The Burden of Disease from Second-hand Smoke in New Zealand

2016

Environmental Health Indicators Programme
Massey University – Wellington

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Executive Summary

This report presents an estimate of the burden of disease from second-hand smoke in New Zealand in 2006 and 2010. Second-hand smoke is one of the main sources of indoor air pollution in New Zealand, and can cause illness and premature death.

This study followed the comparative risk assessment methods outlined by the World Health Organization (2010), which are based on the *population attributable fraction* (PAF) and population-level data on exposure to second-hand smoke. Exposure data mostly came from the New Zealand Health Survey and the Well Child / Tamariki Ora data collection. Health statistics came from the New Zealand Mortality Collection, the Global Burden of Disease Study and the New Zealand Burden of Disease Study. Evidence on exposure–risk relationships came from recent reviews and meta-analyses.

Results are presented for the attributable burden in terms of deaths for 2010, and DALYs (disability-adjusted life years) for 2010 and 2006. DALYs measure health loss from illness, disability and premature death. Results are presented by age group and sex, and where possible, Māori and non-Māori.

These results are only estimates, and should be used to guide policy decisions, rather than as an exact number of deaths or DALYs that could be prevented.

Key findings

In 2010, an estimated 104 people died due to second-hand smoke exposure in New Zealand (plausible range 66–137 deaths). These included 65 deaths from ischaemic heart disease, 28 deaths from stroke and 5 deaths from lung cancer in non-smoking adults, and 6 deaths from SUDI (sudden unexpected death in infancy) in children.

In 2010, second-hand smoke exposure caused an estimated 1989 DALYs in New Zealand (plausible range 1288–2748 DALYs). The majority (84%) of this health loss was due to premature death (years of life lost, or YLL), rather than illness and disability. Children experienced 30% of the total health loss due to second-hand smoke, mainly from sudden unexpected death in infancy (SUDI).

Māori were disproportionately affected by second-hand smoke exposure. Māori accounted for about 17% of the attributable deaths (17 deaths) in 2010, and 39% of health loss (883 DALYs) in 2006. Māori experienced five times as much health loss from second-hand smoke exposure as non-Māori in 2006, after standardising for age. The majority of the health loss in Māori was fatal.

These analyses have several sources of uncertainty, including in the estimates of relative risks and exposure prevalence. Plausible ranges, based on the confidence limits of the relative risks, are included. Sensitivity analyses tested a variety of assumptions, to give the potential impact on the estimated health burden. The sensitivity analyses indicated that if smokers are susceptible to second-hand smoke, the true health burden from second-hand smoke exposure would almost double. The attributable burden from second-hand smoke

would also be higher if second-hand smoke exposure outside of the home (such as in workplaces or cars) was included.

These findings show that second-hand smoke exposure is an entirely preventable source of indoor air pollution, but continues to contribute to poor health and early death in New Zealand. Second-hand smoke affects vulnerable populations (including children, older adults and Māori) more than other people. Health gains could be made by encouraging smokefree homes and cars, and encouraging women and their partners to quit smoking before or during pregnancy and to remain smokefree once the infant is born.

Introduction

Key points:

- This study estimates the burden of disease due to second-hand smoke in New Zealand, in terms of deaths and DALYs (disability-adjusted life years), which measure health loss from illness, disability and premature death.
- Second-hand smoke is one of the main sources of indoor air pollution in New Zealand.
- Infants and children exposed to second-hand smoke are at higher risk of sudden unexpected death in infancy (SUDI), asthma, lower respiratory tract infections, and middle ear infection (otitis media).
- In adults, second-hand smoke exposure increases the risk of ischaemic heart disease, stroke and lung cancer.
- Globally, second-hand smoke exposure causes over 600,000 deaths each year.

About this study

This study estimates the health burden due to exposure to second-hand smoke in New Zealand.

Second-hand smoke is one of the main sources of indoor air pollution in New Zealand. Health effects from second-hand smoke include respiratory disease, cardiovascular disease, cancer, reproductive outcomes, and effects on childhood development.

In particular, this study:

- estimated how many people died from second-hand smoke exposure in New Zealand
- estimated the health loss caused by second-hand smoke exposure in New Zealand
- identified the population groups (age groups, sex, Māori/non-Māori) that experience the greatest burden from second-hand smoke exposure in New Zealand.

The burden is measured in deaths and DALYs (disability-adjusted life years). DALYs are a summary measure of health loss that includes both fatal and non-fatal outcomes. We have used the most recent evidence of health effects linked to second-hand smoke exposure, including the 2014 US Surgeon General's review, which includes stroke for the first time (US Department of Health and Human Services, 2014).

The results of this study will help policymakers and other people working in the health sector to understand the health consequences and burden from second-hand smoke in New Zealand. In particular, the results should help in targeting policies and interventions, particularly at those groups more likely to be affected.

This study is part of an on-going New Zealand Environmental Burden of Disease project, carried out by the Environmental Health Indicators team, at the Centre for Public Health Research, Massey University, and funded by the Ministry of Health.

Second-hand smoke and health

What is second-hand smoke?

Second-hand smoke (also known as *environmental tobacco smoke* or *passive smoking*) is a source of indoor air pollution.

Second-hand smoke is made up of sidestream smoke (from the burning tip of the cigarette) and mainstream smoke (drawn through the cigarette, and exhaled by the smoker). Sidestream smoke is the main component of second-hand smoke, as more of the cigarette is burned while smouldering between puffs from the smoker (Cal-EPA, 2005).

Second-hand smoke contains a complex mix of thousands of gases and particulate matter (Cal-EPA, 2005). Particulate matter in second-hand smoke includes particles of arsenic, cadmium, and chromium(VI). Gaseous compounds in second-hand smoke include carbon monoxide, benzene, formaldehyde and acrolein.

Particulate matter (such as that from second-hand smoke) can travel deep into the lungs, and cause serious health effects. Additionally, over 250 chemicals in second-hand smoke are toxic or carcinogenic to humans, according to estimates by the US National Toxicology Program (US Surgeon General, 2006). Evidence suggests that sidestream smoke is 3–4 times as toxic as mainstream smoke (Schick & Glantz, 2005).

What are the health effects of second-hand smoke?

Evidence indicates there is no safe level of exposure to second-hand smoke (US Surgeon General, 2006).

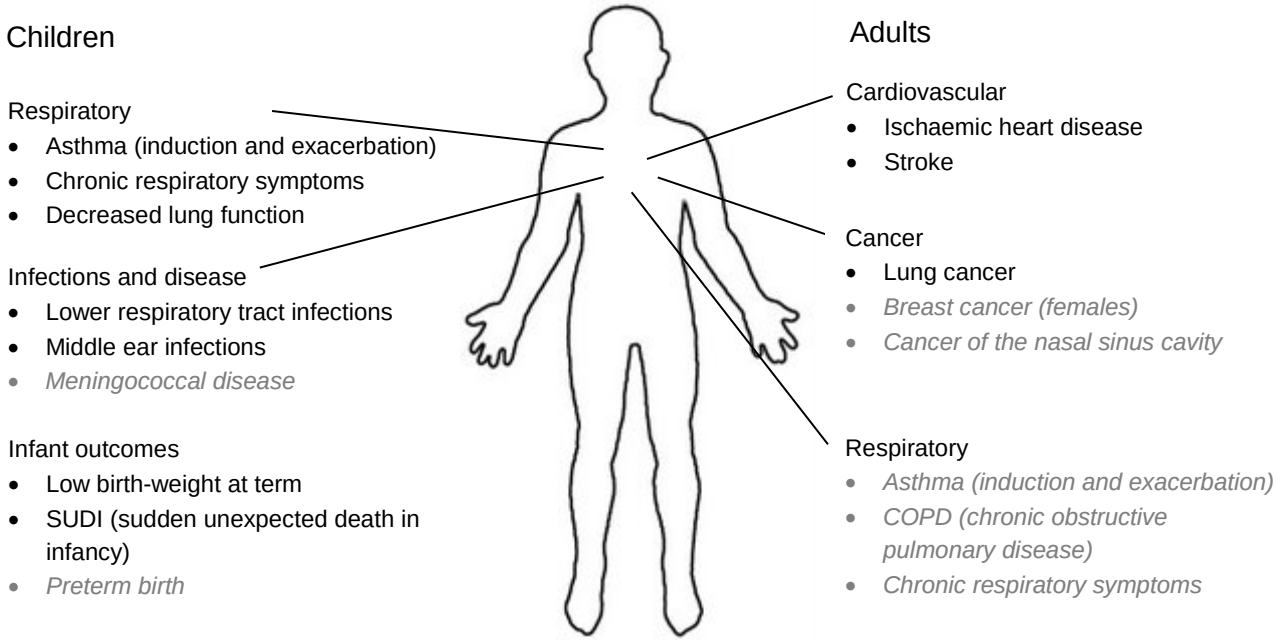
Infants and children exposed to second-hand smoke are at higher risk of sudden unexpected death in infancy (SUDI), asthma, lower respiratory tract infections, and middle ear infection (otitis media). In adults, second-hand smoke exposure increases the risk of ischaemic heart disease, stroke and lung cancer (US Department of Health and Human Services, 2014). Pregnant women exposed to second-hand smoke can experience reproductive outcomes such as low birthweight.

Evidence also suggests that second-hand smoke exposure may lead to other health outcomes, including chronic obstructive pulmonary disease (COPD), asthma in adults, breast cancer and preterm delivery (US Department of Health and Human Services, 2014; US Surgeon General, 2006). More evidence is needed before these health outcomes can be confirmed as being caused by second-hand smoke.

Figure 1 summarises the latest evidence of health outcomes related to second-hand smoke for children and adults. The health outcomes in black text are those caused by second-hand smoke (Level 1 conditions; the evidence is sufficient to infer a causal relationship). Health outcomes in grey text show those where the evidence is less clear (Level 2 conditions;

evidence is suggestive but not sufficient to infer a causal relationship) (US Department of Health and Human Services, 2014).

Figure 1: Health outcomes linked to second-hand smoke in non-smoking adults (black = causal link; grey = suggestive of causal link)



Notes: Black text shows health outcomes proven to be caused by second-hand smoke (Level 1 outcomes); grey text shows the health outcomes possibly caused by second-hand smoke (Level 2 outcomes).
Sources: Cal-EPA (2005); Murray, Britton, & Leonardi-Bee (2012); Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al. (2010); US Department of Health and Human Services (2014); US Surgeon General (2006).

Who is more vulnerable?

Some population groups are more vulnerable to the effects of second-hand smoke. As with exposure to other environmental hazards, people may be more impacted by an environmental hazard if they are:

- less able to avoid the environmental hazard
- more affected by the environmental hazard
- less able to cope with the illness the environmental hazard causes (DANIDA, 2000).

Population groups who are more susceptible to second-hand smoke exposure include children, older people, and people with pre-existing medical conditions.

Children are more sensitive to the effects of second-hand smoke, because their lungs and respiratory tracts are still developing, and are therefore more susceptible to toxins (Cal-EPA, 2005). Within the same environment, second-hand smoke exposure affects children more than adults, because children have a higher breathing rate per body weight and lung surface area (Cal-EPA, 2005). Children (particularly infants) also tend to spend more of their time indoors and may be unable to remove themselves from exposure to second-hand smoke.

Older adults are also more at risk from the effects of second-hand smoke. Older adults tend to spend a large proportion of their time indoors, and mobility difficulties may make it difficult to move themselves away from exposure.

People with pre-existing health conditions (such as chronic respiratory diseases) may also be at more risk of health effects from second-hand smoke. For example, evidence suggests that second-hand smoke may cause acute respiratory symptoms among people with asthma (US Department of Health and Human Services, 2014).

Where are people exposed to second-hand smoke in New Zealand?

People can be exposed to second-hand smoke wherever other people are smoking. In particular, they may be exposed to second-hand smoke in homes, vehicles, and outdoor areas. In New Zealand, most exposure to second-hand smoke is likely to occur in the home.

Evidence suggests that cigarette smoking in vehicles can also lead to high levels of second-hand smoke within a short space of time. For example, a 2006 study found that a single cigarette lit for five minutes in a vehicle led to second-hand smoke levels around ten times more concentrated than levels considered ‘unhealthy’ by the US Environmental Protection Agency (Rees & Connolly, 2006). Even with all the windows down and the fans on high, second-hand smoke still lingered in cars, at levels higher than those in pubs where people smoked. In New Zealand, adults and children spent at least 3–4 hours per week on average in vehicles in 2010–13 (Ministry of Transport, 2014), suggesting that vehicles may be an important source of exposure to second-hand smoke for some people.

Workplace exposure to second-hand smoke has reduced substantially In New Zealand over the past twenty years, and the workplace is now much less likely to be a place of exposure to second-hand smoke. The Smoke-free Environments Act 1990 banned smoking in many workplaces in New Zealand, although not in pubs, clubs, restaurants and factories. Later, the Smoke-free Environments Amendment Act 2003 banned smoking in all indoor workplaces from 10 December 2004.

Global burden of disease due to second-hand smoke

Studies show that second-hand smoke has a large impact on people’s health and wellbeing, and leads to many hundreds of thousands of deaths worldwide each year.

The Global Burden of Disease Study 2010 estimated that second-hand smoke exposure led to 601,900 deaths worldwide in 2010, and 19.9 million healthy years of life lost (measured as DALYs) (Lim et al., 2012). The results of this study suggest that one out of every ten tobacco-related deaths worldwide was due to second-hand smoke exposure in 2010 (total tobacco-related deaths: 6,297,287).

From 1990 to 2010, the worldwide health burden due to second-hand smoke decreased. Deaths attributable to second-hand smoke decreased from about 754,000 deaths in 1990, to about 602,000 deaths in 2010. DALYs also decreased, from 38.0 million DALYs in 1990, to 19.9 million DALYs in 2010 (Lim et al., 2012).

Previously, the World Health Organization estimated that, in 2004, second-hand smoke caused an estimated 603,000 deaths globally, and 10.9 million DALYs (Őberg, Jaakkola, Woodward, Peruga, & Prűss-Űstűn, 2010).

Previous estimates of the burden of disease from second-hand smoke in New Zealand

Several studies have investigated the burden of disease due to second-hand smoke in New Zealand. These studies are based on evidence available at the time of the study. However, there may be differences in methods, data sources, and the health outcomes included, meaning the results may not be directly comparable.

(1) Estimates from the 1980s

The first study estimated that, in 1985, second-hand smoke caused 273 deaths from ischaemic heart disease and lung cancer each year in New Zealand (range: 112–442) (Kawachi, Pearce, & Jackson, 1989).

(2) Estimates from the 1990s

Another study found that second-hand smoke exposure caused about 347 deaths each year in New Zealand in 1996/97 (plausible range: 174–490 avoidable deaths), from lung cancer, ischaemic heart disease, stroke and sudden infant death syndrome (SIDS) (Woodward & Laugeson, 2001a).

Additionally, it was estimated that second-hand smoke resulted in (Woodward & Laugeson, 2001b):

- more than 500 hospital admissions of children under 2 years suffering from chest infections
- almost 15,000 episodes of childhood asthma
- more than 27,000 GP consultations for asthma and other respiratory problems in childhood
- 1500 hospital operations to treat glue ear
- about 50 cases of meningococcal disease
- about 1200 hospital admissions for ischaemic heart disease
- almost 500 hospital admissions for people suffering from strokes.

The study estimated that second-hand smoke cost the country $8.7 million per year in hospitalisation costs.

(3) 2006 New Zealand Burden of Disease Study

The 2006 New Zealand Burden of Disease Study estimated that second-hand smoke exposure contributed to 2800 DALYs (disability-adjusted life years), or about 3% of health loss due to tobacco smoke. This study examined exposure to second-hand smoke, as part of a comprehensive study of diseases and injuries in New Zealand (Ministry of Health, 2013a).

This analysis was based on the linked health outcomes of: lung cancer, ischaemic heart disease and asthma for non-smoking adults; and lower respiratory tract infections, asthma, otitis media, small for gestational age, preterm birth complications, and sudden unexpected death in infancy for children. Stroke was not included in the study, as the evidence was not robust enough at the time of the study.

(4) 2010 Global Burden of Disease Study – New Zealand figures

The 2010 Global Burden of Disease (GBD) study estimated that second-hand smoke exposure caused about 1600 DALYs (or 0.15% of all DALYs) in New Zealand in 2010 (IHME, 2013). This estimate was based on the linked health outcomes of lung cancer, ischaemic heart disease and stroke in non-smoking adults, and lower respiratory tract infections, upper respiratory tract infections and otitis media in children under 5 years (Lim et al., 2012). Sudden infant death syndrome (SIDS) was not included, due to a lack of data across all countries.

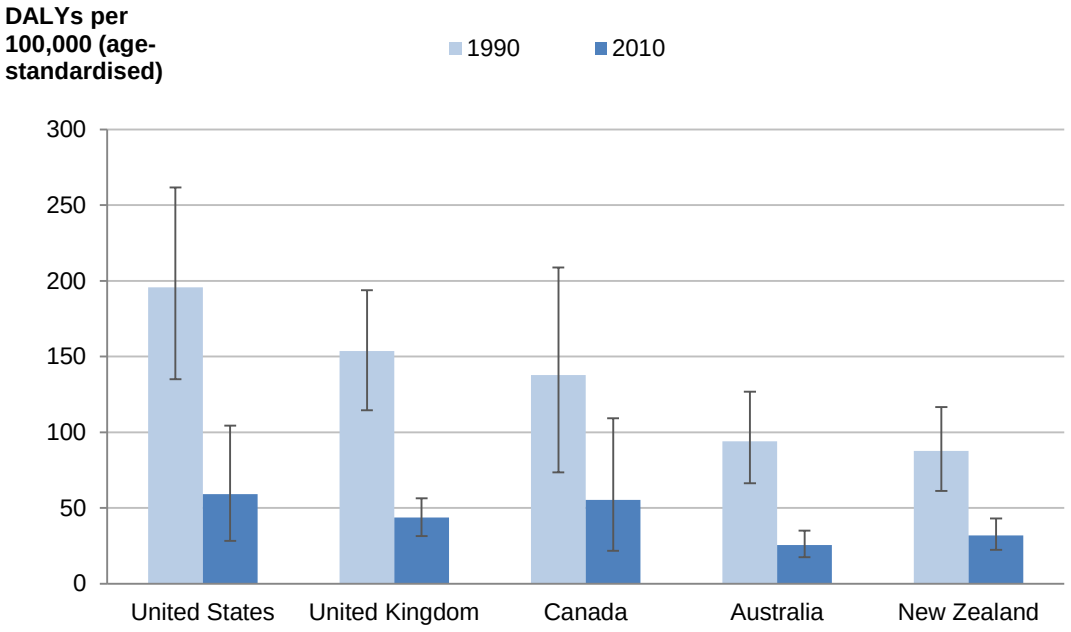
Differences in methods mean the 2010 GBD study is not directly comparable with the 2006 New Zealand Burden of Disease study. Nonetheless, the 2010 GBD study and the 2006 New Zealand Burden of Disease Study gave broadly similar results for DALYs for the main health condition groups (Ministry of Health, 2013a).

