Cancers in Australia in 2010 attributable to tobacco smoke

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The United States Surgeon General first concluded that tobacco smoke was the likely cause of lung cancer in 1957 and issued a definitive report in 1964 stating that cigarette smoking was causally related to lung cancer, noting that the magnitude of the effect of smoking far outweighed all other factors.1 Other cancers have since been causally related to smoking. In their first monograph dedicated to tobacco smoking in 1986, the International Agency for Research on Cancer (IARC) declared that there was sufficient evidence that tobacco smoking causes cancers of the lung, bladder, renal pelvis, oral cavity, oropharynx, hypopharynx, oesophagus, larynx and pancreas.2 Based on further evidence, subsequent monographs in 20043 and 20124 added nasopharynx, nasal cavity and sinuses, stomach, kidney (body), uterine cervix, myeloid leukaemia, colorectum, and ovary (mucinous) to this list. IARC also concluded that second-hand smoke causes lung cancer.1,4 In addition, there is sufficient evidence to show that parental smoking (of mother and/or father during both the preconception period and pregnancy) causes hepatoblastoma, a rare embryonic cancer.4

The mechanisms through which smoking causes cancer are complex. Tobacco smoke releases more than 5,300 compounds, including neutral gases, carbon and nitrogen oxides, amides, aldehydes, phenols and nitrosamines.4 More than 70 carcinogens have been identified in tobacco smoke, of which 16 have been formally evaluated as being carcinogenic to humans. Many of the carcinogens from tobacco smoke are absorbed into the blood stream and carried to distant organs; hence, the effects are not restricted to the airways. The carcinogens in tobacco smoke considered to make the greatest contribution to human disease are polycyclic aromatic hydrocarbons (PAHs), N-nitrosamines, aromatic amines, aldehydes and certain volatile organic compounds.4 Cell culture and animal studies confirm that tobacco smoke is highly mutagenic, causing frameshift mutations, base-substitution mutations and sister chromatid exchanges. Emerging data from mutation databases demonstrate that lung tumours in smokers have significantly higher prevalence of mutations in TP53, K-RAS and loss of heterozygosity at FHIT than those in non-smokers. In addition to these specific genotoxic events, there is strong evidence that tobacco smoke has adverse effects on cell proliferation, differentiation, inflammation and apoptosis.

We calculated the proportion of cancers attributable to tobacco smoking for all of the cancers listed by IARC as causally related to smoking, except hepatoblastoma. The incidence of hepatoblastoma in Australia is very low; only eight cases were diagnosed

Abstract

Objectives: To estimate the population attributable fraction (PAF) and numbers of cancers occurring in Australia in 2010 attributable to tobacco smoking, both personal and by a partner.

Methods: We used a modified Peto-Lopez approach to calculate the difference between the number of lung cancer cases observed and the number expected assuming the entire population developed lung cancer at the same rate as never smokers. For cancers other than lung, we applied the standard PAF formula using relative risks from a large cohort and derived notional smoking prevalence. To estimate the PAF for partners’ smoking, we used the standard formula incorporating the proportion of non-smoking Australians living with an ever-smoking partner and relative risks associated with partner smoking.

Results: An estimated 15,525 (13%) cancers in Australia in 2010 were attributable to tobacco smoke, including 8,324 (81%) lung, 1,973 (59%) oral cavity and pharynx, 855 (60%) oesophagus and 951 (6%) colorectal cancers. Of these, 136 lung cancers in non-smokers were attributable to partner tobacco smoke.

Conclusions: More than one in eight cancers in Australia is attributable to tobacco smoking and would be avoided if nobody smoked.

Implications: Strategies to reduce the prevalence of smoking remain a high priority for cancer control.

Key words: population attributable fraction, cancer, risk factor, tobacco use, second-hand smoke
Cancers in Australia in 2010

Each year on average between 1997 and 2006, we calculated the proportion of lung cancers in non-smokers attributable to exposure to cigarette smoke from a smoking partner living in the home.

