |               |                |             |                   |                |             |               |                              |             |  |  |
|--|--------------------------------|---------------|----------------|-------------|-------------------|----------------|-------------|---------------|------------------------------|-------------|--|--|
|  | Nasopharyngeal carcinoma (NPC) |               |                |             | Non-NPC carcinoma |                |             |               | Lower respiratory tract Lung |             |  |  |
|  | Persons at risk                | Cases (n=175) | HR (95% CI)*   | P for trend | Cases (n=150)     | HR (95% CI)*   | P for trend | Cases (n=821) | HR (95% CI)*                 | P for trend |  |  |
| <b>Status of incense use</b>                 |                                |               |                |             |                   |                |             |               |                              |             |  |  |
| Never users                                  | 6,144                          | 20            | 1.0 (referent) | 0.54        | 10                | 1.0 (referent) | 0.12        | 72            | 1.0 (referent)               | 0.76        |  |  |
| Former users                                 | 7,997                          | 20            | 0.7 (0.4-1.4)  |             | 9                 | 0.7 (0.3-1.8)  |             | 87            | 1.1 (0.8-1.6)                |             |  |  |
| Current users                                | 47,179                         | 135           | 0.8 (0.5-1.3)  |             | 131               | 1.4 (0.7-2.7)  |             | 662           | 1.0 (0.8-1.3)                |             |  |  |
| <b>Duration of incense use</b>               |                                |               |                |             |                   |                |             |               |                              |             |  |  |
| Non current users <sup>†</sup>               | 14,141                         | 40            | 1.0 (referent) | 0.93        | 19                | 1.0 (referent) | 0.03        | 159           | 1.0 (referent)               | 0.75        |  |  |
| Current users with ≤40 years                 | 7,599                          | 22            | 0.9 (0.5-1.5)  |             | 13                | 1.2 (0.6-2.5)  |             | 84            | 0.9 (0.7-1.2)                |             |  |  |
| Current users with 41+ years                 | 39,580                         | 113           | 1.0 (0.7-1.4)  |             | 118               | 1.7 (1.0-2.7)  |             | 578           | 1.0 (0.8-1.2)                |             |  |  |
| <b>Frequency and duration of incense use</b> |                                |               |                |             |                   |                |             |               |                              |             |  |  |
| Non-current users <sup>†</sup>               | 14,141                         | 40            | 1.0 (referent) | 0.93        | 19                | 1.0 (referent) | 0.04        | 159           | 1.0 (referent)               | 0.75        |  |  |
| Current users                                |                                |               |                |             |                   |                |             |               |                              |             |  |  |
| Less than daily use                          | 3,460                          | 7             | 0.7 (0.3-1.5)  |             | 9                 | 1.4 (0.6-3.0)  |             | 49            | 1.0 (0.7-1.4)                |             |  |  |
| Daily use for ≤40 years                      | 6,981                          | 22            | 1.0 (0.6-1.7)  |             | 13                | 1.3 (0.6-2.7)  |             | 75            | 0.9 (0.7-1.2)                |             |  |  |
| Daily use for 41+ years                      | 36,738                         | 106           | 1.0 (0.7-1.4)  |             | 109               | 1.7 (1.0-2.8)  |             | 538           | 1.0 (0.8-1.2)                |             |  |  |
| <b>Level of incense use</b>                  |                                |               |                |             |                   |                |             |               |                              |             |  |  |
| Non-current use <sup>†</sup>                 | 14,141                         | 40            | 1.0 (referent) | 0.78        | 19                | 1.0 (referent) | 0.02        | 159           | 1.0 (referent)               | 0.46        |  |  |
| Low (night/intermittent)                     | 40,324                         | 112           | 0.9 (0.6-1.3)  |             | 107               | 1.5 (0.9-2.5)  |             | 569           | 1.0 (0.8-1.2)                |             |  |  |
| High (day/all times)                         | 6,855                          | 23            | 1.1 (0.7-1.9)  |             | 24                | 2.1 (1.1-3.8)  |             | 93            | 0.9 (0.7-1.2)                |             |  |  |

\* Adjusted for age at recruitment, year of interview, gender, dialect group, level of education, body mass index, number of cigarettes/day, number of years of smoking, time since smoking cessation, alcohol consumption, dietary intakes of isothiocyanate, beta-cryptoxanthin, lutein, lycopene and summed Chinese preserved foods, and for women, number of children (see details in the Materials and Methods).

<sup>†</sup> Including both never and former users of incense.