The GBD data can give some useful insights into how New Zealand compares internationally for burden of disease due to second-hand smoke.

New Zealand had a relatively low burden of disease due to second-hand smoke in 2010 compared with similar countries (IHME, 2013) (Figure 2). In particular, New Zealand's burden per 100,000 population was similar to Australia's, after standardising for age. The United States, Canada and the United Kingdom had somewhat higher levels.

The GBD study also showed that all five countries have seen a dramatic decrease in the burden of disease due to second-hand smoke from 1990 to 2010.

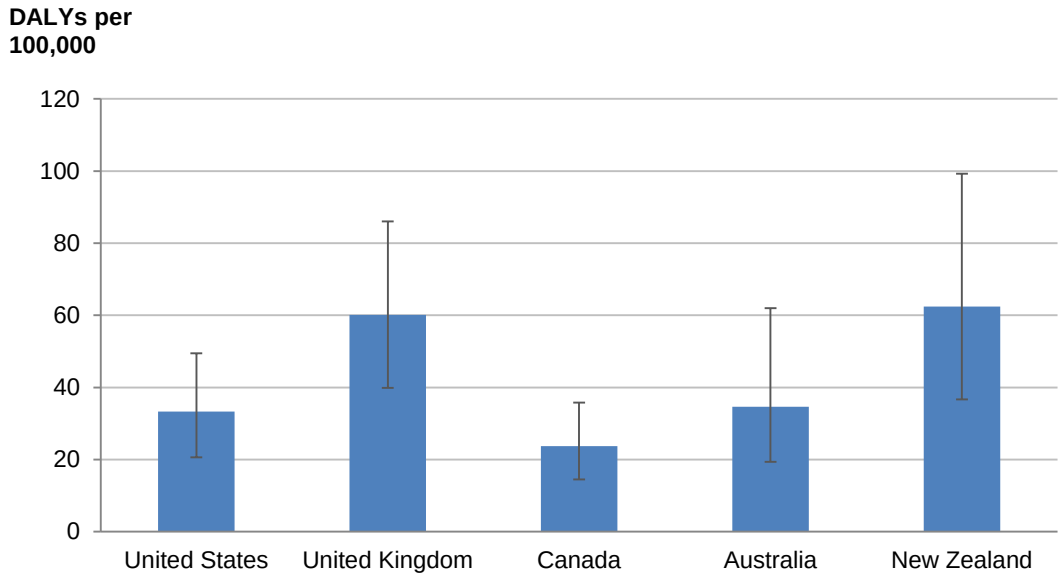
Figure 2: Change in burden of disease attributable to second-hand smoke, 1990 and 2010, selected countries (age-standardised DALY rate per 100,000)



Source: Global Burden of Disease Study (IHME, 2013)

In young children (0–4 years), New Zealand had a higher burden of disease attributable to second-hand smoke than other countries in 2010 (Figure 3). This estimate did not include SIDS, so the results will underestimate the true burden in this age group.

Figure 3: Burden of disease in children aged 0–4 years attributable to second-hand smoke in selected countries, 2010 (unadjusted DALY rate per 100,000)



Source: Global Burden of Disease Study 2010 (IHME, 2013)

Outline of this report

This report presents our estimates of the health burden from second-hand smoke exposure in New Zealand. The report is broken into the following sections:

- **Who is exposed to second-hand smoke?** The latest data on who is exposed to second-hand smoke in New Zealand.
- **Methods for calculating attributable burden:** A brief overview of the methods used to estimate the attributable burden.
- **Deaths attributable to second-hand smoke in 2010**
- **Health loss attributable to second-hand smoke**: Results for the years 2010 and 2006.
- **Uncertainties and sensitivity analyses:** Sources of uncertainty, and sensitivity analyses showing the effect of changing inputs on final results.
- **Discussion:** Discussion of the results, strengths and limitations of the study, and conclusions from this study.
- **References**
- **Appendix 1 Details of the methods:** Further details of the methods.
- **Appendix 2 Results tables:** Includes tables of population attributable fractions, attributable burdens by population group, and sensitivity analyses.

Who is exposed to second-hand smoke?

Key points:

- In 2012/13, 5.0% of children aged 0–14 years, and 3.7% of non-smoking adults, were exposed to second-hand smoke in their home in New Zealand. This is about 150,000 people exposed to second-hand smoke in their homes.
- The proportion of children and non-smoking adults exposed to second-hand smoke has decreased from 2006/07 to 2012/13.
- Children and young people were more likely to be exposed to second-hand smoke than other people.
- Māori children and non-smoking adults were much more likely to be exposed to second-hand smoke in the home (9%) than non-Māori children and non-smoking adults (3–4%).

This section presents the prevalence of exposure to second-hand smoke in New Zealand.

These data are important input for estimating the burden of disease due to second-hand smoke. It is also useful evidence to help understand the population groups most at risk in New Zealand.

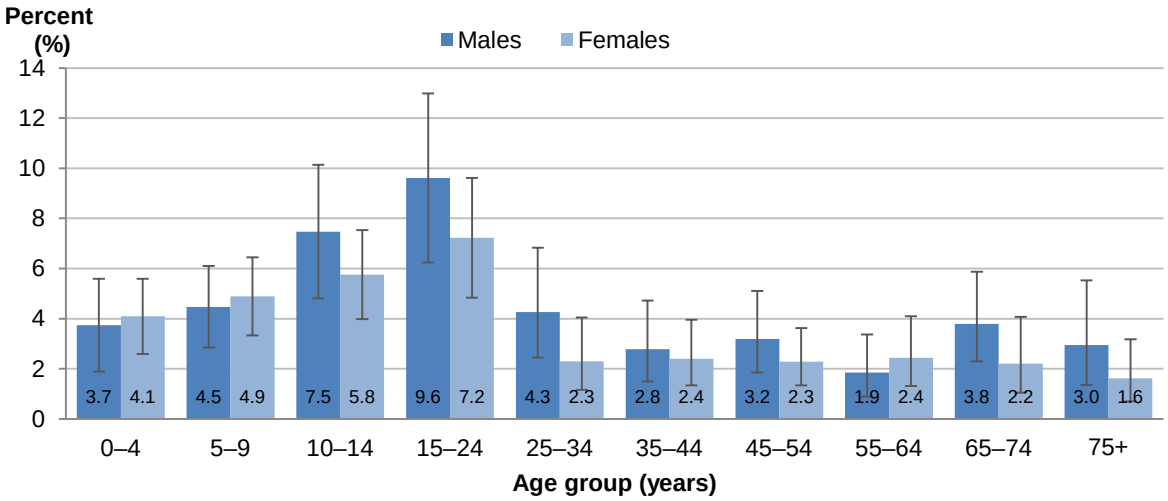
Children and young people are more exposed

Exposure to second-hand smoke in the home and car is collected as part of the New Zealand Health Survey. Adults and caregivers of children aged 0–14 years were asked questions about whether anyone smokes inside their house, and whether anyone smokes in the car they (or their child) usually travel in.

In 2012/13, 5.0% (95% confidence interval: 4.2–5.9) of children aged 0–14 years and 3.7% (3.1–4.2) of non-smoking adults aged 15+ years were exposed to second-hand smoke in their home in New Zealand. This is an estimated 44,900 children and 106,500 non-smoking adults exposed to second-hand smoke in their home.

By age group, children and young people (particularly those aged 10–24 years) were the most likely to be exposed to second-hand smoke in their home in 2012/13 (Figure 4).

Figure 4: Prevalence of exposure to second-hand smoke in the home, among children (0–14 years) and non-smoking adults (15+ years), by age group and sex, 2012/13

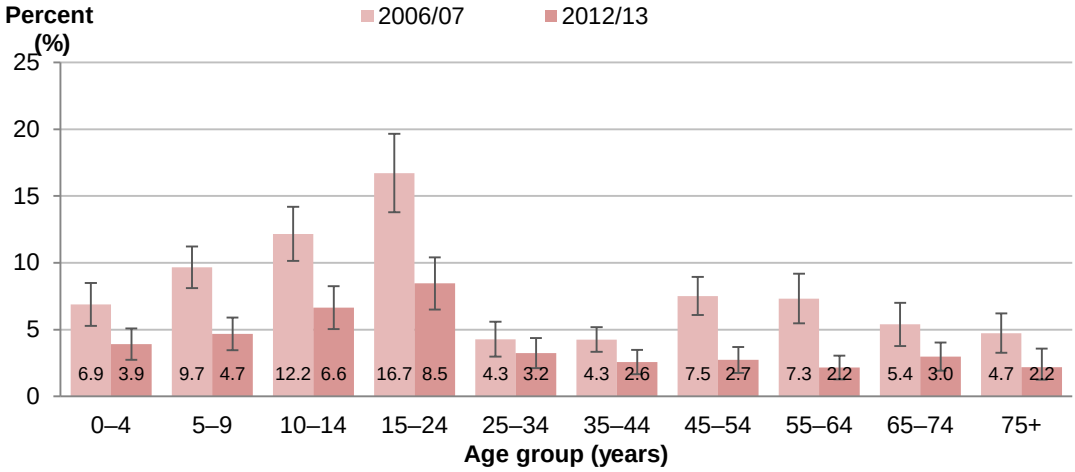


Source: 2012/13 New Zealand Health Survey

Large drop in exposure to second-hand smoke

The proportion of children and non-smoking adults exposed to second-hand smoke in their home has decreased significantly from 2006/07 to 2012/13 in most age groups (Figure 5). In particular, there have been large decreases for children and young people.

Figure 5: Prevalence of exposure to second-hand smoke in the home, among children and non-smoking adults, 2006/07 and 2012/13



Source: 2006/07 and 2012/13 New Zealand Health Surveys

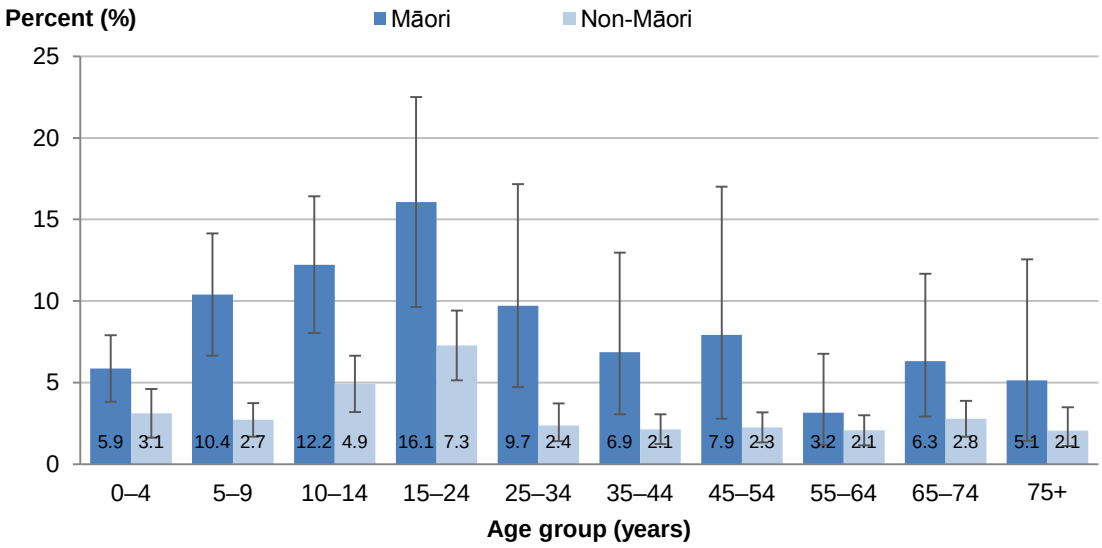
Māori more exposed to second-hand smoke

In 2012/13, Māori children and non-smoking adults were much more likely to be exposed to second-hand smoke in the home than non-Māori in New Zealand.

Among children under 15 years of age, 9.2% of Māori children were exposed to second-hand smoke in the home, compared with 3.6% of non-Māori children. There were similar results among non-smoking adults (9.4% for Māori, and 3.1% for non-Māori).

The highest rates of exposure were in non-smokers aged 15–24 years; in this age group, Māori were more than twice as likely to be exposed to second-hand smoke in the home (16.1%) as non-Māori (7.3%) (Figure 6).

Figure 6: Prevalence of exposure to second-hand smoke in the home, among Māori and non-Māori children and non-smokers, 2012/13



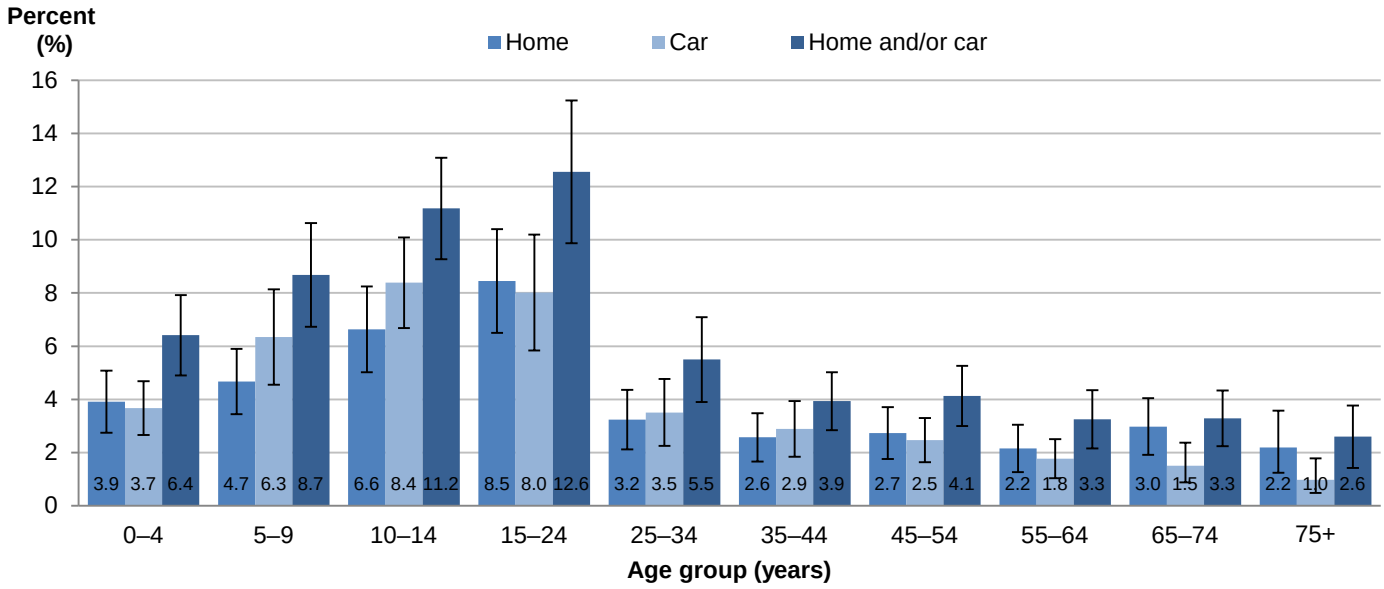
Source: 2012/13 New Zealand Health Survey

Vehicles are a common source of exposure

Vehicles were also a common source of exposure to second-hand smoke. Among children under 15 years, 6.1% were exposed to second-hand smoke in the car they travel in, in 2012/13. A smaller proportion of non-smoking adults (3.3%) were exposed.

In many age groups, exposure to second-hand smoke in the car was about as common as exposure in the home (Figure 7). People exposed to second-hand smoke in vehicles were not always those who were exposed in the home. For example, almost 7% of 10–14-year-olds were exposed to second-hand smoke in their home, but 11% were exposed in their home and/or car.

Figure 7: Prevalence of exposure to second-hand smoke in the home and/or car, among children and non-smoking adults, 2012/13



Source: 2012/13 New Zealand Health Survey

By comparison, the ASH survey found that 23% of 14-year-olds had been exposed to second-hand smoke in vehicles in the previous seven days, while 33% had been exposed in their homes in that time (Healey et al., 2015).

Workplace exposure decreases over time

Evidence suggests that workplace exposure to second-hand smoke has decreased over the past two decades. These changes are likely due to legislation changes (such as the Smoke-free Environments Act 1990 and the Smoke-free Environments Amendment Act 2003) that banned smoking in indoor workplaces.

In 1996, 19% of non-smoking men and 6% of non-smoking women reported being exposed to second-hand smoke in their workplace during working hours (Ministry of Health, 1996) (Table 1).

Another survey found that exposure to second-hand smoke in the workplace in non-smokers had decreased from 16.3% in 2003, to 14.8% in 2004, 7.0% in 2005, and 7.8% in 2006 (Waa & McGough, 2006b).

Table 1: Workplace exposure to second-hand smoke in New Zealand

Year	Sex	Prevalence of exposure in non-smokers	Source
1996	Men Women	19 % 6 %	Ministry of Health (1996)
2003	Total	16.3%	Waa & McGough (2006b)
2004	Total	14.8%	
2005	Total	7.0%	
2006	Total	7.8%	

One in eight infants have a mother who smokes

Data on smoking for women with small children is also available from the Well Child / Tamariki Ora programme. This programme is a free service provided by the government for children from birth to five years of age, and covers about 85% of infants in New Zealand (Ministry of Health, 2013b).

From July to December 2012, one in eight (13%) mothers with newborns were smoking at two weeks after birth (Ministry of Health, 2013b). The rate was much higher among Māori mothers, with one in three (35%) smoking at two weeks after birth (Table 2).

Table 2: Mother smokefree at two weeks post-natal, July–December 2012

Population group	Mother smokefree at two weeks post-natal	Mother not smokefree at two weeks post-natal
Total New Zealand	87%	13%
High deprivation	76%	24%
Māori	65%	35%
Pacific	90%	10%

Source: Ministry of Health (2013b).

These data are relevant because evidence suggests that having a mother who smokes doubles an infant's risk of dying of SIDS / SUDI (Anderson & Cook, 1997).

There is also evidence that many women may start smoking again after giving birth. The Growing Up in New Zealand cohort study found that, among women who smoked before pregnancy but quit before or during pregnancy, 39% were smoking again when the baby was nine months old (Morton et al., 2012). This cohort of children born in 2009–2010 is broadly comparable to the demographic characteristics of the New Zealand population (Morton et al., 2014).