Methods

Tobacco smoking

To calculate the population attributable fraction (PAF) and number of cancers attributable to tobacco smoking, we used the method developed by Petto and Lopez and refined by Parkin in the United Kingdom burden of cancer project. This approach was developed to overcome the complexities of estimating the proportions of former and current smokers when the strengths of the smoking-cancer associations differ depending on the duration and intensity of past smoking. It assumes that tobacco smoking is by far the most important cause of lung cancer, that the incidence of lung cancer among non-smokers is small (and similar across populations), and that the incidence of lung cancer is determined almost entirely by the cumulative exposure of any given population to tobacco smoke. Thus, the number of cancer cases attributable to smoking is the difference between the number of cancer cases observed in the population and the number expected if the entire population developed cancer at the same incidence rate as ‘never smokers’.

The calculations require, from the same population, incidence rates of lung cancer in never smokers and relative risks of specific cancers in smokers relative to never-smokers. As for both Parkin and Petto and Lopez, we used data from the American Cancer Society’s second Cancer Prevention Study (CPS II) in our primary analyses. The CPS II is a prospective cohort study with approximately 1.2 million participants, aged 30 years and over at recruitment in 1982 (median age: 57yrs). Incidence rates of lung cancer in never smokers were sourced from Parkin who estimated these rates from death rates in the CPS II study for the follow-up period of 1982–2002.

We conducted a sensitivity analysis using Australian data from the Melbourne Collaborative Cohort Study (MCCS) for incidence rates of lung cancer in never smokers. The MCCS is a prospective cohort study of approximately 40,000 participants over at recruitment in 1982 (median age: 56 yrs) at recruitment (1990–1994). The follow-up for incident cancers in the MCCS analysis was the minimum of either diagnosis of cancer of interest, or the date of death, or the date of emigration from Australia, or 10 years post-baseline attendance. The average follow-up time for lung cancer, for example, was 9.23 years. We used MCCS data for sensitivity analyses rather than the primary analyses due to the small number of cancers diagnosed during the follow-up period and the restricted age group. The sample used to calculate incidence rates of lung cancer in never-smokers and the relative risks was 40,164 (41% men, 59% women); 25% of participants were of Southern European origin. Where relative risks for site-specific cancers from the MCCS were less than 1.0 (stomach, ovary (mucinous) and myeloid leukaemia), we used the relative risks from CPS II.

Relative risk estimates

For comparability with the UK PAF project, we used the relative risks of death from cancer for current smokers at baseline versus never smokers, summarised in Table 1. While the relative risks for cancer mortality are likely conservative for cancer incidence, they have the advantage of being derived from a well-characterised cohort with a long duration of follow-up and a sample size sufficiently large to generate precise estimates of risk for less common cancers. For all these reasons, the mortality risk estimates of this cohort were considered the most desirable for our purposes. The only exception was for mucinous cancer of the ovary, a site for which no risk estimates have been published from the CPS II cohort. For that cancer site, we used the relative risk estimate for cancer incidence (not mortality) from a meta-analysis by Jordan and colleagues. As above, we conducted sensitivity analyses using relative risks for incident (as opposed to fatal) cancers from the MCCS for each of the specified sites for current smokers versus never smokers (Table 1).

Statistical analysis

The number of lung cancer cases expected in Australian adults in the absence of smoking was calculated by applying the estimated incidence rates of lung cancer in never smokers in the CPS II study to

