Carcinogenesis, 2021, Vol. 42, No. 12, 1461–1474

https://doi.org/10.1093/carcin/bgab082
Advance Access publication September 6, 2021
Original Article

ORIGINAL ARTICLE

Association between previous lung diseases and lung cancer risk: a systematic review and meta-analysis

Lina Ang[1], Pratyusha Ghosh[2] and Wei Jie Seow[1,3,*]

[1]Saw Swee Hock School of Public Health, National University of Singapore, Singapore [2]Department of Biological Sciences, National University of Singapore, Singapore [3]Department of Medicine, Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore

*To whom correspondence should be addressed. Tel: +65 6601 1243; Fax: +65 6779 1489; Email: ephswj@nus.edu.sg

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

Abstract

Previous lung diseases (PLD) are known risk factors for lung cancer. However, it remains unclear how the association varies by lung cancer subtype and socio-demographic characteristics. We conducted a systematic literature search in three electronic databases from the inception of each database up until 13 January 2021. A total of 73 studies (18 cohort and 55 case–control studies) consisting of 97 322 cases and 7 761 702 controls were included. Heterogeneity was assessed using the I^2 statistic. Based on the heterogeneity, either the fixed-effects or random-effects model was used to estimate the pooled summary estimate (PSE) and 95% confidence interval (CI) for the association between PLD and lung cancer risk. A history of asthma, chronic bronchitis, emphysema, pneumonia, tuberculosis, and chronic obstructive pulmonary disease (COPD) was associated with higher lung cancer risk, with a history of COPD and emphysema having at least twofold relative risk. A history of hay fever was associated with lower lung cancer risk (PSE= 0.66, 95% CI= 0.54–0.81), particularly among ever-smokers (PSE= 0.55, 95% CI= 0.41–0.73). Individuals with a diagnosis of asthma, emphysema, or pneumonia within 1–10 years prior to lung cancer diagnosis were observed to have a higher lung cancer risk as compared to those who were diagnosed more than 10 years prior to lung cancer diagnosis. Ever-smokers with a history of COPD or emphysema were observed to have at least twofold relative risk of lung cancer compared to those without this history. Due to the observed association between PLD with higher risk of lung cancer, it is advisable that individuals with PLD should be closely monitored and prioritised for lung cancer screening.

Introduction

Lung cancer remains the leading cause of cancer incidence and mortality worldwide with 1 796 144 new deaths from lung cancer and 2 206 771 new lung cancer diagnoses in 2020 (1). Lung diseases affect respiratory function and are primarily caused by viral, fungal, or bacterial infections (2). Presence of previous lung disease (PLD) is a well-established risk factor for lung cancer (3). Current literature showed that PLDs such as chronic obstructive pulmonary disease (COPD), asthma, pneumonia, and tuberculosis were found to be significant risk factors for lung cancer (4,5). Lung cancer incidence was higher among those who reported a history of lung disease in both Western (6) and Asian (7) countries.

Previous consortium studies among Western countries found that history of emphysema, chronic bronchitis, pneumonia, and tuberculosis were positively associated with lung cancer risk (3,4). A previous meta-analysis of prospective cohort studies showed a significant increased risk of lung cancer for history of COPD and emphysema among ever-smokers and never-smokers (8). Other meta-analyses reported significant associations between history of tuberculosis and risk of lung adenocarcinoma (9), as well as between history of COPD, chronic bronchitis, emphysema, pneumonia, or tuberculosis and lung cancer risk (10). However, some results remain conflicting. An international consortium pooled analysis found a positive association between history of asthma and lung cancer risk (11). However, history of asthma was also found to be inversely associated with lung cancer risk in a different large consortium pooled study conducted in Europe and Canada (4).

Received: May 21, 2021; **Revised:** August 29, 2021; **Accepted:** September 6, 2021

© The Author(s) 2021. Published by Oxford University Press. All rights reserved. For Permissions, please email: journals.permissions@oup.com.

Abbreviations

CI	confidence interval
COPD	chronic obstructive pulmonary disease
MOA	measure of association
PLD	previous lung diseases
PSE	pooled summary estimate
RR	relative risk

Some of the drawbacks of previous meta-analyses conducted on PLD and lung cancer risk are that they were either performed on history of specific lung diseases such as COPD (8) or tuberculosis (9), or were conducted at least a decade ago (10). This meta-analysis sought to provide an overview of the current literature by including all the available studies on PLD and lung cancer risk from January 1900 to January 2021 and stratifying the analyses by lung cancer subtypes and sociodemographic characteristics.

Material and methods

Search strategy

We followed the guidelines of the preferred reporting items for systematic reviews and meta-analyses (12) (Supplementary Table S1). A search for eligible studies was conducted using three electronic databases: PubMed, Embase, and Web of Science from the inception of each database until 13 January 2021. Both keywords and MeSH terms related to lung cancer and diseases of the respiratory system as listed in the International Statistical Classification of Diseases and Related Health Problems 10th Revision—Version 2016 (13) were used as search terms (Supplementary Table S2). The search was limited to peer-reviewed studies that used either a case–control or cohort study design and published in the English language. The search results from the three electronic databases were then saved and exported for screening by title and abstract using a citation manager, EndNote X8 (Clarivate Analytics). Full-text copies of the remaining studies were downloaded and further assessed for their eligibility. Additionally, backward citation tracking was performed on all the included studies and previous systematic reviews on a similar topic to ensure that all eligible studies were included. The literature search, screening, and selection process for all eligible studies was based on a set of inclusion and exclusion criteria (Supplementary Table S3) and conducted independently by two reviewers (LA and PG). Discrepancies of the included studies were resolved through discussions between the independent reviewers.

Data extraction

The following data were extracted and tabulated in a standard form: study, setting, study design, data collection period, sample size, sample characteristics, measure of association (MOA), previous lung disease(s), and all control variables used in the analysis. The adjusted MOA [hazard ratio, incidence rate ratio, odds ratio, relative risk (RR), and standardized incidence ratio] and its corresponding 95% CI between PLD and lung cancer risk were extracted. MOA and 95% CI for stratified analyses of PLD and lung cancer risk were also extracted from the individual studies when available. Data extraction was conducted independently by the two reviewers.

Risk of bias assessment

The methodological quality of all the included studies was assessed using the Newcastle–Ottawa scale (14). The Newcastle–Ottawa scale assessed the methodological quality of each study based on three components: 1) selection bias, 2) comparability between the study groups, and 3) the determination of outcome. A total possible score of nine points can be given to a study based on the following breakdown: a maximum of four points for selection bias, a maximum of two points for comparability, and a maximum of three points for the determination of outcome of interest. To ensure reliability, two reviewers rated all the included studies independently and the average score between both reviewers were used for quality assessment. Studies were considered of 'low quality', 'moderate quality', or 'high quality' if the average score rated by both reviewers ranged from '0 to 3.9', '4 to 6.9', and '7 to 9' points respectively (15). Inter-rater reliability was calculated as a percentage of the number of studies that have a similar total score rated by the independent reviewers out of the total number of studies included.

Statistical analysis

The MOAs and 95% CIs of all studies were natural log-transformed before meta-analysis. When the overall MOA for a specific lung disease and lung cancer risk was not reported in the study, MOAs from subgroup analyses were combined using fixed or random effects to obtain the overall MOA. The MOAs for all lung diseases reported in the study were combined using meta-analysis to obtain the overall pooled summary estimate (PSE) for history of any PLD and lung cancer risk. 'History of any PLD' mentioned in this review refers to the following lung diseases examined in the included studies: asthma, chronic bronchitis, emphysema, pneumonia, tuberculosis, COPD, hay fever, pleurisy, sarcoidosis, silicosis, fibrosis, respiratory allergies, rhinosinusitis, asbestosis, bulbar polio, influenza, lung infection, punctured lung, lung diseases due to external factors, interstitial lung disease, and other unspecified lung diseases. Inverse variance weighting was used to weigh the individual studies based on their sample size. The degree of heterogeneity among the included studies for the meta-analysis and stratified analyses were assessed using the I^2 statistic (16). The random-effects model was used when there was a moderate to high heterogeneity level between studies ($I^2 > 50\%$), whereas the fixed-effects model was used when $I^2 \leq 50\%$. The extracted MOAs with their 95% CIs from all included studies were meta-analysed to obtain the PSE and 95% CI. Both the Egger's test and the funnel plot were used to assess publication bias of the included studies. The Egger's test was used to test for small-study effects in the included studies (17).

Stratified analyses by geographical region, study design, sex, smoking status *[never-smokers and ever-smokers (former and current smokers)], age of participant at lung cancer diagnosis (<55 and ≥55 years old), histology of lung cancer (non-small cell carcinoma (adenocarcinoma, squamous cell carcinoma, and large cell carcinoma), small cell carcinoma, and carcinoma of other cell types), and time since diagnosis of lung disease (1–<10 and ≥10 years) were performed for overall and each specific PLD. There was only one cohort study (18) that examined history of emphysema and lung cancer risk, therefore, a stratified analysis based on cohort studies could not be conducted. The cut-off age of participants at lung cancer diagnosis (<55 and ≥55 years old) and time since diagnosis of lung disease (<10 and ≥10 years) were chosen based on majority of the included studies having similar cut-offs—11 out of 14 studies (78.6%) for age at lung cancer diagnosis and 13 out of 16 studies (81.3%) for time since diagnosis of lung disease.

All meta-analysis and forest plots were generated using the *METAN* and *eform* commands in STATA version 15.0 (Stata Corporation, TX, USA).

Results

Search results

The search in the three electronic databases from January 1900 to January 2021 yielded a total of 12 195 records. After removing 686 duplicated records, a total of 11 509 records were screened by title and abstract. An additional 11 273 records were excluded as they were irrelevant to our review topic. Full-text copies of 236 studies were downloaded and assessed for eligibility. A further 184 records were excluded as they did not meet the inclusion criteria. The excluded studies were reviewed, and were comprised of studies with indirect or no data reported on the association between PLD and lung cancer risk, pooled studies, duplicates, studies that reported on lung cancer mortality or the association between any existing lung disease and lung cancer risk, non-English studies, studies where estimates could not be calculated, or where full-text was not available, or studies that were not cohort/case–control study. Backward citation tracking of the included studies and previous reviews yielded

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

an additional 19 eligible studies. A total of 71 primary publications were included in this review, two of the included publications included two case–control and two cohort studies each, resulting in a total of 73 included studies (Fig. 1).

Characteristics of the included studies

Of the 73 included studies, 71 studies were unique studies while two studies (19,20) were earlier works superseded by recent studies as relevant data such as the association of PLD and lung cancer risk by sex were not reported in the recent studies. Estimates reported for sex were extracted from both studies and were included in the stratified analyses but were excluded from the overall pooled summary estimate to avoid inflation of the estimate. The estimate used in the overall pooled summary estimate for overlapping studies was determined based on the most recent publication date as the data collection period was longer in the recent studies. There was a total of 55 case–control studies and 18 cohort studies. The total number of participants included in this review was 7 859 024 with 97 322 cases and 7 761 702 controls. Sample sizes ranged from 142 to 6 567 909. Most of the included studies were conducted in North America (43.8%), followed by Asia (32.9%), Europe (17.8%), Oceania (4.1%), and Africa (1.4%). There was a total of 48 studies from European-descendent majority regions (North America, Europe, and Oceania), 24 Asian studies, and one African study in this meta-analysis. Most of the included studies (approximately 90.1%) were consistent with current literature that a history of any PLD was associated with an increased risk of lung cancer (MOA > 1) except for seven studies (6,21–26) which found a protective effect (MOA < 1). The PLDs examined in this meta-analysis included asthma, chronic bronchitis, emphysema, pneumonia, tuberculosis, COPD, pleurisy, hay fever, and other lung diseases (Supplementary Table S4).