Methods for calculating attributable burden

Key points:

- This study used a *comparative risk assessment* approach, as described by the World Health Organization (2010). The attributable burden is estimated using the *population attributable fraction* (PAF), and population-level data on exposure to second-hand smoke.
- The health burden from second-hand smoke was measured using deaths and disability-adjusted life years (DALYs). Data on exposure to second-hand smoke was sourced from the New Zealand Health Survey, Well Child / Tamariki Ora data and the Growing Up in New Zealand Study.
- Our analysis included the following health outcomes: lung cancer, ischaemic heart disease (15+ years); stroke (35+ years); asthma, middle ear infection (0–14 years); lower respiratory tract infections (0–1 years); sudden unexpected death in infancy (SUDI) (0–12 months); and low birth-weight (small for gestational age) (0 years).
- Results were calculated by age group and sex. Estimates were also calculated for Māori and non-Māori where possible.

This section gives an overview of how the environmental burden of disease due to second-hand smoke was estimated.

Environmental burden of disease studies are a way of quantifying the health impact that a specific environmental hazard has on the population. These studies use a comparative risk assessment approach to estimate the burden of disease attributable due to an environmental hazard.

This study followed the method outlined by the World Health Organization for estimating the national burden of disease due to second-hand smoke (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010). This method is also similar to those used in previous New Zealand studies investigating the burden due to second-hand smoke (Ministry of Health, 2013a; Woodward & Laugeson, 2001a).

The concept behind environmental burden of disease studies

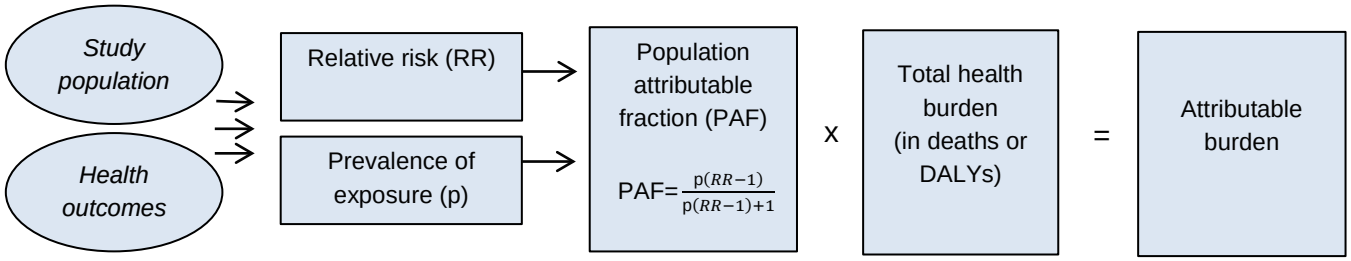
The basis of the methodology is the population attributable fraction (PAF).

The PAF is the proportion of cases of a disease that are attributable to a risk factor. The PAF suggests the proportion of cases that could be prevented if exposure to the risk factor was removed.

The PAF is calculated using the prevalence of exposure, and the relative risk of a disease for people exposed to a hazard (compared with people not exposed).

To estimate the preventable number of deaths or DALYs due to a risk factor (*attributable burden*), the population attributable fraction is calculated for each disease, then multiplied by the number of deaths or DALYs for that disease (Figure 8).

Figure 8: Schematic diagram showing how attributable burden is calculated



In our study, we estimated the attributable burden in each age- and sex-group, for each health outcome, and then summed these to get the population total.

Uncertainty was examined with a sensitivity analysis, which tested the impact of changing various assumptions and inputs one at a time.

Method for calculating attributable burden

This section explains each part of the above diagram. More details of the methodology are in Appendix 1.

i. Study population

Our study focuses on the attributable burden in children and non-smoking adults in New Zealand.

Current smokers are excluded from the analysis. The reason is not because smokers' health is not affected by second-hand smoke, but because most epidemiological evidence is for non-smokers, and there is uncertainty in the health impact on current smokers from second-hand smoke (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010).

We estimated the health burden for two time periods:

- 2010 (for deaths, and DALYs)
- 2006 (for DALYs, particularly for Māori / non-Māori).

ii. Health outcomes selected

This study only included health outcomes shown to be caused by second-hand smoke exposure, and which could be quantified with health statistics.

The following health outcomes were selected:

- Adults
    - lung cancer (15+ years)
    - ischaemic heart disease (15+ years)
    - stroke (35+ years)

- Children
    - lower respiratory tract infections (0–1 years)
    - asthma (induction and exacerbation) (0–14 years)
    - middle ear infections (otitis media) (0–14 years)
    - sudden unexpected death in infancy (SUDI) (or sudden infant death syndrome, SIDS, when SUDI data not available for New Zealand) (0–12 months)
    - small for gestational age (low birthweight) (0 years).

The health outcomes were selected based on the latest evidence and meta-analyses, in particular focussing on major reviews such as those by the World Health Organization (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010) and US Surgeon General (US Department of Health and Human Services, 2014; US Surgeon General, 2006).

In contrast with some previous studies, we have included stroke as a linked health outcome, based on a recent review by the US Surgeon General (US Department of Health and Human Services, 2014).

While the health evidence is for SIDS (Anderson & Cook, 1997), we have chosen to use data for SUDI (sudden unexpected death in infancy) where possible to estimate deaths and DALYs for New Zealand. SIDS is defined as 'the sudden death of an infant under one year of age which remains unexplained after a thorough case investigation, including performance of a complete autopsy, examination of the death scene, and review of the clinical history' (Willinger, James, & Catz, 1991). However, issues have arisen with classifying SIDS, particularly with the coding of unexpected deaths that occur in the presence of known risk factors like cigarette smoke. Given this, the New Zealand Child and Youth Mortality Review Committee has recommended using the broader definition of SUDI, which encompasses unexpected deaths that were either unexplained or explained (Child and Youth Mortality Review Committee, 2009). In our analysis, the definition of SUDI includes SIDS deaths, accidental suffocation or strangulation in bed, and ill-defined/unspecific causes, consistent with the 2006 New Zealand Burden of Disease Study (Ministry of Health, 2013c).

We have not included asthma in adults in our main study, as the latest review by the US Surgeon General found the evidence to be 'suggestive but not sufficient to infer a causal relationship' between second-hand smoke and both (i) adult-onset asthma and (ii) a worsening of asthma control (US Department of Health and Human Services, 2014). Asthma, and other conditions that are likely caused by second-hand smoke, have been included in our sensitivity analyses, to show the impact if they are included in the analysis.

Decreased lung function and chronic respiratory symptoms were not included in this study, as these health effects are too imprecise and/or difficult to quantify as a health outcome.

iii. Relative risk estimates

Relative risks give the risk of a particular event or disease in one group compared with another, that is, the exposure–risk relationship. In this study, the relative risks for the health

outcomes (for people exposed to second-hand smoke compared with those who are not exposed) are used to calculate the population attributable fractions.

Table 3 summarises the health outcomes, relative risks and populations used in this study. We used the relative risks recommended by the World Health Organization (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010), with updates using the latest evidence where appropriate. These relative risks mostly come from meta-analyses. In some cases, the review gives an odds ratio, which is an estimate of the relative risk from certain types of studies.

Table 3: Relative risk for health outcomes included in the calculation of attributable burden from second-hand smoke

Health outcome	Relative risk estimate	Age group/ population	Exposure	Study/ source
Lung cancer (in non-smokers)	1.21 (1.13–1.30)	15+ years	At home	US Surgeon General (2006)
Ischaemic heart disease (in non-smokers)	1.27 (1.19–1.36)	15+ years	At home or at work	US Surgeon General (2006)
Stroke (in non-smokers)	1.25 (1.12–1.38)	35+ years	At home or at work	Oono et al (2011)
Lower respiratory infections (including bronchitis, bronchiolitis, pneumonia and acute respiratory infection)	1.54 (1.40–1.69)	0–1 years	Any household member smoking	Jones et al (2011)
Sudden infant death syndrome (SIDS)[1]	1.94 (1.55–2.43)	<1 year	Smoking mother (postnatal exposure)	Anderson and Cook (1997)
Small for gestational age (<2500g at term)	1.38 (1.13–1.69)	0 year	Non-smoking mother exposed at work or at home	Windham et al (1999)
Middle ear infection (otitis media)	1.32 (1.20–1.45)	0–14 years	Household smoker	Jones et al (2012)
Asthma in children	1.32 (1.23–1.42)	0–14 years	Either parent smokes	Tinuoye et al (2013), similar to estimates from Cal-EPA (2005)

[1] Where possible, our analyses use SUDI instead of SIDS, as it is considered to be a better measure in the New Zealand context.

Relative risks can be interpreted as the increase (or decrease) in disease risk for people, for a particular exposure. For example, the relative risk of 1.27 for ischaemic heart disease means that adults exposed to second-hand smoke have a 27% increase in risk of ischaemic heart disease compared with adults not exposed. Infants who have a mother who smokes have almost twice the risk (odds ratio of 1.94) of dying of SIDS compared with other infants.

The relative risks used for active smoking and in the sensitivity analysis are provided in Appendix 1.

iv. Prevalence of exposure

The prevalence of exposure to second-hand smoke is an important input in this study, for calculating the population attributable fraction. We needed appropriate measures of

exposure data, for the appropriate time periods, matching as closely as possible to the exposures used for the relative risk calculations (Table 3).

For most health outcomes, we used data on exposure to second-hand smoke in the home, from the New Zealand Health Survey (1996/97, 2006/07 and 2012/13). In these cases, exposure in the home was used a proxy for any exposure to second-hand smoke. We analysed the confidentialised unit record files for the New Zealand Health Survey, using standard survey analysis techniques, and calculated prevalence and confidence intervals for children and non-smoking adults. For prevalence estimates between survey dates, we interpolated data for each specific age-sex-ethnic cohort, based on an exponential decay curve. We also calculated the prevalence of active smoking among adults.

For the health outcomes that occur in adults, there is a lag between exposure and development of disease. It is recommended to use a lag period of 10–20 years for lung cancer, and a lag of 1–5 years for ischaemic heart disease and stroke (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010). For estimating the burden in 2010, we used a lag period of 14 years for lung cancer (using 1996/97 New Zealand Health Survey (NZHS)) and 4 years for ischaemic heart disease and stroke (using the 2006/07 NZHS). For the 2006 analysis, we used a lag of 10 years for lung cancer (using the 1996/97 NZHS), but used the 2006/07 survey data for ischaemic heart disease and stroke. Not using lagged data is not likely to have made a major difference, as survey results suggested a similar or slightly lower prevalence in 2002/03 compared with 2006/07.

For SIDS/SUDI, the evidence of health outcomes is based on maternal smoking after birth (post-natally). The evidence shows an increased risk of SIDS for infants whose mother smokes, independent of whether the mother smoked during pregnancy (Anderson & Cook, 1997). We used data from the national Well Child / Tamariki Ora health checks programme for infants, which collects smoking status of mothers two weeks after birth (Ministry of Health, 2013b).

For small for gestational age (low birthweight), we used the exposure of pregnant non-smoking women exposed to second-hand smoke, as measured by a smoking partner. This data came from the antenatal interviews of the Growing Up in New Zealand cohort study (Morton et al., 2010).

v. Calculating the population attributable fraction

The *population attributable fraction* (PAF) is the proportion of health outcomes attributable to a specific exposure. The PAF can be calculated with the standard formula:

$$\text{Population attributable fraction (PAF)} = \frac{p(RR-1)}{p(RR-1)+1}$$

where p is the prevalence of exposure, and RR is the relative risk for a specific health outcome for exposed people compared with non-exposed.

In the example of SIDS/SUDI, 13.5% of infants have a mother who smokes (p=0.135), and infants whose mother smokes have a 94% increased risk of dying of SIDS compared with

other infants (relative risk of 1.94). Therefore, the population attributable fraction can be calculated using the formula to give a PAF of 0.11261. In other words, about 11% of SIDS cases are attributable to second-hand smoke.

$$\text{Population attributable fraction (PAF)} = \frac{0.135 \times (1.94 - 1)}{0.135 \times (1.94 - 1) + 1} = 0.11261$$

We calculated population attributable fractions for each selected health outcome, for each age-sex group, and where appropriate, by ethnic group as well.

vi. Health statistics to measure the burden of disease

We used data on deaths and DALYs to measure the health burden in the population.

Data on deaths came from the New Zealand Mortality Collection. To give robust estimates for 2010, we calculated an annual average for the three year period of 2009–2011. We redistributed deaths that were coded to improbable or imprecise codes ('garbage codes'), according to the algorithm used in the New Zealand Burden of Disease Study (Ministry of Health, 2013c). This study found that about 10% of all deaths were considered to be garbage codes.

For DALYs, we used two different sources: the 2010 Global Burden of Disease Study, and the 2006 New Zealand Burden of Disease Study, available from the relevant study websites. The DALYs for these two different sources cannot be compared directly. However, including the 2006 DALYs allowed us to compare Māori and non-Māori health burdens.

DALYs are an overall measure of health loss from illness, disability and premature death, and are useful because they give a consistent framework across different diseases and risk factors. DALYs are estimated with burden of disease studies, and are a combination of fatal health loss (years of life lost, or YLL) and non-fatal health loss (years lived with disability, or YLD).

$$\text{DALY} = \text{YLL} + \text{YLD}$$

vii. Calculating the attributable burden in non-smokers

The attributable burden due to second-hand smoke exposure can be estimated by multiplying the PAF by the total health burden:

$$\text{Attributable burden}_{(\text{SHS})} = \text{PAF}_{(\text{SHS})} \times \text{total burden}$$

Children

For children aged 0–14 years, we calculated the attributable burden directly, using the above formula.

Adults

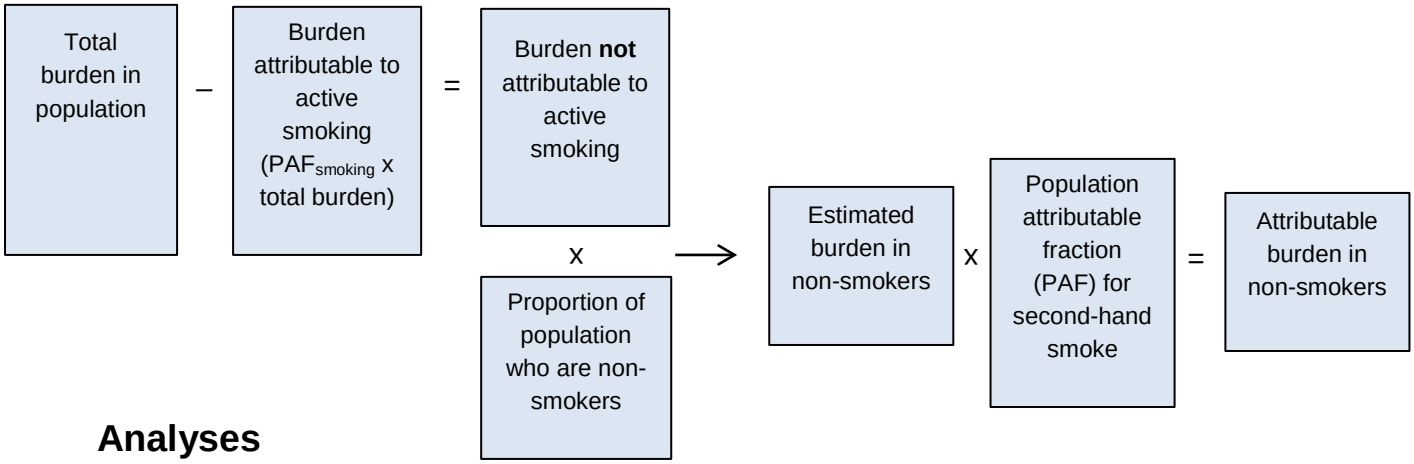
For adults, we estimated the attributable burden only in non-smokers (Figure 9). Current smokers were excluded from the analysis, because most epidemiological evidence is for

non-smokers, and there is uncertainty in the health impact on current smokers from second-hand smoke (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010).

First, we estimated the burden attributable due to active smoking in the population, and subtracted this from the total burden, to calculate the burden not attributable to active smoking. We then estimated this burden in non-smokers, by multiplying the burden not attributable to active smoking by the proportion of non-smokers in the population.

The burden in non-smokers was then multiplied by the PAF for second-hand smoke, to estimate the attributable burden in non-smoking adults. This method is described in more detail in Appendix 1.

Figure 9: Method for estimating the attributable burden in non-smoking adults



Analyses

Total estimates are summations of age- and sex-specific analyses

Analyses were conducted for the total population by sex (males, females) and age group (generally: 0, 1–4, 5–9, 10–14, 15–24, 25–34, 35–44, 45–54, 55–64, 65–74, 75+ years). These analyses were then summed, to get the total attributable burden for the population.

Māori and non-Māori analyses

For deaths (2010) and DALYs (2006), we examined the difference in attributable burden for Māori and non-Māori.

We estimated Māori attributable burden as the difference between total and non-Māori burdens. Directly estimating the attributable burden among Māori gave inconsistent results, with some Māori results similar or greater than the calculated total attributable burden. These issues were likely to be due to uncertainties in the Māori prevalence and health burden estimates, and problems in extrapolating relative risks based on overseas populations to the Māori population. Our sensitivity analyses suggested that using this indirect approach gave a conservative result for Māori.

Age-standardised rates and standardised rate ratios

For sex and ethnic comparisons, age-standardisation was carried out to ensure comparability between populations. Age-standardised rates were calculated using the direct

method, standardised to the WHO world population (Ahmad et al., 2001). Rates were calculated among the total population within the specified age group.

Standardised rate ratios (SRRs) have been calculated as the ratios of two age-standardised rates.

Sensitivity analyses used to show uncertainty and plausible ranges

Estimates of attributable burden have many sources of uncertainty, including in the data inputs (such as relative risks and prevalence estimates), as well as various assumptions in the methods. Uncertainty can be difficult to quantify in these types of environmental burden of disease studies.

We used a sensitivity analysis approach, as recommended by the World Health Organization (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010). Sensitivity analyses test the impact of changing various assumptions one at a time, and can be used to estimate the likely plausible range for the estimates.

For example, we tested the impact of using the lower and upper limits of the 95% confidence intervals for relative risks, and for prevalence estimates.

The sensitivity analyses also tested the impact of including some Level 2 health outcomes (asthma in adults, preterm birth, invasive meningococcal disease and pre-menopausal breast cancer), where causality has yet to be proven.

We have also explored the effect of including other sources of exposure to second-hand smoke. We included historic data on workplace exposure to second-hand smoke for the health conditions of lung cancer (1996 exposure), and ischaemic heart disease and stroke (2006 exposure). We assumed that the health impacts from home and workplace exposure were additive; however data on workplace exposure does not take into account any exposure at home, so may potentially double-count exposure. We also included exposure to second-hand smoke in the home and/or car, to test the effect of including in-vehicle exposure.

The sensitivity analyses are presented on page 33.

Deaths attributable to second-hand smoke in 2010

Key points:

- In 2010, an estimated 104 people died due to second-hand smoke exposure in New Zealand (plausible range 66–137 deaths).
- Most of these deaths were due to ischaemic heart disease (65 deaths) and stroke (28 deaths) in non-smoking adults.
- Six infants died from SUDI (sudden unexpected death in infancy), attributable to second-hand smoke exposure. The population attributable fraction shows that about 11% of SUDI deaths in 2010 were attributable to second-hand smoke.
- Māori were almost three times as likely to die from second-hand smoke exposure as non-Māori, after standardising for age.