| Cancer (ICD-10 code) | Source | Study (follow-up period) | Relative Risks | Sensitivity analysis |
|----------------------|--------|--------------------------|----------------|---------------------|
|                      |        |                          | Males | Females | Study (follow-up period) | Males | Females |
| oral cavity and pharynx (C00-C14) | US Department of Health and Human Services | CPS II (1982-1988) | 10.9 | 5.1 | MCCS (average 10 yrs) | 12 | 2.84 |
| oesophagus (C15) | US Department of Health and Human Services | CPS II (1982-1988) | 6.8 | 7.8 | MCCS (average 10 yrs) | 12 | 3.96 |
| stomach (C16) | Ezzati et al. (2005) | CPS II (1982-1988) | 2.2 | 1.5 | MCCS (1982-1988) | 12 | 2.2 (M) 1.5 (F) |
| colorectum (C18-C20) | Hannan et al. (2009) | CPS II Nutrition Cohort (1992-2005) | 1.2 | 1.3 | MCCS (average 10 yrs) | 12 | 1.09 |
| liver (C22) | Ezzati et al. (2005) | CPS II (1982-1988) | 2.3 | 1.5 | MCCS (average 10 yrs) | 12 | 4.14 |
| pancreas (C25) | Ezzati et al. (2005) | CPS II (1982-1988) | 2.2 | 2.2 | MCCS (average 10 yrs) | 12 | 1.15 |
| larynx (C32) | US Department of Health and Human Services | CPS II (1982-1988) | 14.6 | 13.0 | MCCS (average 10 yrs) | 12 | 4.69 |
| lung (C34) | Ezzati et al. (2005) | CPS II (1982-1988) | 21.3 | 12.5 | MCCS (average 10 yrs) | 12 | 23.14 |
| uterine cervix (C53) | Ezzati et al. (2005) | CPS II (1982-1988) | 1.5 | | MCCS (average 10 yrs) | 12 | 1.12 |
| ovary (mucinous) (C56) | Jordan et al. (2006) | Meta-analysis of 1 cohort, 6 case-control, and 1 pooled analysis of case-control studies | 2.1 | | Meta-analysis of 1 cohort, 6 case-control, and 1 pooled analysis of case-control studies | 2.1 |
| urinary bladder (C67) | Ezzati et al. (2005) | CPS II (1982-1988) | 3.0 | 2.4 | MCCS (average 10 yrs) | 12 | 3.37 |
| kidney and ureter (C64-C66) | Ezzati et al. (2005) | CPS II (1982-1988) | 2.5 | 1.5 | MCCS (average 10 yrs) | 12 | 1.17 |
| myeloid leukaemia (C92) | Ezzati et al. (2005) | CPS II (1982-1988) | 1.9 | 1.2 | MCCS (1982-1988) | 12 | 1.9 (M) 1.2 (F) |

**Abbreviations:** CPS II: American Cancer Society’s Second Cancer Prevention Study, MCCS: Melbourne Collaborative Cohort Study, M: male, F: female.

* Based on 677 cases in never smokers in the MCCS.
the population of Australia in 2010. The number and percentage of lung cancer cases attributable to smoking was then calculated by subtracting the expected number of cases from those actually observed in 2010.17

The Peto-Lopez method could not be used for other sites, as estimates of cancer incidence in never smokers for other sites were not available. So, to be able to apply the standard PAF formula for the remaining cancer sites, we estimated the 'notional prevalence' ($P_n$) of smoking for each age and sex category in the Australian population. The notional prevalence is an abstract construct that reflects the average past smoking experience of the population. Thus, $P_n$ is the prevalence of smoking necessary to produce the incidence of cancer observed in the Australian population assuming the relative risks of the CPS II study had persisted. Essentially, it cumulates the person-time contributions of former smokers and current smokers into a single quantity. We calculated notional prevalence using the formula:6,7

$$P_n = \frac{I_o - I_e}{I_e (RR_{lung} - 1)}$$

where $I_o$ is the observed incidence of lung cancer, $I_e$ is the incidence expected in the absence of smoking and $RR_{lung}$ is the relative risk of lung cancer in current smokers versus never smokers from the CPS II study.

The notional prevalences of smoking in Australia are presented in Table 2. Using these notional prevalences and the relative risks for the additional cancers listed in Table 1, we used the standard formula to estimate the PAFs for each cancer site.18

$$PAF = \frac{\sum (p_e \times ERR)}{1 + \sum (p_e \times ERR)}$$

where $p_e$ is the notional prevalence of smoking in the population and ERR the excess relative risk (RR–1) of cancer associated with current smoking.