**Table 4**  
**Hazards ratio (HR) of respiratory tract carcinomas in relation to combined levels of cigarette smoking status, and frequency of incense use, Singapore Chinese Health Study 1993-2005**

|   | Non-current users <sup>‡</sup> | Level of incense use        |                         | P for trend |
|---|--------------------------------|-----------------------------|-------------------------|-------------|
|   |                                | Low<br>(night/intermittent) | High<br>(day/all times) |             |
| <b>Upper respiratory tract Nasopharyngeal carcinoma</b>     |                                |                             |                         |             |
| Never smokers   |                                |                             |                         |             |
| No. cases   | 30                             | 57                          | 14                      |             |
| HR (95% CI)*  | 1.0 (referent)                 | 0.7 (0.5-1.2)               | 1.0 (0.5-2.0)           | 0.49        |
| Ever smokers  |                                |                             |                         |             |
| No. cases   | 10                             | 55                          | 9                       |             |
| HR (95% CI)*  | 1.0 (referent)                 | 1.4 (0.7-2.7)               | 1.4 (0.6-3.5)           | 0.38        |
| <b>Upper respiratory tract Non-nasopharyngeal carcinoma</b> |                                |                             |                         |             |
| Never smokers   |                                |                             |                         |             |
| No. cases   | 5                              | 25                          | 7                       |             |
| HR (95% CI)*  | 1.0 (referent)                 | 2.2 (0.8-5.9)               | 3.3 (1.0-10.7)          | 0.04        |
| Ever smokers  |                                |                             |                         |             |
| No. cases   | 14                             | 82                          | 17                      |             |
| HR (95% CI)*  | 1.0 (referent)                 | 1.3 (0.7-2.4)               | 1.7 (0.8-3.5)           | 0.16        |
| <b>Lung cancer</b>  |                                |                             |                         |             |
| Never smokers   |                                |                             |                         |             |
| No. cases   | 69                             | 140                         | 23                      |             |
| HR (95% CI)*  | 1.0 (referent)                 | 0.8 (0.6-1.1)               | 0.7 (0.4-1.1)           | 0.09        |
| Ever smokers  |                                |                             |                         |             |
| No. cases   | 90                             | 429                         | 70                      |             |
| HR (95% CI)*  | 1.0 (referent)                 | 1.1 (0.8-1.3)               | 1.0 (0.7-1.4)           | 0.88        |

\* Adjusted for age at recruitment, year of interview, gender, dialect group, level of education, body mass index, number of cigarettes/day, number of years of smoking, time since smoking cessation, alcohol consumption, dietary intakes of isothiocyanate, beta-cryptoxanthin, lutein, lycopene and summed Chinese preserved foods, and for women, number of children (see details in the Materials and Methods).

<sup>‡</sup> Including both never and former users of incense.

**Table 5**  
**Hazards ratio (HR) of respiratory tract carcinoma by histological subtype in relation to frequency of incense use, Singapore Chinese Health Study 1993-2005**

| Histology and site                             | Level of incense use           |                             |                         | P for trend |
|--|--------------------------------|-----------------------------|-------------------------|-------------|
|  | Non-current users <sup>†</sup> | Low<br>(night/intermittent) | High<br>(day/all times) |             |
| <b>Squamous cell carcinoma</b>                 |                                |                             |                         |             |
| All respiratory tract <sup>‡</sup>             |                                |                             |                         |             |
| No. cases                                      | 47                             | 226                         | 59                      |             |
| HR (95% CI) *                                  | 1.0 (referent)                 | 1.2 (0.9-1.6)               | 1.8 (1.2-2.6)           | 0.004       |
| Upper respiratory tract                        |                                |                             |                         |             |
| No. cases                                      | 18                             | 97                          | 22                      |             |
| HR (95% CI) *                                  | 1.0 (referent)                 | 1.4 (0.8-2.3)               | 1.9 (1.0-3.6)           | 0.049       |
| Lower respiratory tract                        |                                |                             |                         |             |
| No. cases                                      | 29                             | 129                         | 37                      |             |
| HR (95% CI) *                                  | 1.0 (referent)                 | 1.1 (0.7-1.6)               | 1.7 (1.0-2.8)           | 0.03        |
| <b>Non-squamous cell carcinoma<sup>§</sup></b> |                                |                             |                         |             |
| All respiratory tract <sup>‡</sup>             |                                |                             |                         |             |
| No. cases                                      | 171                            | 562                         | 81                      |             |
| HR (95% CI) *                                  | 1.0 (referent)                 | 1.0 (0.8-1.1)               | 0.8 (0.6-1.1)           | 0.16        |
| Upper respiratory tract                        |                                |                             |                         |             |
| No. cases                                      | 41                             | 122                         | 25                      |             |
| HR (95% CI) *                                  | 1.0 (referent)                 | 1.0 (0.7-1.4)               | 1.2 (0.8-2.1)           | 0.50        |
| Lower respiratory tract                        |                                |                             |                         |             |
| No. cases                                      | 130                            | 440                         | 56                      |             |
| HR (95% CI) *                                  | 1.0 (referent)                 | 0.9 (0.8-1.2)               | 0.7 (0.5-1.0)           | 0.047       |

\* Adjusted for age at recruitment, year of interview, gender, dialect group, level of education, body mass index, number of cigarettes/day, number of years of smoking, time since smoking cessation, alcohol consumption, dietary intakes of isothiocyanate, beta-cryptoxanthin, lutein, lycopene and summed Chinese preserved foods, and for women, number of children (see details in the Materials and Methods)

<sup>†</sup>No current use comprise never and ex-users of incense.

<sup>‡</sup>The sum of all respiratory tract carcinomas may differ from the total number of cases listed in Tables 2 and 3 since the present table counted the first incident cancer for a given individual.

<sup>§</sup>Non-squamous cell carcinoma included adenocarcinoma, small cell carcinoma, undifferentiated, other and unspecified carcinoma.