This section presents the key findings of the number of deaths attributable to second-hand smoke in the home in New Zealand in 2010.

Over 100 deaths each year due to second-hand smoke
Exposure to second-hand smoke caused an estimated 104 deaths in New Zealand in 2010 (Table 4).

The main causes of death were ischaemic heart disease (65 deaths, 63%) and stroke (28 deaths, 27%), mainly due to the large number of deaths from these conditions in older adults.

Sudden unexpected death in infancy (SUDI) was the primary cause of death due to second-hand smoke for children, contributing six deaths (6% of all attributable deaths). The population attributable fraction shows that about 11% of SUDI deaths in 2010 were attributable to second-hand smoke.

Table 4: Estimated number of deaths attributable to second-hand smoke in New Zealand, 2010

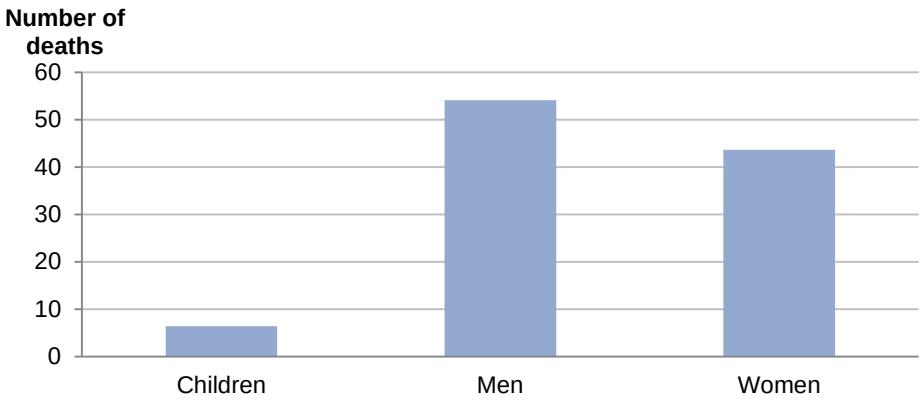
Cause of death	Age group	Deaths in non-smoking adults and children	Attributable deaths		Percentage of deaths that were attributable to second-hand smoke (%)
			Number (%)	Deaths per 100,000 population (unadjusted rate)[1]	
Ischaemic heart disease	15+ years	4649	65 (63)	1.9	1.4
Stroke	35+ years	2236	28 (27)	1.2	1.2
Lung cancer	15+ years	250	5 (5)	0.1	1.9
SUDI (sudden unexpected death in infancy)	0 years	54	6 (6)	9.6	11.3
Small for gestational age	0 years	3	0 (0)	0.1	2.5
Lower respiratory tract infections	0–1 years	9	0 (0)	0.1	1.8
Asthma	0–14 years	2	0 (0)	0.0	1.9
Otitis media (middle ear infections)	0–14 years	0	0 (0)	0.0	–
Total		7203	**104 (100)**	**2.4**	**1.4**

Note: Figures have been rounded.
[1] Within age group.

Males more likely to die from second-hand smoke exposure

The majority of the deaths from second-hand smoke were in adults, particularly in men (Figure 10).

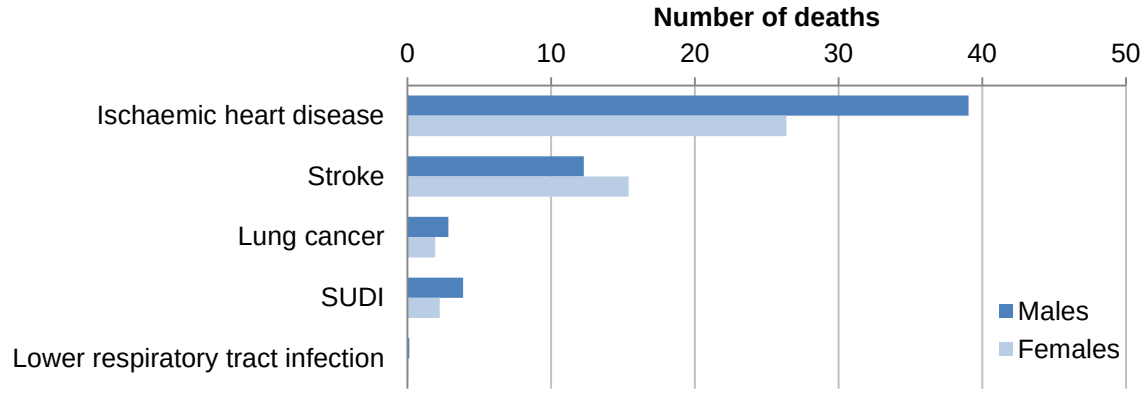
Figure 10: Number of deaths attributable to second-hand smoke, for children, men and women, 2010



Note: Children aged 0–14 years, adults aged 15+ years.

The difference between men and women is primarily due to the higher number of deaths from ischaemic heart disease in men already (Figure 11).

Figure 11: Number of deaths attributable to second-hand smoke, by sex, 2010



After standardising for age, males were over 60% more likely to die from second-hand smoke exposure than females (standardised rate ratio SRR=1.66).

Māori non-smokers are more likely to die from second-hand smoke exposure

In 2010, an estimated 17 Māori died due to exposure to second-hand smoke (Table 5). This is about 17% of all deaths due to second-hand smoke in New Zealand.

Māori were about three times as likely to die from second-hand smoke exposure as non-Māori, standardising for age (SRR = 2.93). Māori males were about 2.5 times as likely as non-Māori males to die due to second-hand smoke (SRR = 2.48). Among females, Māori were about 3.5 times as likely to die from second-hand smoke as non-Māori (SRR = 3.49).

Table 5: Estimated number of deaths attributable to second-hand smoke, by sex and ethnic group, 2010

Sex	Ethnic group	Attributable deaths		Standardised rate ratio (SRR) (Māori vs non-Māori)
		Number	Age-standardised rate per 100,000 population	
Total	Māori	17	3.6	2.93
	Non-Māori	87	1.2	
	Total	104	1.5	
Males	Māori	10	3.9	2.48
	Non-Māori	49	1.6	
	Total	58	1.9	
Females	Māori	8	3.2	3.49
	Non-Māori	38	0.9	
	Total	46	1.1	

Note: Rates age-standardised to the WHO world standard population. Numbers have been rounded, and may not add to 100%.

Plausible range for estimates

For deaths, the plausible range was 66 to 137 deaths, based on the upper and lower confidence intervals for the relative risk estimates. For more information on the sensitivity analyses for deaths in 2010, see page 35.

Health loss attributable to second-hand smoke

Key points:

- Health loss is measured with DALYs (disability-adjusted life years). DALYs consist of years of life lost due to early death, and years spent in disability due to illness.
- In 2010, second-hand smoke exposure caused an estimated 1989 DALYs in New Zealand (plausible range 1288–2748 DALYs).
- The majority (84%) of this health loss was due to early death (years of life lost, or YLL), rather than illness and disability.
- Children accounted for 30% of health loss due to second-hand smoke in 2010.
- In 2006, Māori experienced five times the health loss from second-hand smoke than non-Māori, after standardising for age.

This section presents the key findings of health loss attributable to second-hand smoke in New Zealand in 2010 and 2006.

The term *health loss* refers to how many healthy years of life is lost due to early death, illness and disability. For this study, health loss is measured in DALYs. In many ways, DALYs are a better measure of the health burden than the number of deaths, as they take into account both fatal and non-fatal health loss.

DALYs combine the number of years lost due to early death (based on age at death), and the number of years lived with illness or disability (taking into account the severity of illness or disability). Using this common framework of DALYs allows comparison of different health outcomes and risk factors, regardless of whether the health loss is due to illness, disability or early death.

In this section, we have included results based on two different sources of DALY data:

- 2010 Global Burden of Disease (GBD) Study
- 2006 New Zealand Burden of Disease Study (NZBDS).

The 2010 GBD study provides the most up-to-date DALY data for New Zealand. However, this study did not use New Zealand-specific data for many of the epidemiological inputs (instead imputing data based on other similar countries), and did not provide DALY data by ethnicity.

Data from the 2006 New Zealand Burden of Disease Study has also been used. Although it provides older data, this study mostly used New Zealand-specific data and therefore is likely to give more precise estimates of health loss, as well as providing Māori and non-Māori data.

These two studies cannot be directly compared, due to different methods and data inputs in calculating DALYs. Our estimates of the burden from second-hand smoke may also differ

from those published previously as part of the above two studies (Lim et al., 2012; Ministry of Health, 2013a), as we have used updated data and evidence.

Estimates of health loss for 2010 based on GBD study

This section uses DALY data published in the 2010 Global Burden of Disease Study for New Zealand.

Health loss mostly due to ischaemic heart disease, SIDS and stroke

In 2010, an estimated 1,989 DALYs were lost due to second-hand smoke exposure in New Zealand, based on DALYs from the 2010 Global Burden of Disease Study (Table 6).

Ischaemic heart disease accounted for the majority of health loss (49%), followed by SIDS[1] (21%) and stroke (16%).

SIDS had the largest burden of disease attributable to second hand smoke, in terms of DALYs per 100,000 (within age groups). About 11% of DALYs from SIDS were attributable to second-hand smoke. Additionally, 2.3% of health loss from lung cancer in non-smokers was due to exposure to second-hand smoke in the home.

Children experienced disproportionate health loss from second-hand smoke. About 30% of the total attributable health loss to second-hand smoke was in children aged 0–14 years, despite children making up 22% of the population.

Table 6: Estimated number of DALYs attributable to second-hand smoke in New Zealand, in children and non-smokers, 2010

Health outcome	Age group	DALYs in non-smokers and children	Attributable DALYs (2010)		Percentage of DALYs that were attributable to second-hand smoke (%)
			Number (%)	DALYs per 100,000 population[2]	
Ischaemic heart disease	15+ years	63,163	970 (49)	28.2	1.5
Stroke	35+ years	24,674	328 (16)	14.4	1.3
Lung cancer	15+ years	3,906	91 (5)	2.6	2.3
SIDS (sudden infant death syndrome)[1]	0 years	3,706	417 (21)	654.7	11.3
Asthma	0–14 years	6,928	151 (8)	16.7	2.2
Otitis media (middle ear infections)	0–14 years	833	16 (1)	1.7	1.9
Lower respiratory infections	0–1 years	1,274	15 (1)	4.8	1.2
Total		**104,484**	**1,989 (100)**	**45.7**	**1.9**

Note: Figures have been rounded, and may not sum to total. Data for small for gestational age were not available as part of the GBD study.
[1]SIDS is used instead of SUDI, as only SIDS was available in the GBD study.
[2]Within age group.
Source of DALYs: 2010 Global Burden of Disease Study

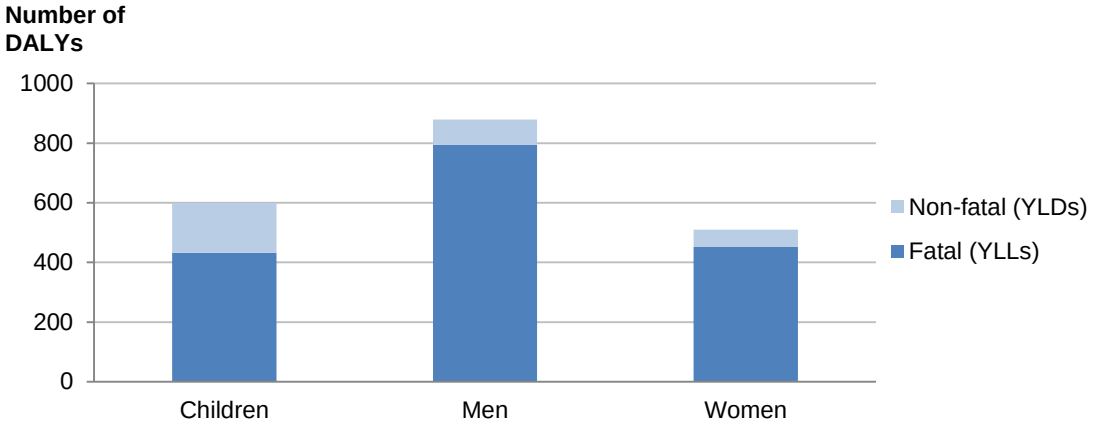
[1] SIDS is used instead of SUDI, as only SIDS was available in the GBD study.

Most health loss from second-hand smoke is fatal

For all population groups (children, men and women), the vast majority of health loss from second-hand smoke was due to the fatal burden (Figure 12).

When measuring health loss (rather than number of deaths), children carried a much higher burden from exposure to second-hand smoke, since DALYs take into account age at death and time spent in ill-health.

Figure 12: Number of DALYs attributable to second-hand smoke, by fatal and non-fatal health loss, among children, men and women, 2010



For most conditions, health loss was primarily due to premature death (years of life lost), rather than illness or disability. However, for asthma and otitis media (middle ear infections) in children, almost all of the health loss was due to illness (Table 7).

Table 7: Estimated number of DALYs attributable to second-hand smoke in New Zealand, in children and non-smokers, by fatal and non-fatal health loss, 2010

Health outcome	Age group	Attributable health loss			Proportion of attributable DALYs that were fatal
		DALYs (YLL + YLD)	YLLs (fatal)	YLDs (non-fatal)	
Ischaemic heart disease	15+ years	970	872	99	90%
Stroke	35+ years	328	285	43	87%
Lung cancer	15+ years	91	90	1	99%
SIDS (sudden infant death syndrome)	0 years	417	417	0	100%
Asthma	0–14 years	151	2	150	1%
Otitis media (middle ear infections)	0–14 years	16	0	15	1%
Lower respiratory tract infections	0–1 years	15	13	2	85%
Total		**1,989**	**1,678**	**310**	**84%**

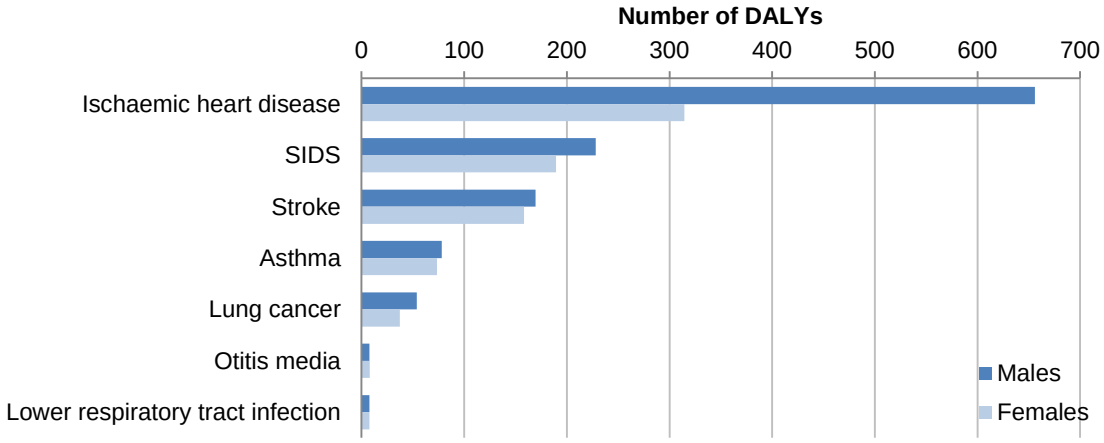
Note: Figures may not sum to stated totals, due to rounding. Small for gestational age is not available in the GBD study. DALY = disability-adjusted life year, YLL = years of life lost, YLD = years of life lived with disability or illness.

Source of DALYs: 2010 Global Burden of Disease Study

Males experience more health loss due to second-hand smoke

Overall, males experienced much more health loss than females, particularly due to ischaemic heart disease (Figure 13).

Figure 13: Number of DALYs attributable to second-hand smoke, by sex and health outcome, in children and non-smoking adults, 2010



Note: Attributable burden is in children and non-smoking adults only.

After standardising for age, males experienced almost 60% more health loss due to second-hand smoke than females in New Zealand (SRR = 1.56).

Plausible range for estimates

For attributable DALYs in 2010, the plausible range was 1288 to 2748 DALYs, based on the upper and lower confidence intervals for the risk estimates. For more information on the sensitivity analyses for health loss in 2010, see page 37.

Estimates of health loss for 2006

This section uses DALY data published in the 2006 New Zealand Burden of Disease Study.

These results cannot be directly compared with the 2010 GBD results above. However, these results provide useful information, particularly about ethnic differences in the burden.

Health loss mainly due to ischaemic heart disease, SUDI and stroke

In 2006, an estimated 2,286 DALYs were lost due to second-hand smoke exposure in New Zealand, based on DALYs from the 2006 New Zealand Burden of Disease Study (Table 8).

Table 8: Estimated number of DALYs attributable to second-hand smoke in New Zealand, 2006

Health outcome	Age group	DALYs in non-smokers and children	Attributable DALYs (2006)		Percentage of DALYs that were attributable to second-hand smoke (%)
			Number (%)	DALYs per 100,000 population[1]	
Ischaemic heart disease	15+ years	68,820	1,033 (45)	31.4	1.5
Stroke	35+ years	30,379	389 (17)	18.1	1.3
Lung cancer	15+ years	4,377	96 (4)	2.9	2.2
SUDI (sudden unexpected death in infancy)	0 years	5,289	596 (26)	997.5	11.3
Lower respiratory tract infections	0–1 years	1,387	42 (2)	14.7	3.1
Asthma	0–14 years	2,969	93 (4)	10.5	3.1
Otitis media (middle ear infections)	0–14 years	1,189	31 (1)	3.5	2.6
Small for gestational age	0 years	244	6 (0)	10.3	2.5
Total		**114,654**	**2,286 (100)**	**54.7**	**2.0**

[1] Within age group.

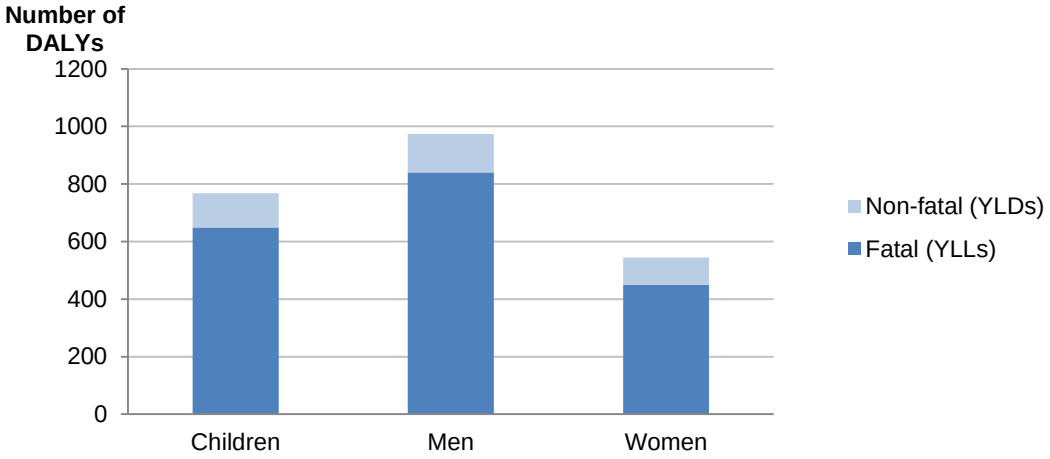
Note: Figures have been rounded and therefore may not sum to totals.