Methodological quality of the included studies

Most of the included studies were of high quality with an average score of 7.4 (Supplementary Table S5). Fifteen out of the 73 included studies were rated to be of moderate quality and none of the studies were of poor quality. Inter-rater reliability was low (approximately 29%), where only 21 out of all included studies was rated similarly between the independent reviewers.

History of previous lung disease(s) and lung cancer risk

The overall association between history of any PLD and lung cancer risk from 71 studies was 1.67 (95% CI= 1.39–1.99) (Table 1, Fig. 2). Stratified analysis by study design showed a significant overall PLD association with lung cancer risk among case–control studies (PSE= 1.61, 95% CI= 1.46–1.77), but no significant association was found among cohort studies (PSE= 1.56, 95% CI= 0.96–2.55) (Fig. 3). Stratified analysis by geographical region showed that the PSE was 1.39 (95% CI= 1.26–1.52) for studies from European-descendent majority regions, 2.22 (95% CI= 1.46–3.36) for Asian studies, and 4.16 (95% CI= 1.76–9.84) for the African study (Table 1).

History of asthma and lung cancer risk

History of asthma was found to be positively associated with lung cancer risk (PSE= 1.16, 95% CI= 1.05–1.28) among case–control studies (PSE= 1.14, 95% CI= 1.00–1.29) and cohort studies (PSE= 1.17, 95% CI= 1.05–1.30) (Table 1), particularly among never-smokers (PSE= 1.28, 95% CI= 1.08–1.52), and individuals aged ≥55 years old (PSE= 1.45, 95% CI= 1.07–1.95) (Table 2). Individuals with asthma diagnosis within 1–10 years prior to lung cancer diagnosis (PSE= 1.29, 95% CI= 1.07–1.56) were associated with lung cancer risk but no significant association was found for asthma diagnosis of more than 10 years prior to lung cancer diagnosis (PSE= 1.02, 95% CI= 0.83–1.23) (Table 2). Stratified analysis showed a significant association between history of asthma and lung cancer risk among Asian females (PSE= 1.46, 95% CI= 1.09–1.97) (Table 2). The association between asthma diagnosis within 1–10 years prior to lung cancer diagnosis and lung cancer risk was significant among studies from European-descendent majority regions (PSE= 1.32, 95% CI= 1.23–1.41) but not among Asian studies (PSE= 1.99, 95% CI= 0.76–5.18) (Table 2). No significant association was found between asthma diagnosis of more than 10 years prior to lung cancer diagnosis and lung cancer risk among studies from European-descendent majority regions (PSE= 0.98, 95% CI= 0.80–1.20) (Table 2).

History of chronic bronchitis and lung cancer risk

History of chronic bronchitis was significantly and positively associated with higher lung cancer risk (PSE= 1.49, 95% CI= 1.32–1.69). This association was significant among case–control studies (PSE= 1.49, 95% CI= 1.27–1.75) and cohort studies (PSE= 1.51, 95% CI= 1.37–1.67) (Table 1). The association between history of chronic bronchitis and lung cancer risk was significant among males (PSE= 1.87, 95% CI= 1.55–2.27), females (PSE= 1.38, 95% CI= 1.19–1.61), never-smokers (PSE= 1.24, 95% CI= 1.03–1.51), ever-smokers (PSE= 1.55, 95% CI= 1.41–1.70), former smokers (PSE= 1.88, 95% CI= 1.49–2.36), current smokers (PSE= 1.75, 95% CI= 1.28–2.39), and individuals aged ≥55 years old (PSE= 1.62, 95% CI= 1.36–1.94) (Table 2). No significant association was found between individuals with chronic bronchitis diagnosis within 1–10 years (PSE= 1.27, 95% CI= 0.93–1.74) and individuals with chronic bronchitis diagnosis of more than 10 years (PSE= 1.49, 95% CI= 0.89–2.50) prior to lung cancer diagnosis and lung cancer risk (Table 2). Stratified analysis by histology of lung cancer showed a significant association between a history of chronic bronchitis with risk of non-small cell carcinoma (PSE= 1.43, 95% CI= 1.22–1.67) and carcinoma of other cell types (PSE= 2.05, 95% CI= 1.37–3.06). A significant association was found for individuals with chronic bronchitis diagnosed within 1–10 years prior to lung cancer diagnosis only among Asian studies (PSE= 1.41, 95% CI= 1.09–1.83). Individuals with a history of chronic bronchitis have at least twofold RR of lung cancer among Asian males (PSE= 2.47, 95% CI= 1.39–4.38) and current smokers of European-descendent majority regions (PSE= 2.00, 95% CI= 1.44–2.78) (Table 2).

History of emphysema and lung cancer risk

A positive significant association between history of emphysema and lung cancer risk was found (PSE= 2.21, 95% CI= 2.04–2.40), and this association was significant among case–control studies (PSE= 2.35, 95% CI= 2.10–2.62) (Table 1). The association between history of emphysema and lung cancer risk was significant among males (PSE= 1.73, 95% CI= 1.24–2.40), females (PSE= 1.98, 95% CI= 1.48–2.66), ever-smokers (PSE= 2.26, 95% CI= 2.07–2.48), former smokers (PSE= 2.71, 95% CI= 2.23–3.29), current smokers (PSE= 2.56, 95% CI= 2.07–3.17), and individuals aged ≥55 years old (PSE= 2.41, 95% CI= 1.42–4.08) (Table 2). Individuals with emphysema diagnosis within 1–10 years prior to lung cancer diagnosis have at least twofold RR of lung cancer (PSE= 2.31, 95% CI= 1.89–2.83) as opposed to individuals with emphysema diagnosis of more than 10 years prior to lung cancer diagnosis (PSE= 1.71, 95% CI= 1.11–2.65) (Table 2). Stratified analysis by lung cancer histology revealed a significant association between a history of emphysema with risk of non-small cell carcinoma (PSE= 1.98, 95% CI= 1.41–2.77) and carcinoma of other cell types (PSE= 3.07, 95% CI=

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

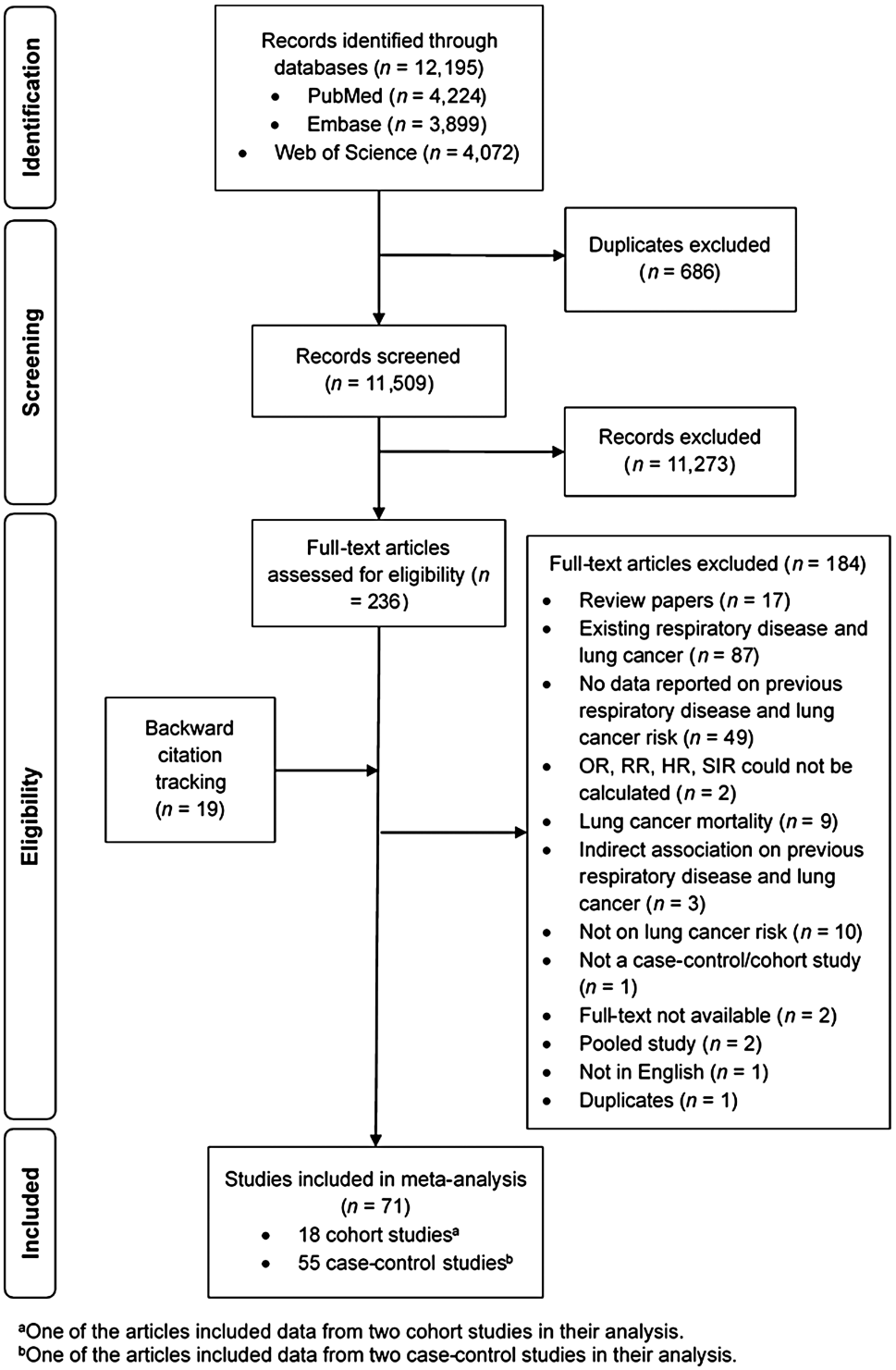


Figure 1. Preferred reporting items for systematic reviews and meta-analyses flow diagram.

1.35–7.03). Stratified analysis showed a significant association between history of emphysema and lung cancer risk among never-smokers in studies from European-descendent majority regions (PSE= 1.73, 95% CI= 1.02–2.19) (Table 2).