To obtain the numbers of cancers attributable to smoking, the PAFs were multiplied by the total numbers of incident cancers at each site.

**Exposure to partner smoking in the home**

Estimating the fraction of cancer among never smokers attributable to smoking by others requires estimates of the relative risks of cancer from this pattern of tobacco smoke exposure, as well as the prevalence of exposure to other people's smoke. The most robust estimates of the effect of ‘second-hand’ smoke arise from studies reporting risks of lung cancer among never smokers who have lived with a smoking partner. We therefore restricted this analysis to estimate the number of cancers attributable to smoking among non-smokers currently living with a smoking partner, as described below.

**Relative risks**

Relative risks for lung cancer among never-smokers exposed to tobacco smoke from a smoking partner were obtained from pooled estimates published by the World Health Organization and IARC in 2004.4 Based on the results of 11 studies (442 lung cancer cases), the pooled relative risk for males was 1.37 (95%CI 1.02–1.82, p=0.03). For females, the pooled relative risk was 1.24 (95%CI 1.14–1.34, p<0.001) based on the results of 46 studies (6,257 lung cancer cases).3

**Prevalence estimates**

We estimated the numbers of non-smoking Australians residing with a smoking partner using marital (and co-habiting) status data from the 2011 Population Census19 and smoking status data from the 2011-12

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### Table 2: Estimated notional prevalence (%) of smoking by age and sex: Australia 2010 and observed smoking prevalence, National Health Survey (NHS) 2007-08.

| Age group (years) | Observed smoking prevalence (%) NHS 2007-08a | Estimated notional prevalence (%) |
|------------------|--------------------------------|----------------------------------|
|                  | Current Smoker | Ex-Smoker | Current Smoker | Ex-Smoker |
|                  | Males | Females | Males | Females | Males | Females |
| 0-14             | 20    | 17     | 0    | 0      | 0    | 0      |
| 15-24            | 22    | 19     | 0    | 0      | 0    | 0      |
| 25-34            | 33    | 26     | 0    | 0      | 0    | 0      |
| 35-44            | 28    | 22     | 0    | 0      | 0    | 0      |
| 45-54            | 24    | 19     | 0    | 0      | 0    | 0      |
| 55-64            | 16    | 12     | 0    | 0      | 0    | 0      |
| 65-74            | 12    | 9      | 0    | 0      | 0    | 0      |
| 75+              | 7     | 5      | 0    | 0      | 0    | 0      |

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### Table 3: Population attributable fraction (PAF) and estimated number of lung cancers (C34) diagnosed in Australia in 2010 attributable to tobacco smoking.

| Age group (years) | Population (’000s) | Observed Incidence (per 10^5/yr) | Cases Observed | Expected Incidenceb (per 10^5/yr) | Cancers Expectedc | Excess Cancersd | PAF* |
|------------------|---------------------|--------------------------------|----------------|--------------------------------|------------------|----------------|------|
| Males            |                     |                                |                |                                  |                  |                |      |
| 0-14             | 2,171               | 0.1                            | 1              | 0.0                            | 0                | 1              | 0.0  |
| 15-24            | 1,620               | 0.1                            | 2              | 0.0                            | 0                | 2              | 0.0  |
| 25-34            | 1,613               | 0.7                            | 7              | 0.7                            | 0                | 0              | 0.0  |
| 35-44            | 1,575               | 4.7                            | 74             | 2.9                            | 46               | 28             | 38.1 |
| 45-54            | 1,508               | 26.5                           | 399            | 6.0                            | 91               | 308            | 77.2 |
| 55-64            | 1,260               | 100.4                          | 1,265          | 14.1                           | 178              | 1,087          | 85.9 |
| 65-74            | 794                 | 250.6                          | 1,990          | 33.0                           | 262              | 1,728          | 86.8 |
| 75+              | 583                 | 428.3                          | 2,498          | 75.8                           | 442              | 2,056          | 82.3 |
| Total            | 11,124              | 56.1                           | 6,240          | -                              | 1,030            | 5,210          | 83.5 |