Source of DALYs: 2006 New Zealand Burden of Disease Study

The 2006 analysis showed broadly similar findings as the 2010 analysis. Ischaemic heart disease contributed to almost half of the attributable health loss (45%), mainly due to the large burden of this disease in New Zealand. This was followed by SUDI (26%) and stroke (17%).

When comparing children, men, and women, men had the largest number of DALYs, followed by children then women (Figure 14). Overall, children aged 0–14 years experienced 34% of health loss due to second-hand smoke in 2006.

Figure 14: Number of DALYs attributable to second-hand smoke, by fatal and non-fatal health loss, among children, men and women, 2006



Notes: Children aged 0–14 years, men and women are 15+ years.

Table 9 presents the estimated number of DALYs, YLLs (years of life lost) and YLDs (years lived in disability) attributable to second-hand smoke in 2006. Similar to the 2010 analysis, most health loss was due to early death. However, for children, almost all of the health loss from asthma and otitis media was due to illness.

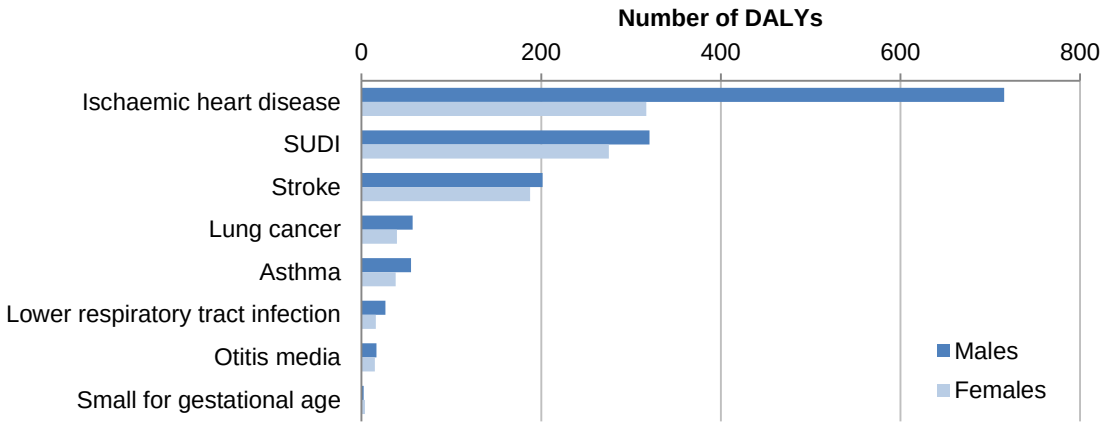
Table 9: Estimated number of DALYs, YLLs and YLDs attributable to second-hand smoke in New Zealand, 2006

Health outcome	Age group	Attributable health loss			Proportion of attributable DALYs that were fatal
		DALYs	YLLs (fatal)	YLDs (non-fatal)	
Ischaemic heart disease	15+ years	1,033	891	142	86%
Stroke	35+ years	389	305	84	79%
Lung cancer	15+ years	96	94	2	98%
SUDI (sudden unexpected death in infancy)	0 years	596	596	0	100%
Lower respiratory infections	0–1 years	42	41	2	96%
Asthma	0–14 years	93	6	87	7%
Otitis media	0–14 years	31	0	31	0%
Small for gestational age	0 years	6	6	0	100%
Total		**2,286**	**1,939**	**347**	**85%**

Note: Figures have been rounded.
Source of DALYs: 2006 New Zealand Burden of Disease Study

Second-hand smoke exposure resulted in twice the amount of health loss in males (1395 DALYs) as in females (892 DALYs). These differences are mainly due to the burden from ischaemic heart disease (Figure 15).

Figure 15: Number of DALYs attributable to second-hand smoke, by sex and health outcome, 2006



After standardising for age, males were about 60% more likely to have health loss due to second-hand smoke than females (SRR=1.61).

Māori disproportionately affected

Māori experienced five times the amount of health loss due to second-hand smoke exposure than non-Māori in 2006, after standardising for age (Table 10).

Māori males had over four times the health loss than non-Māori males (SRR = 4.57), and Māori females had about six times the health loss as non-Māori females (SRR = 5.97), after standardising for age. Additionally, for Māori the health loss was more likely to be fatal than for non-Māori (90% compared with 82% respectively).

Table 10: Estimated number of DALYs and YLLs attributable to second-hand smoke, by sex and ethnic group, 2006

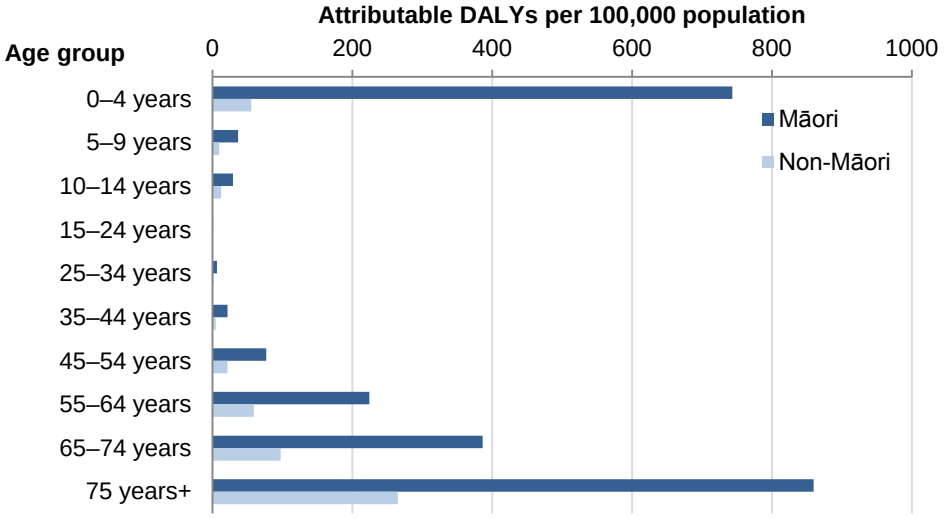
Sex	Ethnic group	Attributable DALYs		Standardised rate ratio (SRR) (Māori vs non-Māori)	Proportion of DALYs that were fatal (YLLs)
		Number	Age-standardised rate per 100,000 population		
Total	Māori	883	144	5.09	90%
	Non-Māori	1403	28		82%
	Total	2286	48		85%
Males	Māori	506	174	4.57	90%
	Non-Māori	889	38		83%
	Total	1395	60		86%
Females	Māori	378	117	5.97	89%
	Non-Māori	514	20		79%
	Total	892	37		84%

Note: Rates are age-standardised to the WHO world standard population.

Māori consistently had a higher burden from second-hand smoke exposure than non-Māori, across all age groups (Figure 16). These differences were particularly seen in young children

(0–4 years) and older adults (65–74 and 75+ years). While these results are based on relatively small numbers and may have some uncertainty, the differences are very large.

Figure 16: DALYs attributable to second-hand smoke per 100,000 population, for Māori and non-Māori, 2006



In particular, Māori children were disproportionately affected by second-hand smoke exposure, accounting for the large majority of health loss from SUDI (85%) and lower respiratory tract infections (73%) in young children (Table 11).

Table 11: Attributable DALYs by health outcome, for Māori and non-Māori, 2006

Health outcome	Age group	Attributable DALY		Proportion of DALYs that were in Maori
		Māori	Non-Māori	
Ischaemic heart disease	15+ years	207	825	20%
Stroke	35+ years	57	332	15%
Lung cancer	15+ years	20	76	21%
SUDI (sudden unexpected death in infancy)	0 years	505	91	85%
Lower respiratory tract infections	0–1 years	31	11	73%
Asthma	0–14 years	44	49	47%
Otitis media	0–14 years	17	14	56%
Small for gestational age	0 years	2	4	34%
Total	**0+**	**883**	**1403**	**39%**

Note: Figures have been rounded.
Source of DALYs: 2006 New Zealand Burden of Disease Study

Uncertainties and sensitivity analyses

Key points:

- Our estimates of the attributable burden have a number of sources of uncertainty, including the estimates of relative risks and exposure prevalence.
- Sensitivity analyses were carried out to show the impact of changing different assumptions and data inputs, one by one, on the final results.
- The attributable burden and plausible ranges were: 104 deaths (plausible range 66–137 deaths) in 2010; 1989 DALYs (plausible range 1288–2748) in 2010, and 2286 DALYs (plausible range 1465–3177) in 2006, based on the confidence limits of the relative risks.
- The largest impact in the sensitivity results was if smokers were in fact susceptible to second-hand smoke; the estimated attributable burden almost doubled.

There is uncertainty in a range of estimates used in this analysis, including the relative risks and prevalence estimates. The estimates are also based on a range of assumptions.

This section describes the main sources of uncertainty in this analysis. The following section on sensitivity analyses shows the impacts of changing different assumptions and data inputs on the final results for deaths and DALYs.

Sources of uncertainty in the analyses

Health conditions selected

The main results only included those health conditions with sufficient evidence to prove they are caused by second-hand smoke exposure.

The sensitivity analyses include four health conditions where evidence is suggestive but not sufficient to prove they are caused by second-hand smoke. These conditions are: preterm births, asthma (induction and exacerbation) in adults, pre-menopausal breast cancer, and meningococcal disease.

Relative risk estimates have uncertainty

The estimates for relative risks used in this study came mainly from meta-analyses, but often still had some uncertainty, generally quantified with confidence intervals.

The sensitivity analyses include estimates using the upper and lower 95% confidence limits of the relative risks. These estimates are used to give the plausible range for results.

Estimates of exposure to second-hand smoke based on survey data

Most of the meta-analyses used for the relative risks had *exposure to second-hand smoke in the home* as their main measure of exposure. We used this measure of exposure in order to be consistent with these studies, and as a proxy for any exposure. This exposure was

measured based on a question about whether anyone smokes inside the house, from the 1996/97, 2006/07 and 2012/13 New Zealand Health Surveys. Estimates of active smoking also came from these surveys.

These exposure estimates can have uncertainty for a variety of reasons.

- Sampling error occurs, because we have used a survey for our estimate rather than a census. The width or range of 95% confidence intervals for exposure estimates reflect this uncertainty.
- The survey question on second-hand smoke exposure does not take into account other factors affecting exposure, such as the number of people smoking in the house, ventilation, climate, and season.
- Responses may be affected by social desirability bias, where survey respondents answer as they think the interviewer wants to hear (in this case that there is no-one smoking in the home).
- People may also be exposed to second-hand smoke outside of their home.

In our sensitivity analyses, we have calculated estimates using the upper and lower 95% confidence limits of the exposure estimates, to show the impact the sampling errors have on the results.

Exposure in the workplace

People may also be exposed to second-hand smoke outside of the home, which will not have been captured in the main analysis.

We included exposure to second-hand smoke in the workplace as part of the sensitivity analyses. We have assumed that the health impacts of home exposure and workplace exposure were independent and therefore able to be added. However, some overlap is likely (ie, if people are exposed both at home and at work), which may lead to overestimating the health burden.

Exposure in vehicles

Vehicles are another potential source of exposure to second-hand smoke, particularly for children and young people.

We included exposure to second-hand smoke in the home and/or car in the sensitivity analysis, to test whether this additional source of exposure would have a large impact on our conclusions. Vehicle exposure was measured with a question in the New Zealand Health Survey, which asked respondents whether anyone smokes in the car they (or their child) usually travel in.

Study population excluding current smokers, including ex-smokers

Our study focuses on the attributable burden in non-smokers, and excludes current smokers. However, a summary of the evidence suggests that current smokers may be as affected by second-hand smoke as non-smokers (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010).

The sensitivity analyses included an estimate testing the impact of including current smokers. In this analysis, current smokers were treated as susceptible to second-hand smoke, and the prevalence of exposure to second-hand smoke in the home was calculated for the total population.

Additionally, our main analyses included ex-smokers, as suggested by the World Health Organization (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010). The assumption that ex-smokers are susceptible to second-hand smoke exposure is plausible, since the health risks from active smoking decrease markedly within five years of stopping smoking, to be similar to the risks for non-smokers. However, there is limited evidence about the impact of second-hand smoke on ex-smokers specifically. To test the potential impact of this assumption, we have included an estimate in our sensitivity analysis that excludes ex-smokers.

Other possible sources of uncertainty

Some other sources of uncertainty also exist, but have not been covered in the sensitivity analysis.

The prevalence of smoking and exposure to second-hand smoke in New Zealand has decreased considerably over the last 10–20 years. To account for these changes, we interpolated the prevalence of exposure to second-hand smoke between survey years (eg, 2006/07 and 2012/13), which may have introduced some uncertainties.

Rates of some diseases have also decreased over time, which is likely to have lowered the attributable burden, regardless of whether exposure to second-hand smoke has changed. We have assumed that the relative risk estimates remain valid given these changes. For example, SUDI rates have decreased dramatically over the past ten years, mainly due to changes in sleep practices. Additionally, mortality rates for ischaemic heart disease and stroke have fallen by 75 percent over the past 40 years, due to reducing risk factors (such as smoking and lower saturated fat intake), earlier detection of disease and better treatment (Ministry of Health, 2014).

Sensitivity analyses

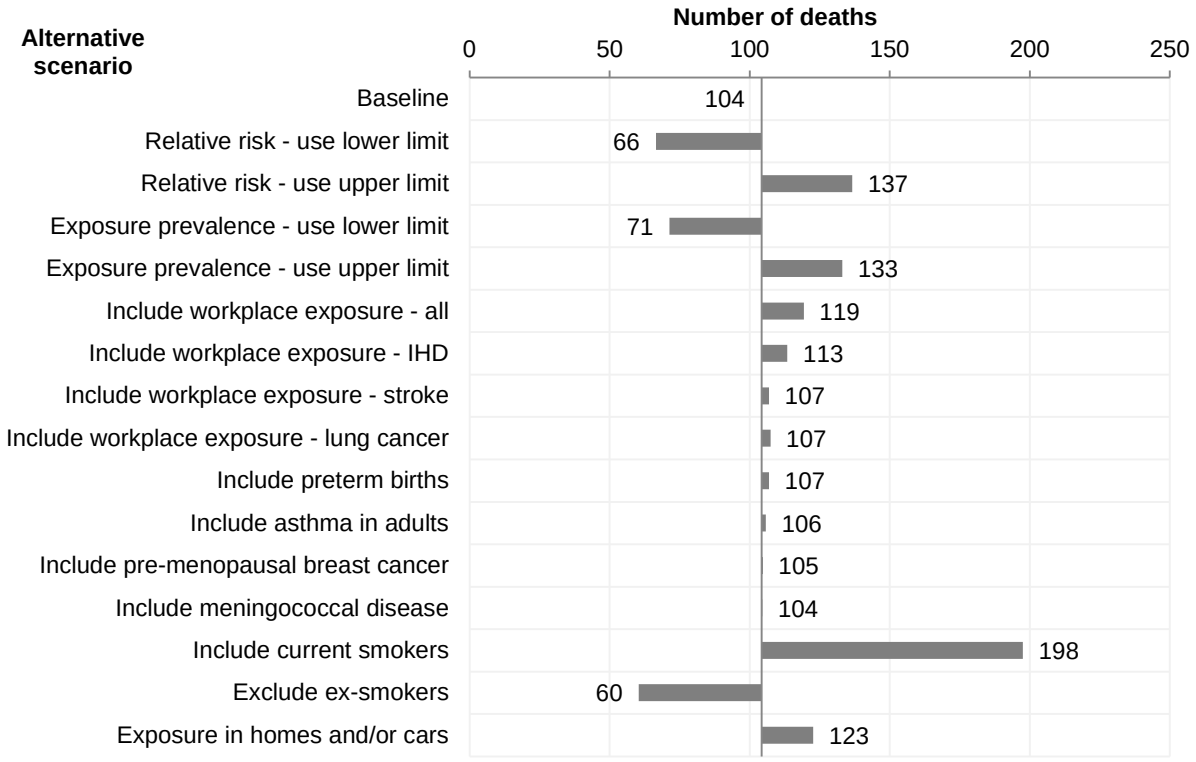
This section presents the sensitivity analyses for the main results. These sensitivity analyses show the impacts of changing certain assumptions in the main analyses. These results cannot be interpreted as statistical bounds or confidence limits.

The full tables of sensitivity analysis results are in Appendix 2.

Sensitivity analyses for deaths (2010)

Figure 17 presents a range of other scenarios we tested in the sensitivity analysis for deaths in 2010. This graph shows the difference made by varying one different variable at a time, on the baseline estimate of 104 deaths. The main results are discussed below.

Figure 17: Sensitivity analysis for deaths attributable to second-hand smoke, under various alternative scenarios, 2010



Note: IHD = ischaemic heart disease.

Plausible range is 66 to 137 deaths, based on relative risks

The sensitivity analysis gives a plausible range of 66–137 deaths due to second-hand smoke each year (compared with the baseline estimate of 104 deaths), based on the lower and upper confidence limits for the relative risks.

Using the lower and upper confidence limits for the exposure prevalence estimates gives a slightly smaller range of 71–133 deaths.

Including workplace exposure from 1996 and 2006 increases deaths by 15

Including workplace exposure to second-hand smoke (with appropriate lag time) resulted in an additional 15 deaths due to second-hand smoke (14% increase). This makes the assumption that the deaths attributable to exposure in the home and in the workplace are additive (ie, that it is not the same people exposed). The majority of these deaths are due to ischaemic heart disease, based on workplace exposure in 2006.

Small increase in deaths if including diseases with less robust evidence

Including health outcomes with weaker evidence (asthma in adults, preterm birth, meningococcal disease, pre-menopausal breast cancer) increases the number of attributable deaths from 104 to 109 deaths. The main contributors to this increase were preterm births (3 deaths) and asthma in adults (2 deaths).

Biggest impact if current smokers are susceptible to second-hand smoke
Overall, the biggest impact found in the sensitivity analysis was if current smokers were also susceptible to second-hand smoke. Including current smokers in the analysis almost doubles the estimated number of attributable deaths each year (to 198 deaths).

Conversely, excluding ex-smokers from the analysis would drop the number of attributable deaths to 60.

Including exposure in cars leads to increase in number of attributable deaths
Including exposure to second-hand smoke in home and/or cars increased the number of deaths by 18, from 104 to 123 deaths. These deaths almost all occurred in adults (particularly in older non-smoking females).