History of COPD and lung cancer risk

A significant positive association between history of COPD and lung cancer risk was found (PSE= 2.51, 95% CI= 1.71–3.68), and this association was significant among case–control studies (PSE= 2.47, 95% CI= 2.03–3.01) but not among cohort studies (PSE= 2.11, 95% CI= 0.76–5.88) (Table 1). The association between history of COPD and lung cancer risk was significant among males (PSE= 2.94, 95% CI= 1.32–6.58), females (PSE= 1.81, 95% CI= 1.24–2.64), never-smokers (PSE= 1.71, 95% CI= 1.04–2.80), ever-smokers (PSE= 2.05, 95% CI= 1.41–2.99), former smokers (PSE= 1.85, 95% CI= 1.21–2.84), current smokers (PSE= 1.66, 95% CI= 1.23–2.23), individuals aged <55 years old (PSE= 1.55, 95% CI= 1.04–2.30), individuals aged ≥55 years old (PSE= 1.30, 95% CI= 1.05–1.61),

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

Table 1. Meta-analysis results on the association of history of any lung diseases and lung cancer risk stratified by geographical regions, study design, and sociodemographic characteristics

Previous lung disease(s)	No. of studies	PSE	95% CI	p	Heterogeneity (I^2, P)	Model used
History of any lung disease(s)	71	**1.67****	1.39–1.99	P < 0.0005	I^2 = 98.6%, P < 0.0005	Random effects
Asthma	39	**1.16***	1.05–1.28	P = 0.003	I^2 = 58.7%, P < 0.0005	Random effects
Chronic bronchitis	28	**1.49****	1.32–1.69	P < 0.0005	I^2 = 63.7%, P < 0.0005	Random effects
Emphysema	19	**2.21****	2.04–2.40	P < 0.0005	I^2 = 31.6%, P = 0.092	Fixed effects
COPD [a]	21	**2.51****	1.71–3.68	P < 0.0005	I^2 = 99.1%, P < 0.0005	Random effects
Pneumonia	27	**1.43****	1.23–1.66	P < 0.0005	I^2 = 83.6%, P < 0.0005	Random effects
Tuberculosis	35	**1.85****	1.52–2.25	P < 0.0005	I^2 = 69.1%, P < 0.0005	Random effects
Pleurisy	4	1.10	0.92–1.32	P = 0.275	I^2 = 9.4%, P = 0.346	Fixed effects
Hay fever	9	**0.66****	0.54–0.81	P < 0.0005	I^2 = 55.2%, P = 0.022	Random effects
Other lung diseases[b]	15	1.49	0.80–2.75	P = 0.208	I^2 = 98.1%, P < 0.0005	Random effects
Study design						
History of any lung disease(s) in case–control studies	54	**1.61****	1.46–1.77	P < 0.0005	I^2 = 87.9%, P < 0.0005	Random effects
Asthma	31	**1.14***	1.00–1.29	P = 0.043	I^2 = 64.6%, P < 0.0005	Random effects
Chronic bronchitis	25	**1.49****	1.27–1.75	P < 0.0005	I^2 = 66.4%, P < 0.0005	Random effects
Emphysema	18	**2.35****	2.10–2.62	P < 0.0005	I^2 = 28.5%, P = 0.126	Fixed effects
COPD [a]	16	**2.47****	2.03–3.01	P < 0.0005	I^2 = 84.4%, P < 0.0005	Random effects
Pneumonia	25	**1.49****	1.28–1.74	P < 0.0005	I^2 = 80.1%, P < 0.0005	Random effects
Tuberculosis	30	**2.07****	1.68–2.56	P < 0.0005	I^2 = 64.3%, P < 0.0005	Random effects
Pleurisy	4	1.10	0.92–1.32	P = 0.275	I^2 = 9.4%, P = 0.346	Fixed effects
Hay fever	7	**0.63****	0.51–0.76	P < 0.0005	I^2 = 56.9%, P = 0.031	Random effects
Other lung diseases[b]	7	1.07	0.89–1.29	P = 0.449	I^2 = 40.1%, P = 0.124	Fixed effects
History of any lung disease(s) in cohort studies	17	1.56	0.96–2.55	P = 0.075	I^2 = 99.5%, P < 0.0005	Random effects
Asthma	8	**1.17***	1.05–1.30	P = 0.005	I^2 = 0.0%, P = 0.504	Fixed effects
Chronic bronchitis	3	**1.51****	1.37–1.67	P < 0.0005	I^2 = 0.0%, P = 0.504	Fixed effects
COPD [a]	5	2.11	0.76–5.88	P = 0.153	I^2 = 99.8%, P < 0.0005	Random effects
Pneumonia	2	1.00	0.80–1.25	P = 0.989	I^2 = 65.2%, P = 0.090	Random effects
Tuberculosis	5	1.07	0.87–1.32	P = 0.517	I^2 = 19.5%, P = 0.291	Fixed effects
Hay fever	2	1.21	0.66–2.20	P = 0.542	I^2 = 0.0%, P = 0.920	Fixed effects
Other lung diseases[b]	8	1.62	0.69–3.83	P = 0.272	I^2 = 98.8%, P < 0.0005	Random effects
Geographical region						
European-descendent majority regions	48	**1.39****	1.26–1.52	P < 0.0005	I^2 = 90.5%, P < 0.0005	Random effects
North America	32	**1.32****	1.20–1.45	P < 0.0005	I^2 = 85.1%, P < 0.0005	Random effects
Europe	13	**1.38***	1.13–1.68	P = 0.001	I^2 = 89.8%, P < 0.0005	Random effects
Oceania	3	2.75	0.85–8.98	P = 0.093	I^2 = 87.6%, P < 0.0005	Random effects
Africa	1	**4.16***	1.76–9.84	P = 0.001	NA	Fixed effects
Asia	22	**2.22****	1.46–3.36	P < 0.0005	I^2 = 98.7%, P < 0.0005	Random effects
Sex						
Males	23	**1.87***	1.20–2.92	P = 0.022	I^2 = 98.6%, P < 0.0005	Random effects
Females	36	**1.54****	1.33–1.78	P < 0.0005	I^2 = 85.1%, P < 0.0005	Random effects
Smoking status						
Never-smokers	28	**1.33****	1.16–1.53	P < 0.0005	I^2 = 55.7%, P < 0.0005	Random effects
Ever-smokers	21	**1.55****	1.32–1.82	P < 0.0005	I^2 = 90.7%, P < 0.0005	Random effects
Former smokers	11	**1.45***	1.16–1.80	P = 0.001	I^2 = 79.0%, P < 0.0005	Random effects
Current smokers	11	**1.40****	1.17–1.68	P < 0.0005	I^2 = 77.9%, P < 0.0005	Random effects
Age of participant at lung cancer diagnosis						
< 55 years old	5	1.12	0.66–1.90	P = 0.686	I^2 = 81.4%, P < 0.0005	Random effects
≥ 55 years old	11	**1.47****	1.27–1.71	P < 0.0005	I^2 = 73.6%, P < 0.0005	Random effects
Histology of lung cancer						
Non-small cell carcinoma	20	**1.37****	1.21–1.54	P < 0.0005	I^2 = 74.1%, P < 0.0005	Random effects
Adenocarcinoma	17	**1.25***	1.09–1.43	P = 0.002	I^2 = 63.5%, P < 0.0005	Random effects
Squamous cell carcinoma	8	**1.50***	1.18–1.90	P = 0.001	I^2 = 79.9%, P < 0.0005	Random effects
Small cell carcinoma	5	1.18	0.84–1.65	P = 0.352	I^2 = 76.2%, P = 0.002	Random effects
Carcinoma of other cell types[c]	8	**1.42****	1.23–1.64	P < 0.0005	I^2 = 43.7%, P = 0.087	Fixed effects
Time since diagnosis of lung disease						
1–< 10 years	15	**1.60****	1.28–2.01	P < 0.0005	I^2 = 96.4%, P < 0.0005	Random effects
1–4 years	9	**1.56***	1.16–2.10	P = 0.004	I^2 = 97.3%, P < 0.0005	Random effects
5–< 10 years	7	**1.55***	1.17–2.04	P = 0.002	I^2 = 75.1%, P < 0.0005	Random effects
≥ 10 years	12	1.16	0.93–1.44	P = 0.181	I^2 = 92.7%, P < 0.0005	Random effects

* $P < 0.05$;

** $P < 0.001$

PSE: pooled summary estimate; CI = Confidence Interval; COPD = Chronic Obstructive Pulmonary Disease; P *P* = *P* value

[a]Includes six studies that reported chronic bronchitis and/or emphysema.

[b]Includes other lung diseases such as sarcoidosis, silicosis, fibrosis, allergies, rhinosinusitis, asbestosis, bulbar polio, influenza, lung infection, punctured lung, lung diseases due to external factors, interstitial lung disease, and other unspecified lung diseases.

[c]Includes other lung cancer cell type such as other unspecified cell type, and a combination of squamous, large, and small cell lung cancer.

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

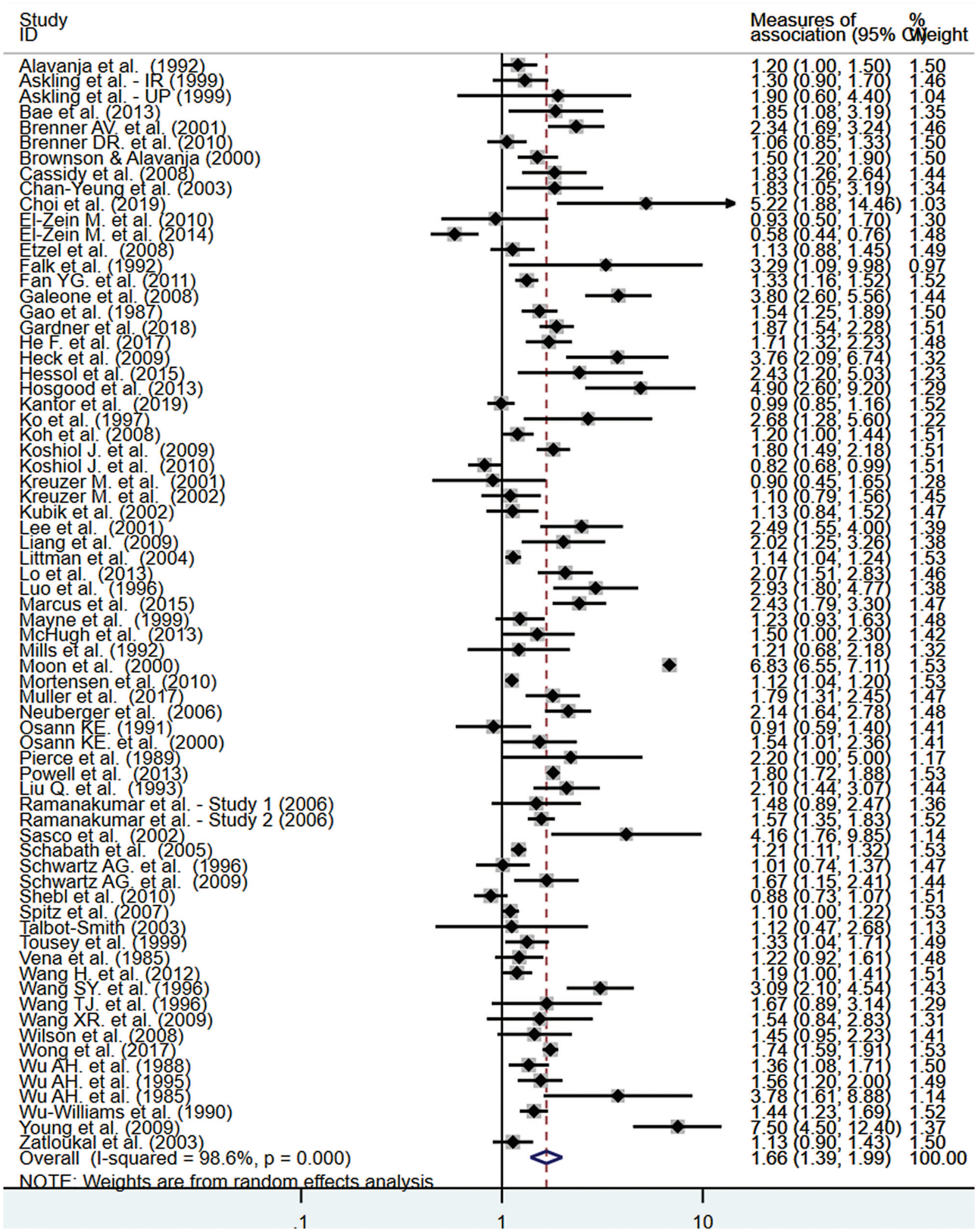


Figure 2. Forest plot of the association between any previous lung disease(s) and lung cancer risk.