### Females

|                  |                     |                                |                |                                  |                  |                |      |
|                  | 2,060               | 0.1                            | 2              | 0.0                            | 0                | 2              | 0.0  |
| 15-24            | 1,530               | 0.2                            | 3              | 0.0                            | 0                | 3              | 0.0  |
| 25-34            | 1,586               | 0.5                            | 9              | 0.5                            | 0                | 0              | 0.0  |
| 35-44            | 1,594               | 4.6                            | 74             | 3.8                            | 60               | 14             | 18.8 |
| 45-54            | 1,537               | 20.9                           | 321            | 7.4                            | 114              | 207            | 64.5 |
| 55-64            | 1,278               | 67.8                           | 866            | 14.7                           | 188              | 678            | 78.3 |
| 65-74            | 826                 | 150.3                          | 1,241          | 28.9                           | 239              | 1,002          | 80.7 |
| 75+              | 806                 | 189.4                          | 1,526          | 56.3                           | 454              | 1,072          | 70.3 |
| Total            | 11,218              | 36.0                           | 4,042          | -                              | 1,064            | 2,978          | 73.7 |

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Grand total: 10,282, 2,094, 8,188, 79.6
Results

Tobacco smoking

An estimated 8,188 lung cancer cases (5,210 in men and 2,978 in women) from a total of 10,282 diagnosed in Australia in 2010 were attributable to tobacco smoking (Table 3). The corresponding PAFs were 84% in men and 74% in women. A further 7,201 cancers at 12 cancer sites other than lung (5,183 in men and 2,018 in women) from a total of 34,248 diagnosed were also attributable to smoking. Cancers other than lung with the highest PAFs were larynx (77%), followed by oesophagus (60%), oral cavity and pharynx (59%) and bladder (32%). Cancers other than lung with the greatest number of estimated cases attributable to smoking in 2010 were oral cavity and pharynx (1,973), colorectum (951) and oesophagus (853) (Table 4). Overall then, we estimated a total of 15,389 cases of cancer across thirteen sites in 2010 were attributable to tobacco smoking. This was 13% of all cancer cases (excluding basal cell and squamous cell carcinomas of the skin), 16% in males and 10% in females.

In sensitivity analyses using data from the MCCS and restricted to age groups 40–69 years, we estimated that the total number of cancers attributable to smoking was 6,284, or about 12% lower than the number estimated in the primary analyses for the same age groups (n=7,160) (Table 5). This was because several common cancers (oral cavity, pharynx, larynx, oesophagus, colorectum)
Table 5: Sensitivity Analysis: comparison of results using data from the Melbourne Collaborative Cohort Study (MCCS) and the American Cancer Society's Second Cancer Prevention Study (CPSII) (restricted to age groups 40-69 yrs).

| Males (40-69 yrs) | Observed Cases | Sensitivity Analysis | Primary Analysis |
|-------------------|---------------|---------------------|------------------|
|                   | (2010)        | Excess cases due to tobacco | % observed cases due to tobacco | Excess cases due to tobacco | % observed cases due to tobacco |
| Oral cavity & pharynx (C00-C14) | 1,559 | 458 | 29.4 | 902 | 57.9 |
| Oesophagus (C15) | 515 | 237 | 46.0 | 290 | 56.4 |
| Stomach (C16) | 600 | 86 | 14.4 | 138 | 23.1 |
| Colorectum (C18-C20) | 4,099 | 127 | 3.1 | 243 | 5.9 |
| Liver (C22) | 588 | 251 | 42.7 | 135 | 22.9 |
| Pancreas (C25) | 621 | 32 | 5.1 | 147 | 23.6 |
| Larynx (C32) | 305 | 157 | 51.5 | 222 | 72.9 |
| Lung (C34) | 2,636 | 2,354 | 89.3 | 2,219 | 84.2 |
| Kidney and ureter (C64-C66) | 1,091 | 53 | 4.9 | 272 | 24.9 |
| Bladder (C67) | 597 | 262 | 43.9 | 206 | 34.6 |
| Myeloid leukaemia (C92) | 322 | 19 | 5.8 | 53 | 16.6 |
| All cancers* in males 40-69 yrs | 34,378 | 4,036 | 11.7 | 4,827 | 14.0 |