Two methodological differences make small difference
Additionally, two methodological differences have been tested in the sensitivity analyses, which are not presented in Figure 17.

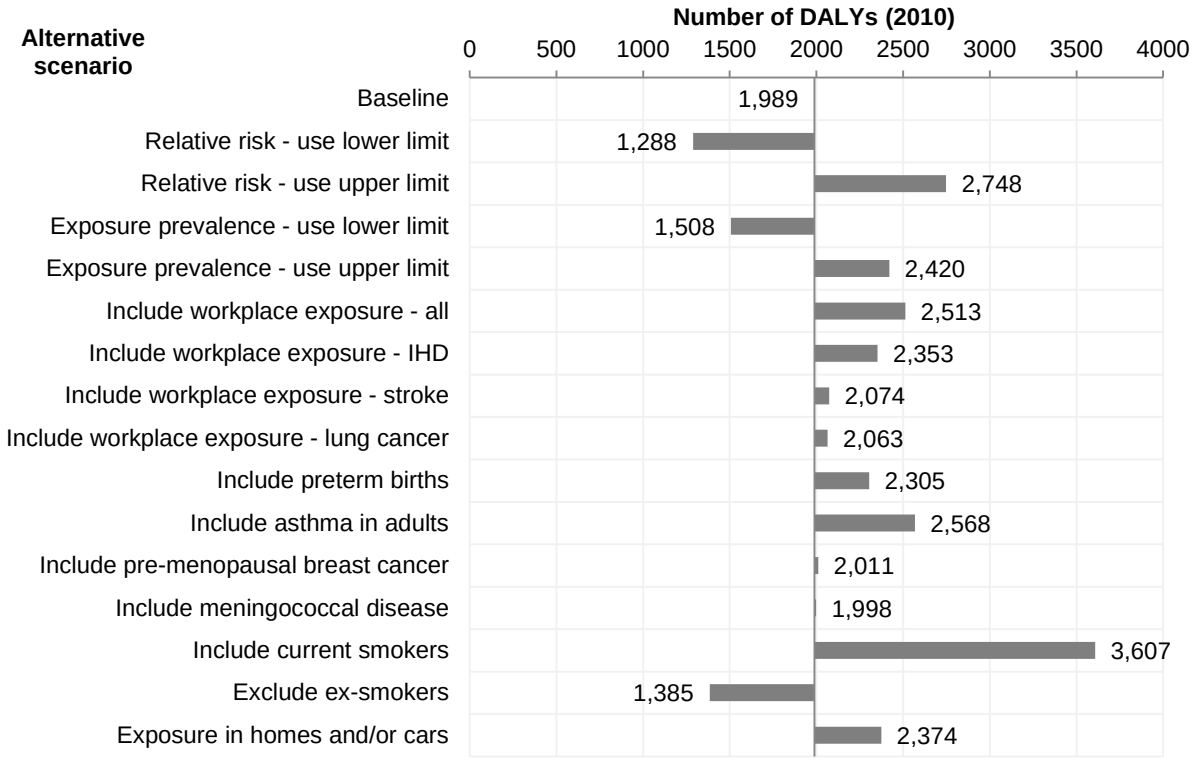
Firstly, in our main analysis, we estimated the Māori burden as the difference between the total estimate and the non-Māori estimate, due to uncertainties in the Māori exposure estimates and relative risks. When we calculated the Māori results directly, it increased the number of Māori deaths from 17 to 22, and increased the overall number of attributable deaths to 109 deaths (5% increase). The estimates for standardised rate ratios (SRR) for Māori compared with non-Māori all increased.

Secondly, when we only used the listed cause of death, not redistributed deaths (where 'garbage codes', implausible or imprecise causes of death, were reassigned to other causes of death using an algorithm), it decreased the overall number of attributable deaths to 100 deaths. This suggests that using only the coded causes of death can lead to a slight underestimation of the true burden.

Sensitivity analyses for DALYs (2010)

Figure 18 presents a range of other scenarios we tested for DALYs in 2010 in the sensitivity analysis, showing the difference made by varying one different variable at a time from the baseline of 1989 DALYs. The main results are discussed below.

Figure 18: Sensitivity analysis for DALYs attributable to second-hand smoke, 2010, under various assumptions



Plausible range for 1989 DALYs is 1288–2748, based on relative risks

This sensitivity analysis suggests that a plausible range of 1288–2748 DALYs (compared with the baseline estimate of 1989 DALYs), based on the upper and lower confidence limits of relative risks.

Using the upper and lower confidence limits for the exposure prevalence estimates gives a slightly smaller range (1508–2420 DALYs).

Workplace exposure contributes a significant amount of health loss in adults

Including workplace exposure increased the health burden attributable to second-hand smoke by 26%, to 2513 DALYs. This was mainly accounted for by ischaemic heart disease, which was based on workplace exposure to second-hand smoke in 2006.

Asthma in adults potentially adds considerable health burden

Including health conditions with weaker evidence increased the attributable burden substantially. In particular, including asthma in adults increased the number of attributable DALYs by 579 DALYs (29% increase). Including preterm births also contributed considerable health burden of 316 DALYs (16% increase).

Pre-menopausal breast cancer and meningococcal disease had a relatively small impact on the attributable burden (an additional 23 and 10 DALYs respectively).

If current smokers are susceptible to second-hand smoke, burden almost doubles
Including current smokers in the analysis increased DALYs by 81%, to 3607 DALYs. This finding suggests that if current smokers are indeed also harmed by second-hand smoke, our main finding underestimates the true burden of disease by a large amount.

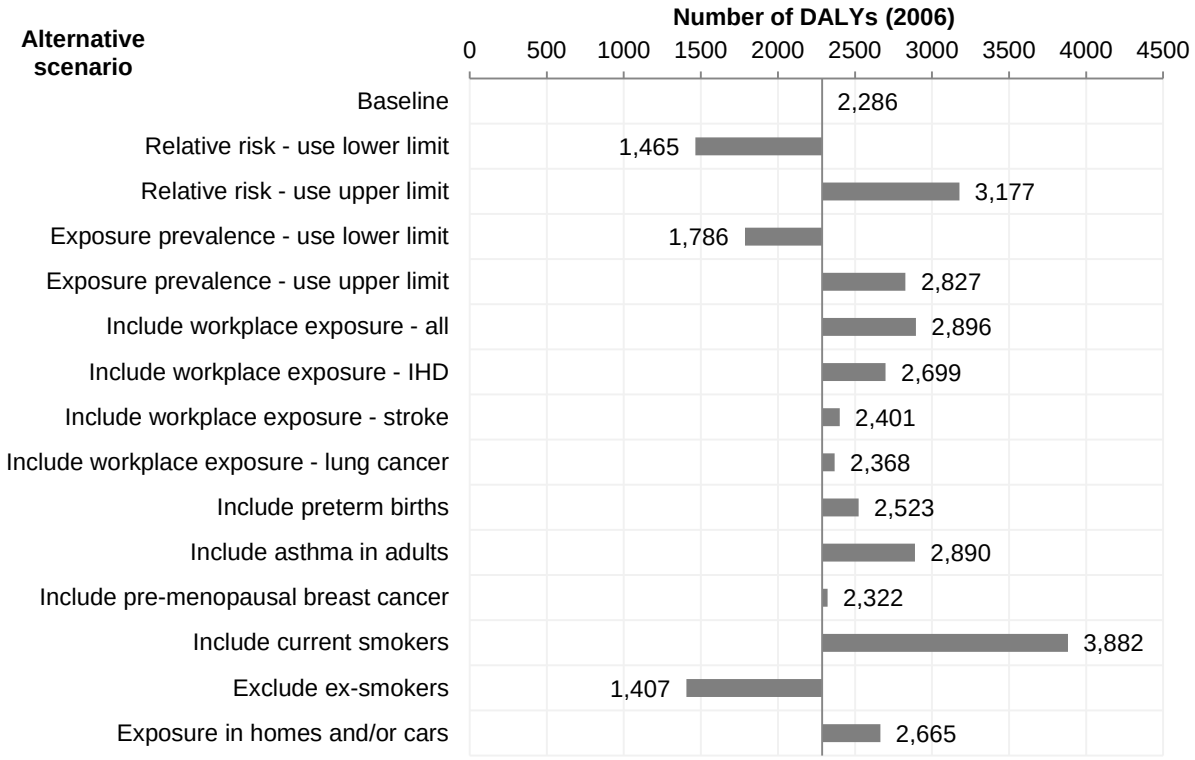
Conversely, if we excluded ex-smokers from the analysis, the DALYs decreased by 30%, to 1385 DALYs.

Exposure in cars
Including exposure in cars as well as homes increased the potential burden by 19%, to 2374 DALYs. A third of this additional health loss was in children, in particular due to an increased burden from asthma.

Sensitivity analyses for DALYs (2006)

Figure 19 presents a range of other scenarios we tested for DALYs in 2006 in the sensitivity analysis, showing the difference made by varying one different variable at a time from the baseline of 2286 DALYs. The main results are discussed below.

Figure 19: Sensitivity analysis for DALYs attributable to second-hand smoke, 2006, under various assumptions



Plausible range is 1465–3177 DALYs, based on relative risk estimates
The sensitivity analysis gives a plausible range of 1465–3177 DALYs due to second-hand smoke in 2010 (compared with a baseline of 2286 DALYs), based on the lower and upper confidence limits for the relative risks.

Using the lower and upper confidence limits for the exposure prevalence estimates gives a smaller range of 1786–2827 DALYs.

Similar findings as in the 2010 DALY sensitivity analysis
Overall, there were similar findings in the sensitivity analyses for 2006 DALYS as for the deaths and DALYs in 2010.

The biggest contribution was from including current smokers as susceptible to second-hand smoke, which included the attributable burden by 70%, to 3882 DALYs.

Other important factors included workplace exposure (an increase of 27% to 2896 DALYs), and including asthma in adults (an increase of 26%, to 2890 DALYs) and preterm births (an increase of 10% to 2523 DALYs).

Including exposure in homes and/or cars also increased the attributable DALYs by 17%, to 2665 DALYs.

Māori results may be underestimates
The issue of whether to estimate the Māori attributable burden indirectly or directly was also tested in the sensitivity analyses (analysis not presented in Figure 19).

In the main analyses, we estimated the Māori burden indirectly, as the difference between the total estimate and the non-Māori estimate, due to uncertainties in the Māori exposure estimates and relative risks.

When we calculated the Māori results directly in the sensitivity analyses, it increased the attributable burden in Māori from 883 DALYs to 1270 DALYs (a 44% increase). It also increased the total attributable burden from 2286 DALYs to 2673 DALYs (a 17% increase). The estimates for standardised rate ratios (SRR) for Māori compared with non-Māori all increased. This suggests that our method of estimating the Māori burden may underestimate the true burden on Māori.

Comparison between the two sources of DALYs
Using both 2006 and 2010 sources of DALYs was also a useful sensitivity analysis, to test the impact of different study methodologies in the two sources of DALYs (the 2006 New Zealand Burden of Disease Study and 2010 Global Burden of Disease Study).

When we applied our condition list, relative risks and prevalence estimates to different sources of DALYs, we got relatively similar findings.

The 2010 GBD results came back slightly lower overall, compared with the 2006 New Zealand Burden of Disease results. One potential reason is a true drop in the attributable burden from 2006 to 2010, due to decreases in the smoking rate, the proportion of the population exposed over time, and the total burden in the population.

Another potential reason is the methodological differences between the two major burden of disease studies. The differences were mainly in estimating the non-fatal burden, such as the different disability weights used in each of the studies, and different sources of prevalence

and incidence data. For example, using the 2006 DALYs gave a higher total and attributable burden due to SUDI, lower respiratory tract infections and otitis media, than when using the 2010 DALYs as source data.

Nonetheless, the similarity in the findings, regardless of the source of DALYs used, suggests that the DALY sources are relatively robust.

Discussion

Key points:

- Second-hand smoke exposure is an entirely preventable environmental cause of ill-health and premature death. An estimated 104 people died from second-hand smoke exposure in New Zealand in 2010.
- Children and infants are more vulnerable to the effects of second-hand smoke, as their lungs are still developing, and they often do not get a choice in their level of exposure. Infants are at almost twice the risk of SUDI in their first year of life if their mother smokes.
- Children are disproportionately affected by second-hand smoke, accounting for about 30% of all health loss from second-hand smoke in 2010. Most of this health loss was fatal.
- Inequalities in health loss from second-hand smoke are clear, with Māori experiencing about five times the health loss of non-Māori, after accounting for age differences. Even among Māori who do not smoke, tobacco use still has a sizeable health impact.
- Sensitivity analyses suggest that the attributable burden from second-hand smoke could be much higher under different assumptions, including if smokers are susceptible to second-hand smoke exposure, and if second-hand smoke exposure outside of the home (such as in workplaces or cars) was included.
- This study shows there is much scope for health gains through providing smokefree environments (for example, in homes and cars), and ensuring women and their partners are smokefree during pregnancy and remain smokefree after their infant is born.

Key findings

Second-hand smoke contributes to illness and early death in New Zealand
Our study found that in 2010, exposure to second-hand smoke caused an estimated 104 deaths in New Zealand. Additionally, second-hand smoke resulted in health loss of about 1989 DALYs in 2010. The majority (84%) of this health loss was from years of life lost due to early death, rather than illness. The main conditions contributing to this burden were ischaemic heart disease, SUDI and stroke.

These results provide an indication of the potential health gain that could be achieved if no one in the population was exposed to second-hand smoke. These results may help guide policy decisions, although it should be remembered that these results are only estimates, rather than an exact number of deaths or DALYs that could be prevented through specific interventions.

Children are disproportionately affected by second-hand smoke

This study found that children are disproportionately affected by exposure to second-hand smoke in New Zealand, experiencing about 30% of the total health loss from exposure to second-hand smoke.

Much of this health loss in children was fatal, particularly through SUDI deaths. An estimated six children died of SUDI due to second-hand smoke exposure (measured by the mother smoking in the first year of the infant's life) in New Zealand in 2010. Health loss from SUDI accounted for about a quarter of all health loss from second-hand smoke.

Additionally, our results showed that other health conditions, including lower respiratory tract infections, asthma and middle ear infections, carried a substantial non-fatal burden for children. This means that children are living in ill-health as a result of their exposure to second-hand smoke in the home.

In 2010, New Zealand children aged 0–4 years had a somewhat higher burden of disease from second-hand smoke compared with Australia, Canada and the United States, according to results published from the 2010 Global Burden of Disease (IHME, 2013). This comparison did not include the burden from SUDI, and will therefore be missing a large portion of the attributable burden in children. Given that New Zealand has relatively high rates of SUDI compared with these countries (International Society for the Study and Prevention of Perinatal and Infant Death, 2012), the disparities between New Zealand and other countries are likely to be larger. There are no obvious causes for these findings; further investigation into these differences may be warranted.

Males experience a higher burden than females

Our results found that males experienced about 60% more health loss than females due to second-hand smoke. For the most part, these differences were driven by higher attributable burden from ischaemic heart disease in males.

This pattern of a higher impact in men was similar to that seen in Australia, the United Kingdom, and to a greater extent, Canada and the United States, when examining the 2010 Global Burden of Disease Study findings (IHME, 2013). Of interest, these results show a different trend to the global findings from 2004, when females experienced a higher burden of disease from second-hand smoke. In 2004, 64% of global deaths attributable to second-hand smoke occurred in females (Őberg, Jaakkola, Prűss-Űstűn, Peruga, & Woodward, 2010), compared with 44% in New Zealand in 2010. This difference may be due to differences in smoking participation and stages of the tobacco epidemic curve for New Zealand, compared with developing countries.

Persisting inequalities for Māori

We found that Māori are disproportionately affected by second-hand smoke in New Zealand. Māori experienced about five times the health loss due to second-hand smoke as non-Māori, after standardising for age. This high burden is largely accounted for by increased SUDI deaths, although a higher burden is also seen in Māori adults, particularly those aged 65 years and over. The sensitivity analyses suggested that the true burden may potentially be underestimated in Māori.

The higher burden among Māori can be partly explained by two factors. Firstly, Māori have a higher total burden of disease than non-Māori, with inequalities particularly seen for ischaemic heart disease, lung cancer and SUDI (Ministry of Health, 2013a). Secondly, Māori have higher rates of exposure to second-hand smoke, with about 9% of Māori children and non-smoking adults exposed in their home, compared with 3–4% of non-Māori children and adults. The higher levels of exposure may partly be explained by higher smoking rates among Māori (39%) compared with non-Māori (14%). These findings suggest that even among Māori who do not smoke, tobacco use still impacts on their health through second-hand smoke exposure.

Evidence suggests a drop in burden of disease from second-hand smoke

There are suggestions that the burden of disease from second-hand smoke has reduced over time. We did not directly examine changes over time, and cannot directly compare our DALY estimates from 2006 and 2010 to show changes over time. Nonetheless, evidence suggests that the health burden from second-hand smoke has decreased.

Firstly, the 2010 Global Burden of Disease Study found that the burden attributable to second-hand smoke had reduced dramatically in New Zealand, from an estimated 3447 DALYs in 1990, to 1873 DALYs in 2010 (IHME, 2013). While these results have some uncertainty and lacked New Zealand-specific data for some of the inputs, the large decrease suggests a likely trend of decreasing burden over time.

Secondly, a previous study estimated a higher attributable burden of 347 deaths in New Zealand in 1996/97, including 247 deaths due to second-hand smoke exposure in the home (Woodward & Laugeson, 2000). Our estimate of 104 deaths in 2010 suggests a drop in attributable burden over time, although different data inputs (including health outcomes, exposure, and relative risk estimates) may account for some of the differences. For example, the relative risks used for the 1996/97 estimate were different from those in our study for many conditions (particularly stroke, RR = 2.10 and 1.66 for men and women respectively, and SIDS, RR=5.3). If the most recent relative risk estimates were used instead, the number of attributable deaths from second-hand smoke exposure in the home would have dropped from 247 to 168 deaths in 1996/97. Additionally, exposure to second-hand smoke in the home has reduced substantially from 2006/07 to 2012/13, and overall levels of disease burden have also dropped over time (including ischaemic heart disease, stroke and SUDI). These factors make the apparent decrease in attributable burden plausible.

This suggested decrease in the attributable health burden from second-hand smoke is likely due to a range of public health initiatives that began with the Smoke-free Environments Act 1990, and consequent shifts in attitudes towards smoking. Since this time, there has been a decrease in (i) smoking rates, (ii) exposure to secondhand smoke in homes and workplaces, and (iii) the overall burden of disease in the population (particularly for ischaemic heart disease, stroke and SUDI) in New Zealand.

Scope for health gain remains high

Second-hand smoke is an entirely preventable environmental exposure, and there is no risk-free level of exposure to second-hand smoke. This study highlights that substantial health gains could be made by reducing people's exposure to second-hand smoke.