individuals with COPD diagnosis within 1–10 years prior to lung cancer diagnosis (PSE= 1.99, 95% CI= 1.29–3.07), and those with COPD diagnosis of more than 10 years prior to lung cancer diagnosis (PSE= 2.15, 95% CI= 1.35–3.43) (Table 2). Stratified analysis by lung cancer histology revealed a significant association between a history of COPD and risk of non-small cell carcinoma

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

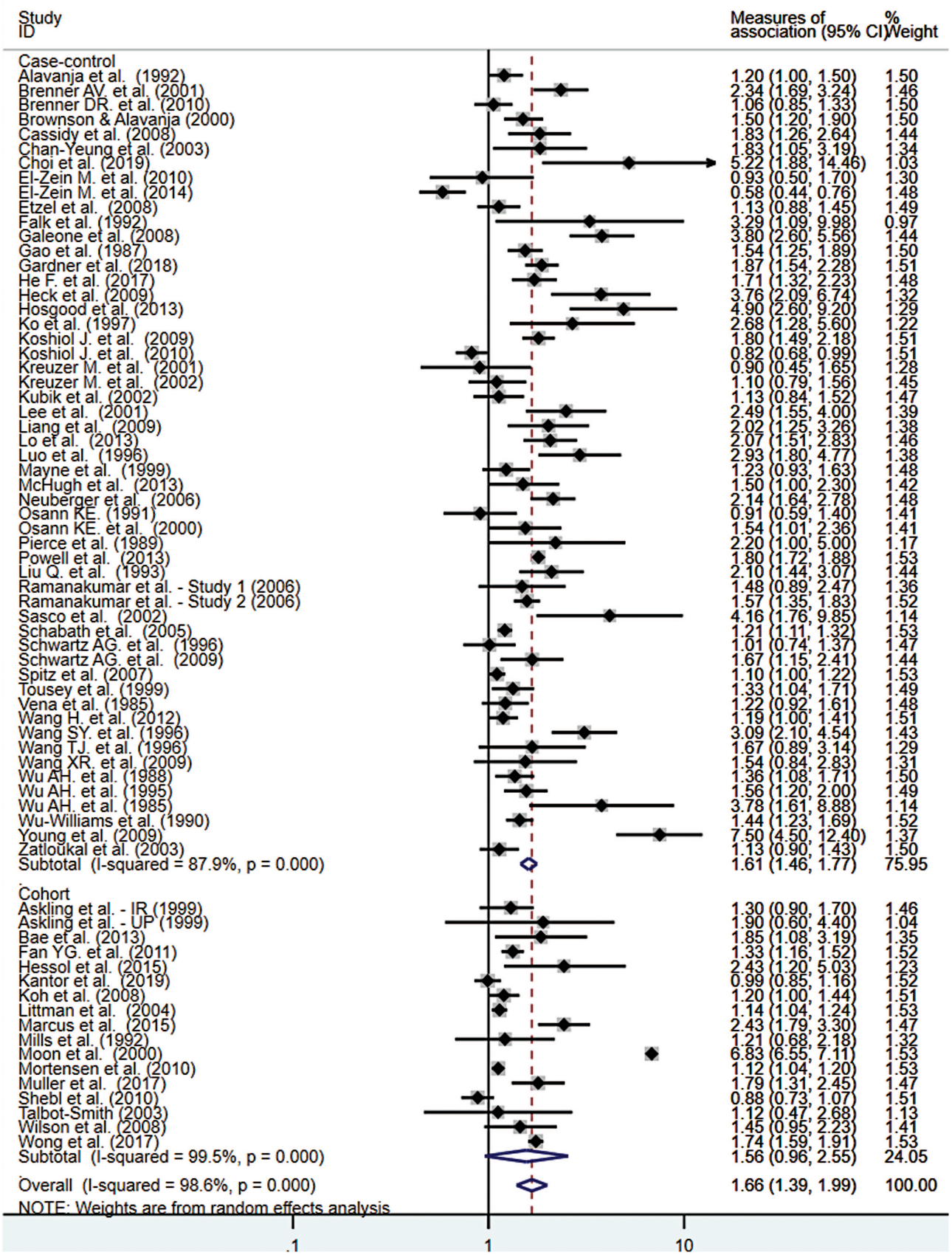


Figure 3. Forest plot of the association between any previous lung disease(s) and lung cancer risk stratified by case–control and cohort studies.

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

Table 2. Meta-analysis results on the association of history of specific lung disease(s) and lung cancer risk among European-descendent majority regions and Asian studies, respectively, stratified by sociodemographic characteristics for strata with at least two studies each

	Overall				Studies from European-descendent majority regions				Asian studies			
Previous lung disease	N	PSE	95% CI	Heterogeneity (I^2, p)	N	PSE	95% CI	Heterogeneity (I^2, p)	N	PSE	95% CI	Heterogeneity (I^2, p)
Asthma												
Males	14	1.04	0.91–1.17	I^2 = 29.3%, P = 0.144	11	1.01	0.86–1.19	I^2 = 42.5%, P = 0.066	3	1.08	0.89–1.31	I^2 = 0.0%, P = 0.696
Females	18	1.22	0.91–1.62	I^2 = 69.3%, P < 0.0005	14	1.12	0.79–1.58	I^2 = 73.4%, P < 0.0005	4	**1.46***	1.09–1.97	I^2 = 31.1%, P = 0.225
Never-smokers	15	**1.28***	1.08–1.52	I^2 = 29.7%, P = 0.133	10	**1.34***	1.09–1.65	I^2 = 7.4%, P = 0.374	5	1.27	0.71–2.28	I^2 = 58.2%, P = 0.048
Ever-smokers	8	0.88	0.63–1.22	I^2 = 76.1%, P < 0.0005	5	0.96	0.63–1.44	I^2 = 70.0%, P = 0.010	3	0.69	0.30–1.56	I^2 = 87.4%, P < 0.0005
Former-smokers	4	1.13	0.52–2.46	I^2 = 78.1%, P = 0.003	4	1.13	0.52–2.46	I^2 = 78.1%, P = 0.003	-	-	-	-
Current-smokers	3	1.00	0.79–1.26	I^2 = 0.0%, P = 0.649	2	0.97	0.75–1.27	I^2 = 0.0%, P = 0.407	-	-	-	-
< 55 years old	4	0.80	0.38–1.69	I^2 = 66.4%, P = 0.030	3	0.63	0.21–1.88	I^2 = 73.8%, P = 0.022	-	-	-	-
≥ 55 years old	4	**1.45***	1.07–1.95	I^2 = 22.8%, P = 0.274	3	**1.43***	1.00–2.05	I^2 = 48.4%, P = 0.144	-	-	-	-
Non-small cell carcinoma[a]	14	1.11	0.99–1.25	I^2 = 38.3%, P = 0.071	12	1.13	0.99–1.29	I^2 = 46.1%, P = 0.040	2	1.06	0.82–1.38	I^2 = 0.0%, P = 0.473
Adenocarcinoma	12	1.01	0.86–1.19	I^2 = 40.0%, P = 0.074	10	1.08	0.80–1.45	I^2 = 50.2%, P = 0.034	2	1.01	0.73–1.40	I^2 = 0.0%, P = 0.605
Squamous cell carcinoma	6	1.10	0.90–1.36	I^2 = 0.0%, P = 0.474	5	1.09	0.86–1.38	I^2 = 10.7%, P = 0.345	-	-	-	-
Small cell carcinoma	4	1.50	0.72–3.12	I^2 = 74.4%, P = 0.008	3	1.19	0.52–2.72	I^2 = 67.0%, P = 0.048	-	-	-	-
Carcinoma of other cell types[b]	5	1.37	0.78–2.41	I^2 = 56.8%, P = 0.055	4	1.51	0.63–3.60	I^2 = 63.8%, P = 0.040	-	-	-	-
< 10 years, tsd of lung disease	10	**1.29***	1.07–1.56	I^2 = 58.7%, P = 0.010	8	**1.32****	1.23–1.41	I^2 = 34.9%, P = 0.150	2	1.99	0.76–5.18	I^2 = 87.6%, P = 0.004
≥ 10 years, tsd of lung disease	9	1.02	0.83–1.23	I^2 = 70.7%, P = 0.001	8	0.98	0.80–1.20	I^2 = 72.8%, P = 0.001	-	-	-	-
Chronic bronchitis												
Males	8	**1.87****	1.55–2.27	I^2 = 46.2%, P = 0.072	4	**1.65***	1.13–2.39	I^2 = 0.0%, P = 0.471	4	**2.47***	1.39–4.38	I^2 = 69.6%, P = 0.020
Females	14	**1.38****	1.19–1.61	I^2 = 46.8%, P = 0.028	7	**1.39****	1.16–1.67	I^2 = 34.2%, P = 0.167	7	1.48	0.91–2.39	I^2 = 60.8%, P = 0.018
Never-smokers	14	**1.24***	1.03–1.51	I^2 = 32.5%, P = 0.115	9	1.23	0.98–1.55	I^2 = 41.8%, P = 0.088	5	1.28	0.89–1.85	I^2 = 26.8%, P = 0.243
Ever-smokers	7	**1.55****	1.41–1.70	I^2 = 26.1%, P = 0.229	5	**1.57****	1.41–1.76	I^2 = 45.4%, P = 0.120	2	**1.49****	1.26–1.77	I^2 = 0.0%, P = 0.468
Former-smokers	5	**1.88****	1.49–2.36	I^2 = 0.0%, P = 0.443	4	**1.82****	1.41–2.34	I^2 = 11.3%, P = 0.336	-	-	-	-
Current-smokers	3	**1.75****	1.28–2.39	I^2 = 50.9%, P = 0.130	2	**2.00****	1.44–2.78	I^2 = 38.7%, P = 0.201	-	-	-	-
< 55 years old	2	1.14	0.35–3.73	I^2 = 68.6%, P = 0.074	2	1.14	0.35–3.73	I^2 = 68.6%, P = 0.074	-	-	-	-
≥ 55 years old	4	**1.62****	1.36–1.94	I^2 = 0.0%, P = 0.623	3	**1.87****	1.39–2.51	I^2 = 0.0%, P = 0.859	-	-	-	-
Non-small cell carcinoma[a]	8	**1.43****	1.22–1.67	I^2 = 0.0%, P = 0.521	5	**1.40***	1.12–1.75	I^2 = 6.1%, P = 0.372	3	**1.45***	1.17–1.80	I^2 = 0.0%, P = 0.473
Adenocarcinoma	7	1.20	0.98–1.46	I^2 = 5.0%, P = 0.389	4	1.25	0.97–1.60	I^2 = 0.0%, P = 0.487	3	1.12	0.81–1.55	I^2 = 45.0%, P = 0.163
Squamous cell carcinoma	3	**1.61****	1.27–2.05	I^2 = 0.0%, P = 0.372	-	-	-	-	2	**1.54***	1.19–1.98	I^2 = 0.0%, P = 0.724
Small cell carcinoma	2	1.54	0.96–2.48	I^2 = 0.0%, P = 0.586	-	-	-	-	-	-	-	-
Carcinoma of other cell types[b]	4	**2.05***	1.37–3.06	I^2 = 0.0%, P = 0.941	3	**2.19***	1.38–3.49	I^2 = 0.0%, P = 0.976	-	-	-	-
< 10 years, tsd of lung disease	6	1.27	0.93–1.74	I^2 = 71.8%, P = 0.003	4	1.21	0.83–1.78	I^2 = 68.7%, P = 0.023	2	**1.41***	1.09–1.83	I^2 = 0.0%, P = 0.562
≥ 10 years, tsd of lung disease	4	1.49	0.89–2.50	I^2 = 93.6%, P < 0.0005	4	1.49	0.89–2.50	I^2 = 93.6%, P < 0.0005	-	-	-	-
Emphysema												
Males	3	**1.73***	1.24–2.40	I^2 = 0.0%, P = 0.669	3	**1.73***	1.24–2.40	I^2 = 0.0%, P = 0.669	-	-	-	-
Females	9	**1.98****	1.48–2.66	I^2 = 0.0%, P = 0.455	8	**1.98****	1.42–2.75	I^2 = 10.0%, P = 0.353	-	-	-	-
Never-smokers	8	1.47	0.96–2.26	I^2 = 0.0%, P = 0.665	7	**1.73***	1.02–2.91	I^2 = 0.0%, P = 0.691	-	-	-	-
Ever-smokers	8	**2.26****	2.07–2.48	I^2 = 41.7%, P = 0.100	7	**2.29****	2.08–2.51	I^2 = 45.4%, P = 0.089	-	-	-	-
Former-smokers	6	**2.71****	2.23–3.29	I^2 = 10.7%, P = 0.347	6	**2.71****	2.23–3.29	I^2 = 10.7%, P = 0.347	-	-	-	-
Current-smokers	4	**2.56****	2.07–3.17	I^2 = 0.0%, P = 0.940	4	**2.56****	2.07–3.17	I^2 = 0.0%, P = 0.940	-	-	-	-
≥ 55 years old	2	**2.41***	1.42–4.08	I^2 = 0.0%, P = 0.859	2	**2.41***	1.42–4.08	I^2 = 0.0%, P = 0.859	-	-	-	-
Non-small cell carcinoma[a]	7	**1.98****	1.41–2.77	I^2 = 0.0%, P = 0.717	6	**1.98****	1.41–2.80	I^2 = 0.0%, P = 0.595	-	-	-	-
Adenocarcinoma	6	1.15	0.82–1.62	I^2 = 0.0%, P = 0.535	5	1.24	0.86–1.79	I^2 = 0.0%, P = 0.577	-	-	-	-