| Females (40-69 yrs) | Observed Cases | Sensitivity Analysis | Primary Analysis |
|---------------------|---------------|---------------------|------------------|
|                   | (2010)        | Excess cases due to tobacco | % observed cases due to tobacco | Excess cases due to tobacco | % observed cases due to tobacco |
| Oral cavity & pharynx (C00-C14) | 504 | 168 | 33.3 | 245 | 48.6 |
| Oesophagus (C15) | 147 | 75 | 51.3 | 96 | 65.1 |
| Stomach (C16) | 251 | 39 | 15.7 | 30 | 11.9 |
| Colorectum (C18-C20) | 2,790 | 99 | 3.6 | 218 | 7.8 |
| Liver (C22) | 148 | 73 | 49.4 | 18 | 12.4 |
| Pancreas (C25) | 420 | 26 | 6.2 | 108 | 25.8 |
| Larynx (C32) | 41 | 22 | 52.1 | 31 | 74.5 |
| Lung (C34) | 1,842 | 1,567 | 85.1 | 1,391 | 75.5 |
| Uterine Cervix (C53) | 429 | 12 | 2.7 | 38 | 8.9 |
| Ovary (C56) | 692 | 19 | 2.7 | 17 | 2.5 |
| Kidney and ureter (C64-C66) | 593 | 35 | 5.8 | 69 | 11.6 |
| Bladder (C67) | 205 | 99 | 48.4 | 61 | 29.6 |
| Myeloid leukaemia (C92) | 234 | 14 | 6.1 | 11 | 4.7 |
| All cancers* in females 40-69 yrs | 26,856 | 2,248 | 8.4 | 2,333 | 8.7 |

| Persons (40-69 yrs) | Observed Cases | Sensitivity Analysis | Primary Analysis |
|---------------------|---------------|---------------------|------------------|
|                   | (2010)        | Excess cases due to tobacco | % observed cases due to tobacco | Excess cases due to tobacco | % observed cases due to tobacco |
| Oral cavity & pharynx (C00-C14) | 2,063 | 626 | 30.3 | 1,147 | 55.6 |
| Oesophagus (C15) | 662 | 312 | 47.2 | 386 | 58.3 |
| Stomach (C16) | 851 | 125 | 14.8 | 168 | 19.8 |
| Colorectum (C18-C20) | 6,889 | 226 | 3.3 | 461 | 6.7 |
| Liver (C22) | 736 | 324 | 44.0 | 153 | 20.8 |
| Pancreas (C25) | 1,040 | 58 | 5.5 | 255 | 24.5 |
| Larynx (C32) | 346 | 179 | 51.6 | 253 | 73.1 |
| Lung (C34) | 4,478 | 3,921 | 87.6 | 3,610 | 80.6 |
| Uterine Cervix (C53) | 429 | 12 | 2.7 | 38 | 8.9 |
| Ovary (C56) | 692 | 19 | 2.7 | 17 | 2.5 |
| Kidney and ureter (C64-C66) | 1,685 | 88 | 5.2 | 341 | 20.2 |
| Bladder (C67) | 802 | 361 | 45.0 | 267 | 33.3 |
| Myeloid leukaemia (C92) | 556 | 33 | 5.9 | 64 | 11.6 |
| All cancers* in persons 40-69 yrs | 61,234 | 6,284 | 10.3 | 7,160 | 11.7 |

* excluding basal cell and squamous cell carcinomas of the skin
a: Using incidence rates of lung cancer in never smokers and relative risks of specific cancers in smokers relative to smokers from the MCCS (except for stomach, ovary and myeloid leukaemia)
b: Using incidence rates of lung cancer in never smokers and relative risks of specific cancers in smokers relative to smokers from the CPS II Study

due to tobacco

Exposure to smoking by a partner

We estimated that about 17% of non-smoking men and 25% of non-smoking women in Australia resided with a partner who had ever smoked (Table 6). Using these estimates, 136 lung cancer cases diagnosed in never smokers in 2010 (63 in men and 73 in women) were attributable to smoking by a partner. This corresponds to 6.1% and 6.7% of lung cancers arising in never smoking men and women respectively.