Children's health can be improved by ensuring they have smokefree homes and cars. Children are more vulnerable to the effects of second-hand smoke, and have little choice in their exposure levels. Our study shows that children are more likely to be exposed to second-hand smoke than non-smoking adults, and experience about 30% of the health burden from second-hand smoke. These results suggest promoting smokefree environments present a potential opportunity for improving child health outcomes.

It is also important that mothers stay smokefree once their child is born. About 11% of SUDI deaths are attributable to second-hand smoke in New Zealand, with infants whose mother smokes being at twice the risk of SUDI. However, two in five women who quit smoking before or during pregnancy take up smoking again after childbirth (Morton et al., 2012). These results suggest that continued support and encouragement is given to women to quit smoking during pregnancy, and to remain smokefree after the infant's birth.

Māori are disproportionately affected by second-hand smoke exposure, experiencing about five times the health loss of non-Māori. In 2006, an estimated 40% of the total health loss from second-hand smoke was in Māori children and non-smokers. These findings suggest that there is scope for health gains and reducing health disparities for Māori, by reducing exposure to second-hand smoke.

The government aim of Smokefree Aotearoa 2025, of the smoking rate dropping below 5%, will continue to improve people's health, by decreasing people's exposure to second-hand smoke.

This analysis is conservative, and may underestimate the true burden

The results in this study are conservative estimates of the health loss attributable to second-hand smoke in New Zealand. The sensitivity analyses provide an indication of the uncertainty in the estimates, by providing the estimated health burden under different assumptions and hypotheses. These sensitivity analyses show that other factors may potentially increase the true burden.

Firstly, health loss from second-hand smoke would be substantially higher if other health conditions (meningococcal disease, pre-menopausal breast cancer, asthma in adults and preterm births) are also caused by exposure to second-hand smoke. In particular, asthma in adults and preterm births would contribute a substantial amount of health loss (an increase in DALYs of 29% and 16% respectively) if they were included. These conditions are currently considered to be 'Level 2' conditions, where the evidence of causality is not sufficient, but is strongly suggestive (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010). Further evidence proving causality would be needed before these conditions could be included in the main analysis.

Secondly, results may underestimate the true burden because we did not include workplace exposure in the main analyses. Workplace exposure is only relevant for lung cancer, ischaemic heart disease and stroke in adults, for past exposure (due to the lag period

between exposure and disease[2]). In 1996 (the period of exposure for lung cancer), workplace exposure was relatively high, with 19% of non-smoking males and 6% of non-smoking females exposed to second-hand smoke in the workplace during work hours (Hill, 2003; Ministry of Health, 1996). In 2006, workplace exposure was lower, at 7.8% among non-smokers (Waa & McGough, 2006a). Including workplace exposure as an additional source of exposure gave an increase of 15 deaths, and a 26% increase in DALYs in 2010, primarily in males. However, given that some of these people may have been exposed in both the workplace and home, this sensitivity analysis gives an upper limit of the estimated burden. With legislation prohibiting smoking in the indoor work environment since late 2004, the burden from workplace exposure is expected to continue decreasing.

Thirdly, our analysis only assessed the attributable burden in non-smokers, which may have under- or over-estimated the true health burden. If current smokers had been included in the analysis, the attributable health burden from second-hand smoke would have been almost twice as high. While there is some evidence to suggest that current smokers may have a similar risk as non-smokers, further research is needed in this area to determine whether smokers are susceptible to second-hand smoke, and if so, the increased health risk. If ex-smokers were excluded from the analysis (based on the evidence not being as strong for ex-smokers as for never-smokers), the attributable burden decreased by 30–40%.

Our analysis also only included second-hand smoke exposure in the home, as the main measure of exposure. Sensitivity analyses showed that including second-hand smoke exposure in vehicles increased the attributable DALYs by 19%, and attributable deaths by 18 deaths. About a third of the additional health loss was in children, with the remaining health loss in older adults; the additional deaths were almost entirely in adults, particularly in older non-smoking women. Evidence suggests that second-hand smoke concentrations are much higher in cars, and people have much less ability to avoid smoke when seat-belted in a car. However, there is some uncertainty around whether being exposed in cars increases the health risk to the same extent as being exposed in homes, given that much less time is spent in vehicles than in homes, and concentrations of second-hand smoke in vehicles can vary depending on a range of factors.

Māori results may also be underestimated, as we estimated the attributable burden in Māori indirectly, as the difference between total and non-Māori burden. This approach was used because there was uncertainty on how well the relative risks apply to the Māori population, and also in the exposure data for Maori. These uncertainties led to relatively unstable estimates of attributable burden for Māori. The sensitivity analysis showed that estimating Māori results directly would have increased the burden in Māori, and exacerbated the differences between Māori and non-Māori, suggesting that our results may underestimate the burden for Māori.

Despite these limitations, our results are relatively consistent with previous estimates of the burden of disease, published as part of burden of disease studies (IHME, 2013; Ministry of Health, 2013a). Differences are mostly explained by an updating of the evidence and health

[2] The lag period between exposure to second-hand smoke and disease is 10–20 years for lung cancer, and 1–5 years for ischaemic heart disease and stroke.

conditions included (for example, we did not include asthma in adults, based on the most recent review of the evidence).

Conclusion

Over time, there appears to have been a large reduction in the health burden from second-hand smoke. Nonetheless, second-hand smoke remains an entirely preventable source of indoor air pollution leading to illness and early death in children and adults in New Zealand.

This study has showed that some population groups are at much higher risk of experiencing health effects from second-hand smoke, including infants, children, older adults and Māori. Health gains could be made by encouraging smokefree homes and cars. Additionally, women and their partners should be encouraged to quit smoking before or during pregnancy, and to remain smokefree once the infant is born. In particular, the first year appears to be particularly important for being smokefree, to protect the health of the infant.

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Appendix 1: Details of the methods

This appendix includes details of the methodology used in this study, in particular:

- health outcomes selected for second-hand smoke burden estimate
- relative risk estimates
- relative risks for active smoking
- health statistics
- exposure data.

Health outcomes selected for second-hand smoke burden estimate

Table 12 and Table 13 summarise the latest evidence on the health outcomes related to second-hand smoke, with the health outcomes included shown in bold. Level 1 conditions are those with sufficient evidence to show a causal relationship (US Department of Health and Human Services, 2014). Level 2 conditions have evidence that strongly suggests causality, although not sufficient to prove causality. Some Level 2 conditions have been included in the sensitivity analysis, to test the impact on the estimate of the burden of disease.

Table 12: Health outcomes linked to second-hand smoke exposure for children, by evidence level

Evidence level used in our study	Children's condition	Level of evidence		
		Cal-EPA (2005)	WHO (2010)	US Surgeon General (2014 and 2006)
Level 1 – Sufficient evidence of causality	**Low birthweight at term**	1	1	1
	Lower respiratory tract infections (eg, bronchitis and pneumonia)	1	1	1
	Middle ear infections (including acute and recurrent otitis media and chronic middle ear effusion)	1	1	1
	Asthma (ever having asthma)	1	1	1
	Asthma onset	1	1	2
	SIDS (Sudden Infant Death Syndrome)	1	1	1
	Decreased lung function	–	1	1
	Chronic respiratory symptoms (cough, phlegm, wheeze, breathlessness)	1	1	1
Level 2 – Evidence of causality is suggestive but not sufficient to infer a causal relationship	**Preterm delivery**	1	2	2
	Meningococcal disease	–	–	–
	Childhood cancers (leukaemias, lymphomas, brain tumours)	2	–	2
Level 3 – Evidence is inadequate to infer the presence or absence of a causal relationship	Spontaneous abortion	2	3	3
	Neonatal mortality	3	–	3
	Congenital malformation	3	3	3
	Adenoidectomy / tonsillectomy		–	3
	Behavioural problems		–	3
	Allergy (atopy)		–	3
	Physical and cognitive development		3	3
	Intrauterine growth retardation	2		

– = no mention. **Bold** indicates conditions included in our study.

Sources: Cal-EPA (2005); Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al. (2010); US Surgeon General (2006); US Department of Health and Human Services (2014).

Table 13: Health outcomes linked to second-hand smoke exposure for adults, by evidence level

Evidence level	Adults condition	Level of evidence		
		Cal-EPA 2005	**WHO 2010**	**US Surgeon General (2014 and 2006)**
Level 1 – Sufficient evidence of causality	**Lung cancer**	1	1	1
	Ischaemic heart disease	1	1	1
	Stroke	2	2	1
	Odor annoyance, nasal irritation	1	-	1
Level 2 – Evidence of causality strongly suggestive/ evidence is suggestive but not sufficient to infer a causal relationship	**Asthma (induction)**	1	1	2
	Asthma (exacerbation)	1	2	2
	Breast cancer (pre-menopausal women)	1	2	2
	Cancer of the nasal sinus cavity	1	2	2
	Chronic obstructive pulmonary disease (COPD)	–	2	2
	Atherosclerosis / subclinical vascular disease			2
	Chronic respiratory symptoms	2	2	2
Level 3 – Evidence of causality is limited or inconclusive / inadequate to infer the presence or absence of a causal relationship	Female fertility or fecundability	2	–	3
	Decline in lung function	–	–	3
	Tuberculosis	–	–	3
	Cancer (all cancer)	2	3	–
	Nasopharyngeal cancer	2	3	3
	Cervical cancer	2	3	3
	Urinary tract/bladder cancer	–	3	–
	Stomach cancer	–	3	–
	Brain cancer	–	3	–
	Leukaemia	–	3	–
	Lymphoma	–	3	–

– = no mention. **Bold** indicates conditions included in our study.

Sources: Cal-EPA (2005); Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al. (2010); US Surgeon General (2006); US Department of Health and Human Services (2014).

The above summaries are based on reviews and meta-analyses reported in a range of reports (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010; US Department of Health and Human Services, 2014; US Surgeon General, 2006; Cal-EPA, 2005). In particular, we have included stroke as a Level 1 condition, based on the recent US Surgeon General report (US Department of Health and Human Services, 2014).

Relative risks for second-hand smoke

Table 14 summarises the health outcomes, relative risks and populations used in this study. These relative risks mostly come from meta-analyses. One modification is in our DALYs analysis (2006 and 2010) for lower respiratory infections, we used a population-weighted average for the relative risks for the age group 1–4 years, on the basis that the relative risk only applied to 0–1 years.

Table 14: Level 1 diseases included in the calculation of attributable burden from SHS

Health effect	Description	Risk estimate	Age group	Exposure variable	Study/ source
Lung cancer	Incidence	RR 1.21 (1.13–1.30) RR 1.22 (1.13–1.33)	15+ years	At home At work	US Surgeon General (2006)
Ischaemic heart disease	Incidence of any IHD	RR 1.27 (1.19–1.36)	15+ years	At home or work	US Surgeon General (2006)
Stroke	Stroke	RR 1.25 (1.12–1.38)	35+ years	At home or at work	Oono et al (2011)
Lower respiratory infections	Lower respiratory infection (including bronchitis, bronchiolitis, pneumonia and acute respiratory infection)	OR 1.54 (1.40–1.69)	0–1 years	Any household member smoking	Jones et al (2011)
Sudden infant death syndrome (SIDS)	Incidence	OR 1.94 (1.55–2.43)	<1 year	Smoking mother (postnatal exposure)	Anderson and Cook (1997)
Small for gestational age	Low birthweight (<2500g) at term	OR 1.38 (1.13–1.69)	0 year	Non-smoking mother exposed at work or at home	Windham et al (1999)
Middle ear infection (otitis media)	Middle ear infection	OR 1.32 (1.20–1.45)	0–14 years	Household smoker	Jones et al (2012)
Asthma	Physician-diagnosed childhood asthma	OR 1.32 (1.23–1.42)	0–14 years	Either parent	Tinuoye et al (2013), similar to estimates from Cal-EPA (2005)

Note: RR = relative risk, OR = odds ratio

Some additional (Level 2) health conditions were also included in the sensitivity analyses (Table 15). Evidence for these conditions suggests a causal relationship with second-hand smoke exposure, but there is currently insufficient evidence to include as Level 1 conditions.

Table 15: Level 2 diseases included in the sensitivity analysis (suggestive of causal relationship, but insufficient evidence)

Health effect	Description	Risk estimate	Age group	Exposure variable	Study/ source
Preterm delivery	Incidence of births before gestation week 37	OR 1.57 (1.35–1.84)	0	Non-smoking mother, with any exposure at work or at home	Cal-EPA (2005)
Asthma (adults)	Adult-onset incident asthma (assume exacerbation is similar)	OR 1.97 (1.19–3.25)	>20 years (can use 15+ years)	At home and/or at work	Jaakkola et al (2003)
Meningococcal disease	Incidence of invasive meningococcal disease	OR 2.18 (1.63–2.92) (bias corrected OR of 1.59 (1.17–2.15))	Children <18 years	Any smoker in household	Murray et al (2012)
Breast cancer	Incidence of pre-menopausal breast cancer	RR 1.36 (1.07–1.72)	Pre-menopausal (assume 15–44 years)	Any source of exposure (home, spouse and/or work)	US Surgeon General (US Department of Health and Human Services, 2014)

Note: RR = relative risk, OR = odds ratio

Relative risks for active smoking

To estimate the burden of disease attributable to smoking, we needed the relative risks for active smoking. These were taken from the Cancer Prevention Study (Thun, Apicella, & Henley, 2000; Thun et al., 2013) for lung cancer, ischaemic heart disease and stroke (Table 16).

In general, we used the latest evidence (2000–2010) cohort for ages 55 years and over. Because the updated data did not cover younger ages, we used the 1982–1988 cohort evidence for those aged 15–54 years.

Table 16: Relative risks for current smoking and trachea, bronchus and lung cancer, ischaemic heart disease and stroke

Condition	Sex	Age group	Estimate of hazard ratio	95% confidence interval
Trachea, bronchus and lung cancer (1982–1988 cohort)	Male	35+	21.3	17.7–25.6
	Female	35+	12.5	10.9–14.3
Death from lung cancer (2000–2010 cohort)	Male	55+ years	24.97	22.20–28.09
	Female	55+ years	25.66	23.17–28.40
Ischaemic heart disease (1982–1988 cohort)	Male	35–64 years	2.6	2.4–2.9
	Male	65+ years	1.5	1.3–1.6
	Female	35–64 years	3.2	2.8–3.6
	Female	65+ years	1.7	1.6–1.9
Death from ischaemic heart disease (2000–2010 cohort)	Male	55+ years	2.50	2.34–2.66
	Female	55+ years	2.86	2.65–3.08
Stroke (1982–1988 cohort)	Male	35–64 years	2.4	1.8–3.0
	Male	65+ years	1.5	1.2–1.8
	Female	35–64 years	3.8	3.1–4.7
	Female	65+ years	1.6	1.4–1.9
Death from any stroke (2000–2010 cohort)	Male	55+ years	1.92	1.66–2.21
	Female	55+ years	2.10	1.87–2.36

Notes: Fully adjusted model; comparison group is never smokers.
Source: Thun et al. (2000); Thun et al. (2013).

For pre-menopausal breast cancer in women, we used the relative risk estimate of 1.12 for female current smokers (US Department of Health and Human Services, 2014).

For asthma in adults, we used the relative risk estimate of 1.33 (Piipari, Jaakkola, Jaakkola, & Jaakkola, 2004).

Exposure data

It is important to get exposure data that matches the exposure used to estimate the relative risks (exposure-response relationship). In this study, we used survey data and administrative data to get exposure to second-hand smoke.

New Zealand Health Survey

The main source of data on exposure to second-hand smoke for children and non-smoking adults was the New Zealand Health Survey. We obtained the confidentialised unit record files for the 1996/97, 2006/07 and 2012/13 New Zealand Health Surveys from Statistics New Zealand, and analysed the question on whether anyone smokes inside their house. We calculated the prevalence of second-hand exposure in the home by age group, sex and ethnic group for each of these years. Weighted data and jackknife weights were used to calculate 95% confidence intervals.

The prevalence of exposure to second-hand smoke has decreased substantially in New Zealand over the past 10–20 years. Given these changes, we estimated exposure to second-hand smoke in 2010 by interpolating values based on the 2006/07 and 2012/13 survey values. This interpolation was conducted for each age-sex-ethnicity cohort, using an exponential decay function, which was shown to fit the data better than a linear function.

For lung cancer, the latency period means there is a 10–20 year delay between exposure and health outcomes. For this reason, we used lagged data for the cohorts, using 1996/97 data (13–14 years prior to 2010). We also applied a 1–5 year lag period for ischaemic heart disease and stroke, for deaths and DALYs from 2010. For the 2006 DALYs, we used 2006/07 survey data as the more reliable measure of exposure in this period.

We have used exposure to second-hand smoke in the home as the proxy for any exposure to second-hand smoke, as suggested by the World Health Organization (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010). However, workplace exposure has been included in the sensitivity analysis.

Additionally, the New Zealand Health Surveys included a question on whether anyone smoked inside their car. This information was used in sensitivity analyses to estimate the number of people exposed to second-hand smoke in either their house or car.

Well Child / Tamariki Ora data for infants

For the health outcome of SUDI, the exposure is maternal smoking. Therefore, we used data from the Well Child / Tamariki Ora programme on the proportion of mothers who smoked at two weeks after birth (Ministry of Health, 2013b).

The Well Child / Tamariki Ora programme covers about 85 percent of infants in New Zealand. Data has been reported since 2012 for all mothers, Māori mothers, Pacific mothers and mothers living in high deprivation areas.

The Well Child / Tamariki Ora data for July – December 2012 showed that 7% of all mothers and 35% of Māori mothers were smoking at two weeks after birth. We used the number of live births for Māori and non-Māori reported by Statistics New Zealand for July–December 2012 (8582 Māori and 21,613 non-Māori babies) to estimate the proportion of non-Māori mothers smoking at two weeks after birth to be 4.8%.

Growing Up in New Zealand data for pregnant women

For the health outcome of low birthweight at term, the exposure is non-smoking mothers exposed to second-hand smoke during pregnancy. We used data from the cohort study 'Growing Up in New Zealand'. Antenatal interviews with mothers collected data on whether the woman and/or their partner smoke (Morton et al., 2010). This cohort study involves about 6000 infants born in 2009–2010 in Auckland and Waikato regions in New Zealand. The cohort has been shown to be broadly representative of New Zealand births (Morton et al., 2014).

This report does not include the effects of active smoking by mothers during pregnancy.

Health statistics

We used two different measures of health outcomes:

- Deaths (annual average 2009–2011)
- DALYs (disability-adjusted life years) in 2006 and 2010

Deaths (2010)

We used death data from the New Zealand Mortality Collection (annual average 2009–2011). Deaths of non-residents were excluded from the analysis.

We used ICD codes consistent with the New Zealand Burden of Disease Study, including for SUDI (Table 17).