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

Table 2. Continued

Previous lung disease	Overall				Studies from European-descendent majority regions				Asian studies			
	N	PSE	95% CI	Heterogeneity (I^2, p)	N	PSE	95% CI	Heterogeneity (I^2, p)	N	PSE	95% CI	Heterogeneity (I^2, p)
Squamous cell carcinoma	3	**2.38****	1.69–3.35	I^2 = 32.3%, P = 0.228	2	**2.08****	1.43–3.03	I^2 = 0.0%, P = 0.703	-	-	-	-
Carcinoma of other cell types[b]	2	**3.07***	1.35–7.03	I^2 = 0.0%, P = 0.620	2	**3.07***	1.35–7.03	I^2 = 0.0%, P = 0.620	-	-	-	-
< 10 years, tsd of lung disease	4	**2.31****	1.89–2.83	I^2 = 45.3%, P = 0.140	4	**2.31****	1.89–2.83	I^2 = 45.3%, P = 0.140	-	-	-	-
≥ 10 years, tsd of lung disease	4	**1.71***	1.11–2.65	I^2 = 68.2%, P = 0.024	4	**1.71***	1.11–2.65	I^2 = 68.2%, P = 0.024	-	-	-	-
COPD[c]												
Males	5	**2.94***	1.32–6.58	I^2 = 97.4%, P < 0.0005	-	-	-	-	4	**3.14***	1.22–8.09	I^2 = 97.1%, P < 0.0005
Females	8	**1.81***	1.24–2.64	I^2 = 91.3%, P < 0.0005	3	**2.08****	1.72–2.52	I^2 = 0.0%, P = 0.796	5	1.68	0.91–3.13	I^2 = 94.8%, P < 0.0005
Never-smokers	7	**1.71***	1.04–2.80	I^2 = 77.4%, P < 0.0005	4	**3.10****	2.26–4.25	I^2 = 5.8%, P = 0.364	3	1.14	0.87–1.51	I^2 = 0.0%, P = 0.379
Ever-smokers	6	**2.05****	1.41–2.99	I^2 = 91.2%, P < 0.0005	4	**2.44***	1.38–4.30	I^2 = 94.5%, P < 0.0005	2	**1.51****	1.21–1.88	I^2 = 0.0%, P = 0.879
Former-smokers	3	**1.85***	1.21–2.84	I^2 = 74.7%, P = 0.019	3	**1.85***	1.21–2.84	I^2 = 74.7%, P = 0.019	-	-	-	-
Current-smokers	4	**1.66***	1.23–2.23	I^2 = 74.3%, P = 0.009	3	**1.73***	1.12–2.66	I^2 = 82.8%, P = 0.003	-	-	-	-
< 55 years old	2	**1.55***	1.04–2.30	I^2 = 0.0%, P = 0.593	-	-	-	-	-	-	-	-
≥ 55 years old	5	**1.30***	1.05–1.61	I^2 = 64.8%, P = 0.023	3	**1.13****	1.06–1.21	I^2 = 0.0%, P = 0.388	2	2.26	0.66–7.75	I^2 = 84.5%, P = 0.011
Non-small cell carcinoma[a]	4	**1.79****	1.31–2.43	I^2 = 53.0%, P = 0.094	4	**1.79****	1.31–2.43	I^2 = 53.0%, P = 0.094	-	-	-	-
Adenocarcinoma	2	1.11	0.80–1.55	I^2 = 0.0%, P = 0.481	2	1.11	0.80–1.55	I^2 = 0.0%, P = 0.481	-	-	-	-
< 10 years, tsd of lung disease	4	**1.99***	1.29–3.07	I^2 = 97.7%, P < 0.0005	3	**1.86***	1.11–3.11	I^2 = 98.4%, P < 0.0005	-	-	-	-
≥ 10 years, tsd of lung disease	3	**2.15***	1.35–3.43	I^2 = 90.5%, P < 0.0005	2	**2.72****	1.70–4.34	I^2 = 87.1%, P = 0.005	-	-	-	-
Pneumonia												
Males	3	1.49	0.80–2.79	I^2 = 79.4%, P = 0.008	2	1.28	0.33–4.95	I^2 = 88.6%, P = 0.003	-	-	-	-
Females	12	**1.42****	1.26–1.59	I^2 = 49.8%, P = 0.025	8	**1.41***	1.14–1.75	I^2 = 57.9%, P = 0.020	4	**1.89****	1.40–2.54	I^2 = 0.0%, P = 0.800
Never-smokers	10	**1.33***	1.13–1.57	I^2 = 23.8%, P = 0.224	8	**1.32***	1.11–1.56	I^2 = 38.7%, P = 0.122	2	1.59	0.81–3.15	I^2 = 0.0%, P = 0.729
Ever-smokers	4	1.46	0.81–2.66	I^2 = 80.6%, P = 0.001	3	1.60	0.66–3.89	I^2 = 84.7%, P = 0.001	-	-	-	-
Former-smokers	3	1.18	0.62–2.23	I^2 = 62.8%, P = 0.068	3	1.18	0.62–2.23	I^2 = 62.8%, P = 0.068	-	-	-	-
Current-smokers	3	1.54	0.64–3.72	I^2 = 84.1%, P = 0.002	2	2.52	0.18–34.23	I^2 = 89.6%, P = 0.002	-	-	-	-
< 55 years old	2	1.89	0.81–4.39	I^2 = 71.7%, P = 0.060	-	-	-	-	-	-	-	-
≥ 55 years old	2	1.28	0.95–1.74	I^2 = 47.0%, P = 0.170	-	-	-	-	-	-	-	-
Non-small cell carcinoma[a]	10	**1.35****	1.20–1.52	I^2 = 39.1%, P = 0.097	9	**1.33****	1.17–1.51	I^2 = 43.4%, P = 0.078	-	-	-	-
Adenocarcinoma	9	**1.29****	1.14–1.46	I^2 = 15.9%, P = 0.301	8	**1.28****	1.13–1.45	I^2 = 24.0%, P = 0.238	-	-	-	-
Squamous cell carcinoma	3	**1.55***	1.00–2.38	I^2 = 74.6%, P = 0.020	2	1.48	0.85–2.59	I^2 = 87.0%, P = 0.006	-	-	-	-
Small cell carcinoma	2	0.97	0.71–1.33	I^2 = 0.0%, P = 0.399	2	0.97	0.71–1.33	I^2 = 0.0%, P = 0.399	-	-	-	-
Carcinoma of other cell types[b]	3	1.40	0.95–2.06	I^2 = 51.3%, P = 0.128	3	1.40	0.95–2.06	I^2 = 51.3%, P = 0.128	-	-	-	-
< 10 years, tsd of lung disease	7	**1.81***	1.24–2.66	I^2 = 94.1%, P < 0.0005	6	**1.68***	1.12–2.52	I^2 = 94.7%, P < 0.0005	-	-	-	-
≥ 10 years, tsd of lung disease	6	**1.20***	1.02–1.42	I^2 = 67.8%, P = 0.008	5	1.17	0.99–1.39	I^2 = 69.7%, P = 0.010	-	-	-	-
Tuberculosis												
Males	10	**1.89****	1.52–2.36	I^2 = 30.5%, P = 0.165	3	1.40	0.79–2.46	I^2 = 19.2%, P = 0.290	7	**2.00****	1.58–2.53	I^2 = 34.6%, P = 0.164
Females	18	**1.74****	1.49–2.03	I^2 = 36.8%, P = 0.060	7	**1.59***	1.18–2.15	I^2 = 0.0%, P = 0.555	11	**2.06****	1.52–2.81	I^2 = 53.6%, P = 0.018
Never-smokers	13	**1.98****	1.59–2.46	I^2 = 11.2%, P = 0.333	7	**1.49***	1.02–2.17	I^2 = 0.0%, P = 0.702	6	**2.28****	1.74–2.99	I^2 = 22.3%, P = 0.266
Ever-smokers	4	**1.63***	1.22–2.20	I^2 = 48.2%, P = 0.122	2	2.05	0.39–10.69	I^2 = 69.3%, P = 0.071	2	**1.97****	1.35–2.89	I^2 = 0.0%, P = 0.743
Former-smokers	2	1.90	0.29–12.54	I^2 = 75.0%, P = 0.046	2	1.90	0.29–12.54	I^2 = 75.0%, P = 0.046	-	-	-	-
Current-smokers	3	**1.93****	1.36–2.74	I^2 = 0.0%, P = 0.914	-	-	-	-	2	**1.97****	1.35–2.89	I^2 = 0.0%, P = 0.743
< 55 years old	2	3.46	0.90 –13.36	I^2 = 59.5%, P = 0.116	-	-	-	-	-	-	-	-
≥ 55 years old	2	**1.68***	1.14–2.48	I^2 = 24.8%, P = 0.249	-	-	-	-	-	-	-	-