Discussion

About 13% of all cancer cases occurring in Australia in 2010 (excluding basal cell and squamous cell carcinomas of the skin) were attributable to tobacco. Of the more than 15,500 cases of cancer attributable to tobacco, more than half (~8,300) were cancers of the lung, including about 130 due to smoking by a partner (about 6% of lung cancers occurring in never smokers). The PAFs appeared to differ slightly for men and women, accounting for 84% and 74% of lung cancer cases respectively. For cancers other than lung, PAFs were highest for larynx (77%), oesophagus (60%) and oral cavity and pharynx (59%), while in absolute terms the greatest number of cases attributable to smoking occurred in the oral cavity and pharynx (1,973).

Our findings can be compared with the UK PAF study, which used very similar methods and identical relative risk estimates. We found that overall, 16% of cancers in men and 10% of cancers in women were attributable to tobacco smoking, which is markedly lower than the UK PAF estimates of 23% of cancers in men and 15% of cancers in women. It is important to note that the ‘total smoking PAFs’ for each population are calculated by summing the counts of attributable cancers at smoking-related sites, and dividing by the sum of the counts for all cancers. The denominator includes all cancers, not just those related to smoking, and there are differences in the relative frequencies of non-smoking-related cancers between Australia and the UK (notably prostate cancer and melanoma, for which Australia has the highest incidence in the world). Having these
cancers in the denominator serves to reduce the 'total smoking PAF' for Australia relative to the UK. Thus, while lower smoking prevalence in Australia explains the lower PAFs at all smoking-related cancer sites, it only partially explains the marked difference in total smoking PAFs between the two populations. Estimates of the fraction of cancers attributable to tobacco smoke in the French population in 2000 were 27% of cancers in men and 6% in women, albeit derived using very different methodology (including a 15-year latency; prevalence data 1985, estimated PAF for 2000).22
Using different approaches, others have estimated the burden of cancer in Australia due to smoking. Begg et al.23 estimated that 20% of the disability-adjusted life years lost to cancers in 2003 were due to tobacco use, while Peto et al.24 estimated that 23% of cancer deaths in 2000 were attributable to smoking. These figures are both higher than our overall estimate of 13% of incident cancers attributable to smoking, but again this is due to the fact that we were reporting on cancer diagnoses not cancer deaths.
Because smoking-related cancer sites have poorer survival than non-smoking related sites on average, the contribution of smoking to cancer mortality is higher than its contribution to cancer incidence. The Peto-Lopez method4 for estimating the fraction of cancer attributable to smoking assumes that the excess incidence of lung cancer, over and above the incidence among never smokers, is due solely to the cumulative effects of past and current tobacco smoking. The observed lung cancer incidence is then used to derive the 'notional prevalence of smoking', that is, the prevalence of smoking in the Australian population that would have been necessary to produce the observed incidence rates, assuming that the CPS II risk estimates for lung cancer had applied. To calculate the fraction of cancer attributable to smoking at each additional site, we applied the notional prevalence of smoking to the standard PAF formula,18 along with the site-specific relative risks. This method is efficient and advantageous because it does not require detailed information about the proportions of current and former smokers in the population, nor separate relative risk estimates for the many categories of 'amount smoked' and 'time since quitting', each with attendant imprecision. The method is not without error however, since its application to populations with different smoking distributions may be imprecise, to an uncertain degree.
Another assumption is that the relative risks of cancer-specific mortality generated from CPS II (and used in previous studies) are appropriate for estimating PAFs for cancer incidence. Given the long duration of follow-up of the CPS II study (out to 20 years from baseline), and the generally high case-fatality rates for each of the smoking-related cancers considered, we contend that relative risks for mortality and incidence should be largely equivalent over the time. Nevertheless, we performed sensitivity analyses using relative risks for incident cancers derived from the MCCS. Being a smaller study than CPS II, and with a restricted age range, the MCCS risk estimates were less precise but, even so, the overall burden of cancer attributable to smoking estimated using those Australian data was of similar magnitude to those obtained using the US-based estimates. PAF estimates at specific cancer sites were not similar using the two approaches, reflecting differences in the relative risk estimates from the CPS-II and MCCS.