Table 17: ICD-10AM codes used for mortality analysis

Health outcome	ICD-10AM codes
Ischaemic heart disease	I20–I25
Stroke	I64–I67, G45–G46, I60–I62
Lung cancer	C33–C34
Asthma	J45–J46
Lower respiratory tract infections	J12, J13–J16, J18, J20, J21, J85, J86
Otitis media	H65, H66
SUDI (sudden unexpected death in infancy)	R95, R99, W75
Small for gestational age	P05
Preterm birth	P05, P07, P08, P22, P25–P28, P77
Breast cancer	C50
Meningococcal disease	A39

Redistributing poorly coded deaths ('garbage codes')

Consistent with the burden of disease approach, we used the underlying cause of death in the analysis. This approach requires recoding any deaths with an invalid or problematic cause of death. In New Zealand, a small proportion (about ten percent) of deaths has a 'problematic' code (Ministry of Health, 2013c), such as:

- implausible causes of death (eg, diseases that are never fatal)
- immediate and intermediate causes of death (steps along the pathway leading to death, but not the underlying cause of death)
- poorly specified or ill-defined causes of death (where the precise cause is not known, such as cancer of unknown primary site)
- conditions that are considered to be risk factors or late complications (sequelae) of other conditions (such as obesity, paraplegia).

For this process, we used the algorithm used in the New Zealand Burden of Disease Study (Ministry of Health, 2013c). This process included redistributing the above types of problematic deaths to more appropriate causes of death. In our study, this process had the largest effect on deaths from coded to ischaemic heart disease (increasing deaths in 2009–11 by 5.3%, from 16,211 to 17,078), stroke (increase of 4.0%, from 7,481 to 7,783) and lower respiratory tract infections (increase of 3.5%, from 28 to 29).

Global Burden of Disease Study 2010

The Global Burden of Disease Study 2010 released New Zealand data for DALYs, YLLs and YLDs for 2010. This data source gives the latest available data for DALYs for New Zealand, by age group and sex.

This study used New Zealand data for mortality and some risk factors. However, many of data inputs differed, with the GBD study using estimated and modelled data for New Zealand for some aspects (including some estimates of incidence, prevalence, severity distribution, case fatality, remission and some risk factor exposure). Nonetheless, there was reasonable agreement between the two studies (Ministry of Health, 2013a).

New Zealand Burden of Disease Study 2006

The New Zealand Burden of Disease Study was a comprehensive study of diseases and injuries that contribute to illness, disability and early death in New Zealand. Data for DALYs, YLLs and YLDs are available by age group, sex and ethnic group (Māori, non-Māori) for 2006.

This data source gives good estimates for Māori and non-Māori, to allow ethnic comparisons. Data was obtained from online tables published with the New Zealand Burden of Disease Study reports.

Analyses

Estimating attributable burden in non-smoking adults

We estimated the attributable burden only in non-smoking adults, to exclude current smokers from the analysis.

Firstly, we estimated the total burden of disease not attributable to smoking. To do this, we calculated the burden attributable to active smoking, and then subtracted this from the total burden of disease.

Secondly, we estimated the burden of disease in non-smokers. This was estimated by multiplying the total burden of disease not attributable to smoking by the percentage of the population who are non-smokers. We used the following formula:

$$B_{\text{non-smokers}} = \left(B - \left(B \times PAF_{\text{smoking}}\right)\right) \times \left(1 - p_{\text{smoking}}\right)$$

where B is the burden of disease (such as deaths or DALYs), p_{smoking} is the prevalence of smoking, and PAF is the population attributable fraction (Őberg, Jaakkola, Prűss-Űstűn, Schweizer, et al., 2010).

Finally, we calculated the burden in non-smokers attributable to second-hand smoke. This involved multiplying the burden of disease in non-smokers by the population attributable fraction for second-hand smoke.

$$\text{Attributable burden}_{\text{SHS}} = PAF_{\text{SHS}} \times B_{\text{non-smokers}}$$

All analyses of mortality and health survey data were done in SAS 9.3.

Calculating Māori estimates

In our analyses, we aimed to present results for Māori and non-Māori separately, consistent with Treaty of Waitangi principles.

There was concern that the relative risk estimates used were calculated mainly from overseas studies, and may potentially overestimate the relative risks for Māori (Hunt, Blakely, Woodward, & Wilson, 2005). There were also no New Zealand-specific relative risk estimates. By comparison, the New Zealand Burden of Disease Study used lowered relative risks for Māori for tobacco-related health loss (Ministry of Health, 2012).

We found that the Māori burden, when calculated directly, was higher than the estimated national attributable burden for some health outcomes. We assumed that estimates and exposure data for the total population and for non-Māori would likely be more accurate (and have less uncertainty) than for Māori specifically. As a result, we estimated Māori attributable burden indirectly, as the difference between the total burden and the burden in non-Māori.

However, we also included the directly-calculated Māori burden in the sensitivity analysis to show the difference that this would make. These results suggest that calculating Māori attributable burden directly would result in larger numbers, and would increase the disparity seen between Māori and non-Māori.

Appendix 2: Results tables

Population attributable fractions

This section presents the population attributable fractions (PAF) for the different health outcomes included in our study, by age group and sex. These PAFs give the percentage of cases of disease in the population that are attributable to second-hand smoke exposure.

Table 18: Population attributable fractions (PAFs) (%) for second-hand smoke exposure in the home, among non-smoking adults, 2010

Health outcome	Sex	PAF (%), by age group (years)						
		15–24	25–34	35–44	45–54	55–64	65–74	75+
Ischaemic heart disease	Male	4.1	2.2	1.2	1.8	2.0	1.6	1.6
	Female	3.8	2.1	0.8	2.0	1.6	1.5	1.1
Stroke	Male	–	–	1.1	1.7	1.8	1.5	1.4
	Female			0.8	1.9	1.5	1.4	1.0
Lung cancer	Male	5.9	5.6	2.9	2.1	2.8	3.3	1.6
	Female	6.3	5.3	3.6	2.4	2.1	1.9	0.9

Table 19: Population attributable fractions (PAFs) (%) for second-hand smoke exposure, among children, 2010

Health outcome	Sex	PAF (%), by age group (years)			
		0	1–4	5–9	10–14
Asthma	Male	1.5	1.5	1.8	2.7
	Female	1.5	1.5	1.9	2.3
Otitis media	Male	1.5	1.5	1.8	2.7
	Female	1.5	1.5	1.9	2.3
SUDI	Total	11.3	–	–	–
Lower respiratory tract infections (0–1 years)	Male	1.9	–	–	–
	Female	1.6			
Small for gestational age	Total	2.6	–	–	–

Attributable deaths (2010)

This section presents the deaths attributable to second-hand smoke exposure in New Zealand in 2010. Results are presented by health outcome, ethnic group, sex and age group. Numbers have been rounded, and therefore may not sum to totals.

Table 20: Ischaemic heart disease deaths attributable to second-hand smoke exposure, among non-smoking adults, 2010

Ethnic group	Sex	Attributable deaths, by age group (years)							Total
		15–24	25–34	35–44	45–54	55–64	65–74	75+	
Total	Male	0.0	0.2	0.3	1.7	4.4	6.7	25.7	39.0
	Female	0.0	0.0	0.0	0.5	1.0	2.5	22.3	26.4
Māori	Male	0.0	0.1	0.2	0.5	1.1	1.5	1.4	4.7
	Female	0.0	0.0	0.0	0.2	0.3	0.7	2.2	3.5
Non-Māori	Male	0.0	0.1	0.2	1.2	3.3	5.2	24.3	34.3
	Female	0.0	0.0	0.0	0.3	0.7	1.8	20.1	22.9

Table 21: Stroke deaths attributable to second-hand smoke exposure in non-smoking adults, 2010

Ethnic group	Sex	Attributable deaths, by age group (years)					Total
		35–44	45–54	55–64	65–74	75+	
Total	Male	0.1	0.3	0.9	1.8	9.2	12.3
	Female	0.1	0.4	0.5	1.4	12.9	15.4
Māori	Male	0.0	0.1	0.2	0.4	0.4	1.1
	Female	0.0	0.1	0.1	0.3	1.2	1.8
Non-Māori	Male	0.0	0.2	0.7	1.4	8.8	11.2
	Female	0.0	0.3	0.4	1.1	11.8	13.6

Table 22: Lung cancer deaths attributable to second-hand smoke exposure in non-smoking adults, 2010

Ethnic group	Sex	Attributable deaths, by age group (years)							Total
		15–24	25–34	35–44	45–54	55–64	65–74	75+	
Total	Male	0.0	0.0	0.0	0.1	0.4	1.2	1.0	2.8
	Female	0.0	0.0	0.1	0.3	0.4	0.6	0.6	1.9
Māori	Male	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3
	Female	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.4
Non-Māori	Male	0.0	0.0	0.0	0.1	0.3	1.2	1.0	2.5
	Female	0.0	0.0	0.1	0.2	0.3	0.4	0.5	1.5

Table 23: Deaths attributable to second-hand smoke exposure in children, 2010

Ethnic group	Sex	Attributable deaths	
		SUDI (0 years)	Lower respiratory tract infections (0–1 years)
Total	Male	3.9	0.1
	Female	2.2	0.0
Māori	Male	3.3	0.1
	Female	2.0	0.0
Non-Māori	Male	0.6	0.0
	Female	0.2	0.0

Attributable DALYs (2006)

This section presents the DALYs attributable to second-hand smoke exposure in New Zealand in 2006. Results are presented by health outcome, ethnic group, sex and age group. Numbers have been rounded, and therefore may not sum to totals.

Table 24: Ischaemic heart disease DALYs attributable to second-hand smoke exposure in non-smoking adults aged 15+ years, 2006

Ethnic group	Sex	Attributable DALYs, by age group (years)							Total
		15–24	25–34	35–44	45–54	55–64	65–74	75+	
Total	Male	2	6	23	97	181	138	269	715
	Female	0	2	5	22	45	71	172	317
Māori	Male	1	3	10	29	48	29	24	143
	Female	0	1	2	9	13	21	19	64
Non-Māori	Male	1	3	13	67	133	109	245	572
	Female	0	1	3	13	33	50	153	253

Table 25: Stroke DALYs attributable to second-hand smoke exposure in non-smoking adults aged 35+ years, 2006

Ethnic group	Sex	Attributable DALYs, by age group (years)					Total
		35–44	45–54	55–64	65–74	75+	
Total	Male	5	15	36	39	106	202
	Female	7	14	24	36	107	188
Māori	Male	2	4	8	6	8	28
	Female	3	3	3	8	11	29
Non-Māori	Male	3	11	28	33	98	174
	Female	4	10	21	28	96	159

Table 26: Lung cancer DALYs attributable to second-hand smoke exposure in non-smoking adults aged 15+ years, 2006

Ethnic group	Sex	Attributable DALYs, by age group (years)							Total
		15–24	25–34	35–44	45–54	55–64	65–74	75+	
Total	Male	0	2	1	3	14	29	8	57
	Female	1	4	3	7	11	8	4	39
Māori	Male	0	0	0	1	3	4	1	9
	Female	0	2	1	2	3	3	0	11
Non-Māori	Male	0	2	1	2	10	25	7	48
	Female	1	2	2	5	8	6	4	29

Table 27: Asthma DALYs attributable to second-hand smoke exposure in children aged 0–14 years, 2006

Ethnic group	Sex	Attributable DALYs, by age group (years)				Total
		0	1–4	5–9	10–14	
Total	Male	1	7	22	26	55
	Female	0	4	15	19	38
Māori	Male	1	4	11	10	26
	Female	0	2	8	8	18
Non-Māori	Male	0	3	10	16	29
	Female	0	2	7	11	20

Table 28: Otitis media DALYs attributable to second-hand smoke exposure in children aged 0–14 years, 2006

Ethnic group	Sex	Attributable DALYs, by age group (years)				Total
		0	1–4	5–9	10–14	
Total	Male	2	6	5	3	16
	Female	1	5	5	3	15
Māori	Male	1	3	3	2	9
	Female	1	3	3	2	8
Non-Māori	Male	1	3	2	2	7
	Female	1	2	2	1	6

Table 29: Other DALYs attributable to second-hand smoke exposure in children, 2006

Ethnic group	Sex	Attributable DALYs		
		SUDI (0 years)	Lower respiratory tract infections (0–1 years)	Small for gestational age (0 years)
Total	Male	320	26	2
	Female	275	16	4
Māori	Male	272	17	1
	Female	233	14	1
Non-Māori	Male	49	9	1
	Female	42	2	3

Sensitivity analyses

This section presents the sensitivity analyses for our estimates of attributable burden from second-hand smoke exposure in New Zealand. Sensitivity analyses are presented for the estimates of attributable deaths in 2010, attributable DALYs in 2010, and attributable DALYs in 2006.

Deaths in 2010

Table 30: Effects of changing assumptions in estimating deaths attributable to second-hand smoke, 2010

Assumption in best estimate	Alternative scenario	Effect on number of deaths (resulting total attributable burden)
Baseline scenario	–	104 deaths
Best estimate for relative risk / odds ratio for SHS from meta-analysis	Use lower bounds of relative risks	Decrease by 36% (66 deaths)
	Use upper bounds of relative risks	Increase by 31% (137 deaths)
Best estimate for prevalence	Use lower 95% confidence limit of all exposure estimates	Decrease by 32% (71 deaths)
	Use 95% upper confidence limit of all exposure estimates	Increase by 28% (133 deaths)
Use exposure in the home as proxy for regular exposure	Include exposure in the workplace for working-age population	Increase by 14% (119 deaths)
	- ischaemic heart disease (exposure in 2006, 4 year lag)	- increase by 9.2 deaths
	- stroke (exposure in 2006, 4 year lag)	- increase by 2.7 deaths
	- lung cancer (exposure in 1996, 14 year lag)	- increase by 3.2 deaths
Use exposure to second-hand smoke in the home	Use exposure to second-hand smoke in home and/or car	Increase by 18% (123 deaths)
Include health outcomes with best evidence (level 1 conditions only)	Include conditions suggestive of causal relationships (level 2 conditions)	Increase by 5% (109 deaths)
	- asthma in adults	- increase by 1.5 deaths
	- preterm birth complications	- increase by 2.7 deaths
	- pre-menopausal breast cancer	- increase by 0.4 deaths
	- invasive meningococcal disease	- increase by 0.2 deaths
Current smokers are not included in the analysis	Include non-smoking burden in smokers and exposure data for total population (not just non-smokers)	Increase by 90% (198 deaths)
Ex-smokers are included in the analysis	Exclude burden in ex-smokers	Decrease by 42% (60 deaths)
Estimate Māori burden as the difference between total and non-Māori	Directly calculate Māori estimates, and sum Māori and non-Māori estimates to get total burden	Increase by 5% (109 deaths) Increase Māori deaths from 17 to 22 deaths, and increase the standardised rate ratios for Māori vs non-Māori.
Using redistributed deaths (to account for miscoded causes of death)	Using only assigned cause of deaths in analysis	Decrease by 4% (100 deaths)

DALYs in 2010

Table 31: Effects of changing assumptions on health loss (DALYs) due to second-hand smoke, 2010

Assumption in best estimate	Alternative condition	Effect on DALYs (resulting total attributable burden)
Baseline scenario	–	1989 DALYs
Best estimate for relative risk / odds ratio from meta-analysis	Use lower bounds of relative risks	Decrease by 35% (1288 DALYs)
	Use upper bounds of relative risks	Increase by 38% (2748 DALYs)
Best estimate for prevalence of exposure	Use lower 95% confidence limit of all exposure estimates	Decrease by 24% (1508 DALYs)
	Use 95% upper confidence limit of all exposure estimates	Increase by 22% (2420 DALYs)
Use exposure in the home as proxy for regular exposure	Include exposure in the workplace for working-age population	Increase by 26% (2513 DALYs)
	- ischaemic heart disease (exposure in 2006, 4 year lag)	- increase by 364 DALYs
	- stroke (exposure in 2006, 4 year lag)	- increase by 85 DALYs
	- lung cancer (exposure in 1996, 14 year lag)	- increase by 75 DALYs
Use exposure to second-hand smoke in the home	Use exposure to second-hand smoke in home and/or car	Increase by 19% (2374 DALYs)
Include health outcomes with best evidence (Level 1 conditions only)	Include conditions suggestive of causal relationships:	Increase by 47% (2916 DALYs)
	- asthma in adults	- increase by 579 DALYs
	- preterm birth complications	- increase by 316 DALYs
	- pre-menopausal breast cancer	- increase by 23 DALYs
	- invasive meningococcal disease	- increase by 10 DALYs
Current smokers are not included in the analysis	Include non-smoking burden in smokers, and exposure data for total population (not just non-smokers)	Increase by 81% (3607 DALYs)
Ex-smokers are included in the analysis	Exclude burden in ex-smokers	Decrease by 30% (1385 DALYs)

DALYs in 2006

Table 32: Effects of changing assumptions on health loss (DALYs) due to second-hand smoke, 2006

Assumption in best estimate	Alternative condition	Effect on DALYs (resulting total attributable burden)
Baseline scenario		2286 DALYs
Best estimate for relative risk / odds ratio from meta-analysis	Use lower bounds of relative risks	Decrease by 36% (1465 DALYs)
	Use upper bounds of relative risks	Increase by 39% (3177 DALYs)
Best estimate for prevalence	Use lower bounds of 95% confidence interval	Decrease by 22% (1786 DALYs)
	Use upper bounds of 95% confidence intervals	Increase by 24% (2827 DALYs)
Use exposure in the home as proxy for regular exposure	Include exposure in the workplace for working-age population	Increase by 27% (2896 DALYs)
	- ischaemic heart disease (exposure in 2006)	- increase by 413 DALYs
	- stroke (exposure in 2006)	- increase by 115 DALYs
	- lung cancer (exposure in 1996, 10 year lag)	- increase by 82 DALYs
Use exposure to second-hand smoke in the home	Use exposure to second-hand smoke in home and/or car	Increase by 17% (2665 DALYs)
Include health outcomes with best evidence (Level 1 conditions only)	Include conditions suggestive of causal relationships:	Increase by 38% (3162 DALYs)
	- preterm birth complications	- increase by 237 DALYs
	- asthma in adults	- increase by 604 DALYs
	- pre-menopausal breast cancer	- increase by 35 DALYs
Current smokers are not included in the analysis	Include non-smoking burden in smokers (and exposure data for total population, not just non-smokers)	Increase by 70% (3882 DALYs)
Ex-smokers are included in the analysis	Exclude burden in ex-smokers	Decrease by 38% (1407 DALYs)
Estimate Māori burden as the difference between total and non-Māori	Directly calculate Māori estimates, and sum Māori and non-Māori estimates to get total burden	Increase by 17% (2673 DALYs) Increase Māori burden by 44% (from 883 to 1270 DALYs); increase in standardised rate ratios for Māori vs non-Māori.