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

Table 2. Continued

Previous lung disease	Overall				Studies from European-descendent majority regions				Asian studies			
	N	PSE	95% CI	Heterogeneity (I^2, p)	N	PSE	95% CI	Heterogeneity (I^2, p)	N	PSE	95% CI	Heterogeneity (I^2, p)
Non-small cell carcinoma[a]	10	**1.62***	1.14–2.30	I^2 = 55.4%, P = 0.017	7	**1.35***	1.01–1.80	I^2 = 40.4%, P = 0.122	3	1.93	0.86–4.36	I^2 = 78.0%, P = 0.011
Adenocarcinoma	10	**1.55***	1.19–2.02	I^2 = 43.2%, P = 0.070	7	1.35	0.95–1.91	I^2 = 26.5%, P = 0.226	3	2.16	0.81–5.75	I^2 = 68.3%, P = 0.043
Squamous cell carcinoma	5	**1.41***	1.00–2.01	I^2 = 17.6%, P = 0.303	3	1.35	0.81–2.28	I^2 = 11.0%, P = 0.325	2	1.39	0.65–3.01	I^2 = 60.9%, P = 0.110
Small cell carcinoma	3	1.56	0.76–3.20	I^2 = 30.3%, P = 0.238	2	0.79	0.25–2.55	I^2 = 0.0%, P = 0.370	-	-	-	-
Carcinoma of other cell types[b]	4	**2.37***	1.40–4.02	I^2 = 28.8%, P = 0.239	3	**1.85***	1.03–3.31	I^2 = 0.0%, P = 0.887	-	-	-	-
< 10 years, tsd of lung disease	5	2.45	0.78–7.66	I^2 = 90.1%, P < 0.0005	2	1.38	0.69–2.75	I^2 = 58.8%, P = 0.088	3	3.19	0.47–21.44	I^2 = 91.2%, P < 0.0005
≥ 10 years, tsd of lung disease	4	1.46	0.90–2.37	I^2 = 56.3%, P = 0.076	3	1.15	0.76–1.73	I^2 = 41.5%, P = 0.181	-	-	-	-
Hay fever												
Males	3	0.70	0.48–1.02	I^2 = 0.0%, P = 0.449	3	0.70	0.48–1.02	I^2 = 0.0%, P = 0.449	-	-	-	-
Females	4	0.69	0.27–1.76	I^2 = 69.3%, P = 0.021	4	0.69	0.27–1.76	I^2 = 69.3%, P = 0.021	-	-	-	-
Never-smokers	2	0.72	0.49–1.05	I^2 = 38.6%, P = 0.202	2	0.72	0.49–1.05	I^2 = 38.6%, P = 0.202	-	-	-	-
Ever-smokers	3	**0.55****	0.41–0.73	I^2 = 73.0%, P = 0.025	3	**0.55****	0.41–0.73	I^2 = 73.0%, P = 0.025	-	-	-	-
Former-smokers	2	**0.64***	0.49–0.83	I^2 = 56.5%, P = 0.130	2	**0.64***	0.49–0.83	I^2 = 56.5%, P = 0.130	-	-	-	-
Current-smokers	2	**0.59****	0.48–0.71	I^2 = 0.0%, P = 0.404	2	**0.59****	0.48–0.71	I^2 = 0.0%, P = 0.404	-	-	-	-
Non-small cell carcinoma[a]	2	**0.39****	0.26–0.56	I^2 = 0.0%, P = 0.908	2	**0.39****	0.26–0.56	I^2 = 0.0%, P = 0.908	-	-	-	-
Small cell carcinoma	2	0.73	0.25–2.15	I^2 = 63.6%, P = 0.097	2	0.73	0.25–2.15	I^2 = 63.6%, P = 0.097	-	-	-	-
< 10 years, tsd of lung disease	2	**0.59****	0.52–0.67	I^2 = 0.0%, P = 0.817	2	**0.59****	0.52–0.67	I^2 = 0.0%, P = 0.817	-	-	-	-
≥ 10 years, tsd of lung disease	2	**0.50***	0.33–0.76	I^2 = 60.9%, P = 0.110	2	**0.50***	0.33–0.76	I^2 = 60.9%, P = 0.110	-	-	-	-
Other lung diseases[d]												
Males	4	2.34	0.69–7.97	I^2 = 97.7%, P < 0.0005	-	-	-	-	3	2.56	0.63–10.51	I^2 = 98.4%, P < 0.0005
Females	5	**1.66****	1.33–2.06	I^2 = 43.3%, P = 0.133	2	**1.39***	1.04–1.86	I^2 = 0.0%, P = 0.580	3	**2.05****	1.49–2.83	I^2 = 45.3%, P = 0.160
Never-smokers	5	1.10	0.75–1.60	I^2 = 58.5%, P = 0.047	4	0.98	0.65–1.48	I^2 = 57.9%, P = 0.068	-	-	-	-
Ever-smokers	2	1.30	0.82–2.05	I^2 = 0.0%, P = 0.418	-	-	-	-	-	-	-	-
Non-small cell carcinoma[a]	7	**1.30***	1.09–1.55	I^2 = 0.0%, P = 0.509	4	1.24	0.99–1.56	I^2 = 11.5%, P = 0.335	3	**1.38***	1.05–1.82	I^2 = 0.0%, P = 0.463
Adenocarcinoma	7	**1.28***	1.03–1.58	I^2 = 25.3%, P = 0.236	4	1.26	0.98–1.63	I^2 = 34.6%, P = 0.204	3	1.31	0.87–1.97	I^2 = 41.4%, P = 0.181
Squamous cell carcinoma	3	**1.35***	1.00–1.82	I^2 = 0.0%, P = 0.747	-	-	-	-	2	**1.45***	1.00–2.10	I^2 = 0.0%, P = 0.699
Small cell carcinoma	2	1.16	0.66–2.03	I^2 = 0.0%, P = 0.522	-	-	-	-	-	-	-	-
Carcinoma of other cell types[b]	3	1.24	0.76–2.03	I^2 = 0.0%, P = 0.571	2	1.19	0.65–2.20	I^2 = 6.5%, P = 0.301	-	-	-	-
< 10 years, tsd of lung disease	4	**1.84****	1.44–2.34	I^2 = 47.6%, P = 0.126	3	**2.22****	1.63–3.02	I^2 = 3.3%, P = 0.356	-	-	-	-
≥ 10 years, tsd of lung disease	3	0.96	0.66–1.39	I^2 = 47.5%, P = 0.149	3	0.96	0.66–1.39	I^2 = 47.5%, P = 0.149	-	-	-	-

*P < 0.05;
**P < 0.001
PSE: pooled summary estimate; CI = confidence interval; COPD = chronic obstructive pulmonary disease; N = number of studies; P = P value; tsd = time since diagnosis
[a]Includes adenocarcinoma and squamous cell carcinoma.
[b]Includes other lung cancer cell type such as other unspecified cell type, and a combination of squamous, large, and small cell lung cancer.
[c]Includes six studies that reported chronic bronchitis and/or emphysema.
[d]Includes other lung diseases such as pleurisy, sarcoidosis, silicosis, fibrosis, allergies, rhinosinusitis, asbestosis, bulbar polio, influenza, lung infection, punctured lung, lung diseases due to external factors, interstitial lung disease, and other unspecified lung diseases.

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

(PSE= 1.79, 95% CI= 1.31–2.43). Further stratified analysis showed a significant association between history of COPD and lung cancer risk among Asian males (PSE= 3.14, 95% CI= 1.22–8.09), and among ever-smokers in Asian studies (PSE= 1.51, 95% CI= 1.21–1.88) (Table 2). Among studies from European-descendent majority regions, a significant association between history of COPD and lung cancer risk among ever-smokers (PSE= 2.44, 95% CI= 1.38–4.30), former smokers (PSE= 1.85, 95% CI= 1.21–2.84), current smokers (PSE= 1.73, 95% CI= 1.12–2.66), and older individuals aged ≥55 years old (PSE= 1.13, 95% CI= 1.06–1.21) (Table 2). Individuals with COPD diagnosis of more than 10 years prior to lung cancer diagnosis (PSE= 2.72, 95% CI= 1.70–4.34) have at least twofold RR of lung cancer as compared to individuals with COPD diagnosis within 1–10 years prior to lung cancer diagnosis (PSE= 1.86, 95% CI= 1.11–3.11) among studies from European-descendent majority regions (Table 2).

History of pneumonia and lung cancer risk

A significant positive association between history of pneumonia and lung cancer risk was found (PSE= 1.43, 95% CI= 1.23–1.66), and this association was significant among case–control studies (PSE= 1.49, 95% CI= 1.28–1.74) but not among cohort studies (PSE= 1.00, 95% CI= 0.80–1.25) (Table 1). The association between history of pneumonia and lung cancer risk was significant among females (PSE= 1.42, 95% CI= 1.26–1.59), never-smokers (PSE= 1.33, 95% CI= 1.13–1.57), individuals with pneumonia diagnosis within 1–10 years (PSE= 1.81, 95% CI= 1.24–2.66), and individuals with pneumonia diagnosis of more than 10 years (PSE= 1.20, 95% CI= 1.02–1.42) prior to lung cancer diagnosis (Table 2). Stratified analysis by lung cancer histology revealed a significant association between a history of pneumonia with risk of non-small cell carcinoma (PSE= 1.35, 95% CI= 1.20–1.52) but not with risk of small cell carcinoma (PSE= 0.97, 95% CI= 0.71–1.33) and carcinoma of other cell types (PSE= 1.40, 95% CI= 0.95–2.06) (Table 2). Among studies from European-descendent majority regions, significant association was found for individuals with pneumonia diagnosis within 1–10 years prior to lung cancer diagnosis (PSE= 1.68, 95% CI= 1.12–2.52) and lung cancer risk but no association was found with pneumonia diagnosis of more than 10 years prior to lung cancer (PSE= 1.17, 95% CI= 0.99–1.39) (Table 2).