Table 6: Prevalence estimates of cohabitation with smoking partner among never smokers in Australia and fraction of lung cancer cases among never smokers in Australia attributable to cohabitation with smoking partner.

| Age Group (yrs) | % Population never smokersa | % Population living with partnerb | Estimated prevalence Never-smokers living with ever smoking partner (%)c | PAF | Lung cancer cases expected in never smokers | Excess cases in never smokers due to exposure to partner smoking |
|----------------|-----------------------------|----------------------------------|-------------------------------------------------|-----|---------------------------------------------|----------------------------------------------------------|
| **Men**        |                             |                                  |                                                 |     |                                             |                                                          |
| 15-24 yrs      | 71                          | 8                                | 1                                               | 0.6 | 0                                           | 0                                                        |
| 25-34 yrs      | 48                          | 57                               | 16                                              | 5.6 | 15                                          | 1                                                        |
| 35-44 yrs      | 47                          | 76                               | 25                                              | 8.4 | 46                                          | 4                                                        |
| 45-54 yrs      | 40                          | 75                               | 27                                              | 9.2 | 91                                          | 8                                                        |
| 55-64 yrs      | 36                          | 77                               | 21                                              | 7.3 | 178                                         | 13                                                       |
| 65-74 yrs      | 36                          | 78                               | 19                                              | 6.7 | 262                                         | 17                                                       |
| 75 + yrs       | 28                          | 72                               | 13                                              | 4.5 | 442                                         | 20                                                       |
| **Total**      | 46                          | 61                               | 17                                              | 6.1d| 1,034                                       | 63                                                       |
| **Women**      |                             |                                  |                                                 |     |                                             |                                                          |
| 15-24 yrs      | 75                          | 15                               | 3                                               | 0.8 | 0                                           | 0                                                        |
| 25-34 yrs      | 58                          | 65                               | 27                                              | 6.1 | 26                                          | 2                                                        |
| 35-44 yrs      | 53                          | 75                               | 30                                              | 6.7 | 60                                          | 4                                                        |
| 45-54 yrs      | 48                          | 73                               | 34                                              | 7.5 | 114                                         | 9                                                        |
| 55-64 yrs      | 56                          | 70                               | 38                                              | 8.3 | 188                                         | 16                                                       |
| 65-74 yrs      | 60                          | 63                               | 34                                              | 7.5 | 239                                         | 18                                                       |
| 75 + yrs       | 67                          | 36                               | 24                                              | 5.4 | 454                                         | 24                                                       |
| **Total**      | 59                          | 59                               | 25                                              | 6.3d| 1,081                                       | 73                                                       |
| **Grand total**|                             |                                  |                                                 | 6.4d| 2,115                                       | 136                                                      |

Abbreviations: PAF = population attributable fraction amongst never smokers (expressed as a percentage).
a: 2011-12 National Health Surveyb: generated from Australian Bureau of Statistics (2011)19c: Estimates are based on cohabitation status and population smoking status, and assume couples are in the same broad age group as those in the table and the relative probability of couple being concordant for smoking status is 0.221d: Age-weighted population attributable fraction (expressed as a percentage)
Pandeya et al.

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NP and LFW contributed equally to this manuscript and share first authorship.

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PAF Project

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