History of tuberculosis and lung cancer risk

A significant positive association between history of tuberculosis and lung cancer risk was found (PSE= 1.85, 95% CI= 1.52–2.25), and this association was significant among case–control studies (PSE= 2.07, 95% CI= 1.68–2.56) but not among cohort studies (PSE= 1.07, 95% CI= 0.87–1.32) (Table 1). The association between history of tuberculosis and lung cancer risk was significant among males (PSE= 1.89, 95% CI= 1.52–2.36), females (PSE= 1.74, 95% CI= 1.49–2.03), never-smokers (PSE= 1.98, 95% CI= 1.59–2.46), ever-smokers (PSE= 1.63, 95% CI= 1.22–2.20), current smokers (PSE= 1.93, 95% CI= 1.36–2.74), and individuals aged ≥55 years old (PSE= 1.68, 95% CI= 1.14–2.48) (Table 2). No significant association was found between tuberculosis diagnosis within 1–10 years (PSE= 2.45, 95% CI= 0.78–7.66) and tuberculosis diagnosis of more than 10 years (PSE= 1.46, 95% CI= 0.90–2.37) prior to lung cancer diagnosis and lung cancer risk (Table 2). Stratified analysis by lung cancer histology found a significant association between a history of tuberculosis with risk of non-small cell carcinoma (PSE= 1.62, 95% CI= 1.14–2.30) and carcinoma of other cell types (PSE= 2.37, 95% CI= 1.40–4.02) (Table 2). Association between history of tuberculosis and risk of non-small cell carcinoma was significant among studies from European-descendent majority regions (PSE= 1.35, 95% CI= 1.01–1.80) but not among Asian studies (PSE= 1.93, 95% CI= 0.86–4.36) (Table 2). Among Asian studies, individuals with a history of tuberculosis have at least twofold RR of lung cancer in males (PSE= 2.00, 95% CI= 1.58–2.53), females (PSE= 2.06, 95% CI= 1.52–2.81), and never-smokers (PSE= 2.28, 95% CI= 1.74–2.99) (Table 2). No significant association was found between tuberculosis diagnosis within 1–10 years prior to lung cancer diagnosis and lung cancer risk among studies from European-descendent majority regions (PSE= 1.38, 95% CI= 0.69–2.75) and Asian studies (PSE= 1.15, 95% CI= 0.76–1.73). In addition, no significant association was found between tuberculosis diagnosis of more than 10 years prior to lung cancer diagnosis and lung cancer risk among studies from European-descendent majority regions (PSE= 3.19, 95% CI= 0.47–21.44) (Table 2).

History of hay fever and lung cancer risk

A significant inverse association was found between history of hay fever and lung cancer risk (PSE= 0.66, 95% CI= 0.54–0.81). The inverse association was significant among case–control studies (PSE= 0.63, 95% CI= 0.51–0.76) but not among cohort studies (PSE= 1.21, 95% CI= 0.66–2.20) (Table 1). The inverse association between history of hay fever and lung cancer risk was significant among ever-smokers (PSE= 0.55, 95% CI= 0.41–0.73), former smokers (PSE= 0.64, 95% CI= 0.49–0.83), current smokers (PSE= 0.59, 95% CI= 0.48–0.83), individuals with hay fever diagnosis both within 1–10 years (PSE= 0.59, 95% CI= 0.52–0.67), and individuals with hay fever diagnosis of more than 10 years (PSE= 0.50, 95% CI= 0.33–0.76) prior to lung cancer diagnosis (Table 2). Stratified analysis by lung cancer histology showed a significant inverse association between history of hay fever and risk of non-small cell carcinoma (PSE= 0.39, 95% CI= 0.26–0.56) but no significant association with small cell carcinoma risk (PSE= 0.73, 95% CI= 0.25–2.15) (Table 2).

Publication bias

Egger's tests for publication bias were not significant for these specific PLDs: asthma (p= 0.32), chronic bronchitis (p= 0.43), emphysema (p= 0.95), COPD (p= 0.20), pneumonia (p= 0.98), tuberculosis (p= 0.06), and hay fever (p= 0.76). However, publication bias was significant for other lung diseases (p= 0.008) by Egger's test. The funnel plots for the specific PLD appeared to be visually symmetrical for asthma, chronic bronchitis, emphysema, COPD, pneumonia, tuberculosis, and hay fever but not for other lung diseases (Supplementary Fig S1).

Discussion

In this systematic review and meta-analysis of 73 studies, a history of asthma, chronic bronchitis, emphysema, pneumonia, tuberculosis, and COPD was found to be significantly and positively associated with lung cancer risk. Similarly, a previous systematic review and meta-analysis on PLD and lung cancer risk conducted in 2011 (10) also found higher lung cancer risk for history of COPD, chronic bronchitis, emphysema, tuberculosis, and pneumonia. In comparison with that review (10) which identified 39 studies, approximately 50% of the studies (34 out of 73 studies) included in this review were new studies. Conversely, a history of hay fever was found to be associated with lower risk of lung cancer. Using stratified analysis, we found the association between history of any PLD and lung cancer risk to be stronger among Asian studies. Older age individuals and individuals with lung disease diagnosis within 1–10 years prior to lung cancer diagnosis have higher lung cancer risk as compared

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

with younger age individuals and individuals with lung disease diagnosis of more than 10 years prior to lung cancer diagnosis.

In this study, we found that a history of emphysema or COPD was found to be associated with at least twofold RR of lung cancer. Our finding was consistent with a previous meta-analysis which found an association between history of COPD, chronic bronchitis, or emphysema and lung cancer risk (10). Inflammation of lung tissue caused by lung diseases was identified as a potential mechanism (27,28). Matrix metalloproteinases in emphysema and COPD have been shown to be responsible for lung tumour initiation, development, invasion and metastasis (29,30). Matrix metalloproteinase-12 was demonstrated *in vivo* to drive inflammation in tobacco-smoke-induced emphysema in mice (30) and found to promote lesion expansion and destabilisation in *in vivo* models (29).

Interestingly, we found that a history of hay fever had a protective effect against lung cancer risk, which is consistent with previous studies. Allergic diseases have a protective effect against cancer occurrence according to the tumour immune surveillance hypothesis where the enhanced immune system is able to detect and destroy neoplastic cells in the body (31). A previous study found low mutagen sensitivity in lung cancer patients with a history of hay fever which was speculated to be a result of either genetic factors of hay fever or anti-inflammatory medication administered for hay fever that have protected cells from DNA damage (32). Among ever-smokers, we found that the protective effect of history of hay fever and lung cancer risk remained significant. The underlying mechanism for history of hay fever and lung cancer risk among ever-smokers has not been explored (33). Future studies could fill this void and examine the interaction of the effects of smoking, history of hay fever and lung cancer risk.

From our stratified analysis, we found that older individuals (aged ≥55 years old) with a history of asthma, chronic bronchitis, emphysema, COPD, or tuberculosis have a higher risk of lung cancer. Ageing is known to be a risk factor for lung diseases such as COPD, idiopathic pulmonary fibrosis, and lung cancer (34,35). Our finding was consistent with a population-based case–control study conducted in USA among non-smokers which found that older individuals (70 years old and above) with a history of emphysema, chronic bronchitis, or asthma were at higher risk of lung cancer (36). Animals with ageing lungs have been found to be susceptible to cell-autonomous changes and functions which limits lung repair as compared with young animals' lungs in *in vivo* studies (35). The effect of a history of emphysema, chronic bronchitis, or asthma coupled with old age is increased risk of lung cancer. Older individuals with a history of emphysema, chronic bronchitis, or asthma may benefit from having priority over younger individuals with the same diseases for lung cancer screening.

In our study, a diagnosis of asthma, emphysema, pneumonia, or other lung diseases within the past 1–10 years prior to lung cancer diagnosis was found to be associated with higher lung cancer risk. We found at least twofold RR of lung cancer with COPD diagnosis of more than 10 years prior to lung cancer diagnosis. Findings from previous studies were conflicting. Contrary to our findings, no significant association was found between chronic bronchitis diagnosis of within 10 years prior to lung cancer diagnosis and lung cancer risk in a United States case–control study (33). A population-based case–control study among women living in USA found higher lung cancer risk among individuals with chronic bronchitis diagnosis of 20 years and longer (37). A meta-analysis found increased lung cancer risk among individuals with tuberculosis diagnosis of 20 years and longer (9). We did not find these associations in our study. Etiologically, the biological mechanism of this observation is postulated to be the effect of lung scarring caused by lung diseases such as tuberculosis that increases with time (38), therefore, this may potentially explain the stronger association between history of COPD and lung cancer risk among individuals with COPD diagnosis of more than 10 years prior to lung cancer diagnosis. However, it is important to note that some lung diseases such as chronic bronchitis tend to be diagnosed earlier as compared with emphysema where symptoms are shown later (37).

A history of chronic bronchitis, emphysema, COPD, or tuberculosis was found to be associated with lung cancer risk in both ever-smokers and never-smokers, and this association is more prominent among ever-smokers for lung diseases such as chronic bronchitis, emphysema, and COPD. Stratified analyses in a previous meta-analysis found a significant association between history of pneumonia or tuberculosis and lung cancer risk among never-smokers (10). Ever-smokers with a history of COPD or emphysema have at least twofold RR of lung cancer. In particular, ever-smokers in Asia and Asian males with a history of COPD have a higher risk of lung cancer as compared with never-smokers in Asia and Asian females respectively. Tobacco smoking has been found to be a major risk factor for developing COPD and lung cancer (39). The RR of lung cancer is of at least threefold among Asian males with a history of COPD as compared with Asian females with a history of COPD. This could be attributed to a higher percentage of males who were ever-smokers as compared with females in Asia. A pooled meta-analysis of 20 prospective cohort studies conducted in Asia found that more Asian men were smokers as compared with Asian women, additionally, Asian men of the post-1930 birth cohort were found to start smoking at a younger age and were heavier smokers as compared with Asian men of the pre-1920 birth cohort (40). Previous studies have established the harmful effects of tobacco smoke on the risk of lung cancer (41) and tuberculosis (42) among Western and Asian populations, and the combined effect of tobacco smoke and PLD could result in elevated risk of lung cancer (43). Therefore, smoking cessation programs targeting male smokers should be developed to reduce the COPD and lung cancer burden in Asia.

Among never-smokers, we found that a history of asthma, chronic bronchitis, emphysema, pneumonia, COPD, or tuberculosis was positively associated with lung cancer risk. Our finding was consistent with a previous meta-analysis (10) and a previous consortium study (3) which reported a positive association between a history of pneumonia or tuberculosis and lung cancer risk among never-smokers. Asthma may increase lung cancer risk by limiting the clearance of inhaled toxins and carcinogens found in the bronchoalveolar epithelium (44). Pneumonia and tuberculosis cause inflammation in lung tissues which may increase genetic mutations, anti-apoptotic signalling, and angiogenesis resulting in lung tumorigenesis (45). Our study found a positive association between history of COPD and risk of lung cancer among never-smokers in studies from European-descendent majority regions but not among never-smokers in Asian studies. We also found a positive association between history of emphysema and lung cancer risk among never-smokers in studies from European-descendent majority regions. A previous meta-analysis found a potentially positive association between history of COPD/emphysema/chronic bronchitis and lung cancer risk among never-smokers at an attenuated significance level (10). Similarly, a previous largest pooled-analysis consortium study also found a positive association between history of emphysema and lung cancer risk among never-smokers from the European-descendent majority regions (3). Further conclusive evidence is needed for the association between history of COPD or emphysema and lung cancer risk among never-smokers in studies from European-descendent majority regions. Future

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

studies are warranted to examine the effects of history of COPD or emphysema and lung cancer risk among never-smokers from European-descendent majority regions.

Our study has several limitations. First, studies published in other languages were not searched and included, which limits the comprehensiveness of this review. Second, high levels of heterogeneity (I^2 > 75%) were detected in most of the analyses as studies varied in study design and sample demographics, which was accounted for using the random-effects model. Third, publication bias was detected in studies that reported a history of other lung disease(s), however, this was expected as different lung diseases were pooled in this analysis. Most studies only reported results for individual as opposed to combined PLDs. However, we did not find publication bias for the majority of the specific PLDs using the Egger's test. Fourth, inter-rater reliability for risk of bias assessment was low, this may be attributed to the limitation of the Newcastle–Ottawa scale as a previous study (46) reported that the scale lacked appropriate reporting of methodological details. Lastly, most studies that examined history of asthma and lung cancer risk did not differentiate between allergic asthma and non-allergic asthma but stated asthma in general, therefore, an in-depth analysis could not be conducted. Therefore, results of this review are to be interpreted with caution due to these limitations. However, this study provided a comprehensive review of the current literature on PLD and lung cancer risk, including both case–control and cohort study designs. We found a protective effect of history of hay fever on lung cancer risk which the previous meta-analysis did not include. Stratified analyses of history of specific PLD and lung cancer risk by sociodemographic characteristics and geographical region were conducted, providing further insights to healthcare professionals to identify vulnerable subpopulations with a history of specific PLD that are at higher risk of lung cancer. Additionally, our study highlighted potential research gaps that warrants future studies in examining the association of specific PLD and lung cancer risk.

PLD is associated with higher risk of lung cancer, across lung cancer subtypes and sociodemographic characteristics. Results from this meta-analysis suggest that individuals with PLD should be closely monitored and prioritised for screening of lung cancer, however, the cost-effectiveness should be evaluated prior to putting it into practice.

Supplementary material

Supplementary data are available at *Carcinogenesis* online.

Funding

Ministry of Education Tier 1 Grant FY2017.

Acknowledgements

None.
Conflict of Interest Statement: None declared.

Data availability

The data underlying this article are available in the article and in its online supplementary material.

References

1. Sung, H. *et al.* (2021) Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA. Cancer J. Clin.*, 71, 209–249.
2. Sciences, N.I.o.E.H. (2020) Lung Diseases. https://www.niehs.nih.gov/health/topics/conditions/lung-disease/index.cfm (7 March 2021, date last accessed).
3. Brenner, D.R. *et al.* (2012) Previous lung diseases and lung cancer risk: a pooled analysis from the International Lung Cancer Consortium. *Am. J. Epidemiol.*, 176, 573–585.
4. Denholm, R. *et al.* (2014) Is previous respiratory disease a risk factor for lung cancer? *Am. J. Respir. Crit. Care Med.*, 190, 549–559.
5. Akhtar, N. *et al.* (2017) Risk factors of lung cancer in nonsmoker. *Curr. Probl. Cancer*, 41, 328–339.
6. Osann, K.E. (1991) Lung cancer in women: the importance of smoking, family history of cancer, and medical history of respiratory disease. *Cancer Res.*, 51, 4893–4897.
7. Koo, L.C. *et al.* (1985) An analysis of some risk factors for lung cancer in Hong Kong. *Int. J. Cancer*, 35, 149–155.
8. Zhang, X. *et al.* (2017) Chronic obstructive pulmonary disease and risk of lung cancer: a meta-analysis of prospective cohort studies. *Oncotarget*, 8, 78044–78056.
9. Liang, H.Y. *et al.* (2009) Facts and fiction of the relationship between preexisting tuberculosis and lung cancer risk: a systematic review. *Int. J. Cancer*, 125, 2936–2944.
10. Brenner, D.R. *et al.* (2011) Previous lung diseases and lung cancer risk: a systematic review and meta-analysis. *PLoS One*, 6, e17479.
11. Rosenberger, A. *et al.* (2012) Asthma and lung cancer risk: a systematic investigation by the International Lung Cancer Consortium. *Carcinogenesis*, 33, 587–597.
12. Moher, D. *et al.*; PRISMA Group. (2010) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int. J. Surg.*, 8, 336–341.
13. World Health Organization. (2016) International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) - WHO Version for 2016. https://icd.who.int/browse10/2016/en#/X World Health Organization (3 January 2021, date last accessed).
14. Wells, G., *et al.* The Newcastle-Ottawa scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp (27 March 2021, date last accessed).
15. Ang, L., *et al.* (2020) Association between family history of lung cancer and lung cancer risk: a systematic review and meta-analysis. *Lung Cancer*, 148, 129–137.
16. Higgins, J.P. *et al.* (2002) Quantifying heterogeneity in a meta-analysis. *Stat. Med.*, 21, 1539–1558.
17. Egger, M. *et al.* (1997) Bias in meta-analysis detected by a simple, graphical test. *BMJ*, 315, 629–634.
18. Wong, J.Y.Y. *et al.* (2017) Lung cancer risk in welders and foundry workers with a history of heavy smoking in the USA: the National Lung Screening Trial. *Occup. Environ. Med.*, 74, 440–448.
19. Liu, Z.Y. *et al.* (1991) Smoking and other risk factors for lung cancer in Xuanwei, China. *Int. J. Epidemiol.*, 20, 26–31.
20. Qiao, Y.L. *et al.* (1997) Risk factors and early detection of lung cancer in a cohort of Chinese tin miners. *Ann. Epidemiol.*, 7, 533–541.
21. El-Zein, M. *et al.* (2014) History of allergic diseases and lung cancer risk. *Ann. Allergy. Asthma Immunol.*, 112, 230–236.
22. El-Zein, M. *et al.* (2010) History of asthma or eczema and cancer risk among men: a population-based case–control study in Montreal, Quebec, Canada. *Ann. Allergy. Asthma Immunol.*, 104, 378–384.
23. Kantor, E.D. *et al.* (2019) Allergies and Asthma in relation to cancer risk. *Cancer Epidemiol. Biomarkers Prev.*, 28, 1395–1403.
24. Koshiol, J. *et al.* (2010) Lower risk of lung cancer after multiple pneumonia diagnoses. *Cancer Epidemiol. Biomarkers Prev.*, 19, 716–721.
25. Kreuzer, M. *et al.* (2001) Lung cancer in lifetime nonsmoking men - results of a case–control study in Germany. *Br. J. Cancer*, 84, 134–140.
26. Shebl, F.M. *et al.* (2010) Pulmonary infections and risk of lung cancer among persons with AIDS. *J. Acquir. Immune Defic. Syndr.*, 55, 375–379.
27. Brody, J.S. *et al.* (2006) State of the art. Chronic obstructive pulmonary disease, inflammation, and lung cancer. *Proc. Am. Thorac. Soc.*, 3, 535–537.
28. Moldoveanu, B. *et al.* (2009) Inflammatory mechanisms in the lung. *J. Inflamm. Res.*, 2, 1–11.
29. Nagase, H. *et al.* (1999) Matrix metalloproteinases. *J. Biol. Chem.*, 274, 21491–21494.

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023

30. Churg, A., *et al.* (2012) Matrix metalloproteinases in COPD. *Eur. Respir. J.,* 39, 197–209.
31. Swann, J.B. *et al.* (2007) Immune surveillance of tumors. *J. Clin. Invest.,* 117, 1137–1146.
32. Wu, X. *et al.* (2007) Interplay between mutagen sensitivity and epidemiological factors in modulatinglung cancer risk. *Int. J. Cancer,* 120, 2687–2695.
33. Schabath, M.B. *et al.* (2005) Opposing effects of emphysema, hay fever, and select genetic variants on lung cancer risk. *Am. J. Epidemiol.,* 161, 412–422.
34. Meiners, S. *et al.* (2015) Hallmarks of the ageing lung. *Eur. Respir. J.,* 45, 807–827.
35. Rojas, M. *et al.* (2015) Aging and lung disease. Clinical impact and cellular and molecular pathways. *Ann. Am. Thorac. Soc.,* 12, S222–S227.
36. Mayne, S.T. *et al.* (1999) Previous lung disease and risk of lung cancer among men and women nonsmokers. *Am. J. Epidemiol.,* 149, 13–20.
37. Schwartz, A.G. *et al.* (2009) Chronic obstructive lung diseases and risk of non-small cell lung cancer in women. *J. Thorac. Oncol.,* 4, 291–299.
38. Auerbach, O. *et al.* (1979) Scar cancer of the lung: increase over a 21 year period. *Cancer,* 43, 636–642.
39. Andreas, S. *et al.* (2007) [Smoking, chronic obstructive pulmonary disease and lung cancer]. *Pneumologie,* 61, 590–594.
40. Yang, J.J. *et al.* (2019) Tobacco smoking and mortality in Asia: a pooled meta-analysis. *JAMA Netw. Open,* 2, e191474.
41. Stellman, S.D. *et al.* (2001) Smoking and lung cancer risk in American and Japanese men: an international case–control study. *Cancer Epidemiol. Biomarkers Prev.,* 10, 1193–1199.
42. Bates, M.N. *et al.* (2007) Risk of tuberculosis from exposure to tobacco smoke: a systematic review and meta-analysis. *Arch. Intern. Med.,* 167, 335–342.
43. Organization, W.H. (2007) *A WHO/The Union monograph on TB and tobacco control: joining efforts to control two related global epidemics*. WHO Press, Geneva, Switzerland. https://www.who.int/tobacco/resources/publications/tb_tobac_monograph.pdf (11 March 2021, date last accessed).
44. Santillan, A.A. *et al.* (2003) A meta-analysis of asthma and risk of lung cancer (United States). *Cancer Causes Control,* 14, 327–334.
45. Kundu, J.K. *et al.* (2008) Inflammation: gearing the journey to cancer. *Mutat. Res.,* 659, 15–30.
46. Lo, C.K.-L., *et al.* (2014) Newcastle-Ottawa Scale: comparing reviewers' to authors' assessments. *BMC Med. Res. Methodol.,* 14, 45.

Downloaded from https://academic.oup.com/carcin/article/42/12/1461/6364950 by guest on 26 April 2023