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The Costs of Smoking and Secondhand Smoke Exposure in Taiwan

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ABSTRACT

Objectives: To assess the costs of the health effects of cigarette smoking and secondhand smoke (SHS) exposure to society.

Design: Prevalence-based, disease-specific cost of illness study. We used an epidemiological population-attributable risk method to determine the costs that can be attributed to smoking and SHS exposure.

Setting: Taiwan.

Participants: All adult population aged 35 and older.

Primary outcome measures: Direct costs of healthcare expenditures spent for treating tobacco-related diseases, indirect mortality costs measured by the value of lost productivity due to tobacco-related premature deaths, and indirect morbidity costs measured by the value of time lost from work due to tobacco-related illness.

Results: In 2010, direct costs of smoking and SHS exposure amounted to \$828 million, accounting for 3.4% of Taiwan's total personal healthcare expenditures. Smoking and SHS exposure also contributed to 15,503 premature deaths — corresponding to a loss of 284,014 years of life and \$818 million in productivity — and \$22 million in indirect morbidity costs. These direct and indirect costs totaled \$1,668 million, representing 0.4% of Taiwan's gross domestic product (GDP) and averaging about \$700 per adult smoker. The share of the total costs was greater from active smoking (93%) than SHS exposure (7%), and greater for men (92%) than women (8%).

Conclusions: Smoking and SHS exposure impose a huge financial loss. Sustained tobacco control efforts to encourage people to quit smoking, prevent smoking uptake by children and young adults, and protect all people from SHS exposure are needed.

Strengths and limitations of this study

- Little is known about the economic costs of secondhand smoke (SHS) exposure in East Asian countries. This is the first study to assess the health effects of smoking by taking into account the economic impact of SHS exposure in Taiwan.
- This study provides evidence on the economic effect of the recent reduction in smoking prevalence and SHS exposure on healthcare costs and productivity losses to the Taiwan society, as a result of implementing a comprehensive tobacco control program in 2009.
- Only adults aged 35 and older were included in the study.

INTRODUCTION

East Asia is the world's largest tobacco epidemic region, consuming nearly half of total global cigarette consumption.[1] Although all East Asian countries ratified the WHO Framework Convention on Tobacco Control (FCTC) in 2004 or 2015, a recent assessment study [2] revealed that the majority of countries in East Asia lagged behind in implementing the FCTC recommended tobacco control programs according to WHO's MPOWER (Monitoring, Protect, Offer, Warn, Enforcement and Raise) criteria.[3] As of 2010, 37−53% of adult men in East Asia were current smokers and more than 46% of men were exposed to passive smoking at workplaces.[2] To enhance the incentives to implement the promises of the ratified FCTC to reduce the tobacco epidemic in East Asia, update evidence on the economic costs due to active and passive smoking-caused illness, disability, and premature mortality in this region is imperative.

Taiwan is regarded as a model in East Asia in tobacco control.[2] During 1960s and 1970s, smoking prevalence among Taiwanese aged 35 and above exceeded 75% for men and 8–12% for women. In 1987, Taiwan's cigarette market was forced to open to foreign brands, leading to a 6% jump in adult male smoking and a 13% jump in youth smoking within three years. As a consequence, the government launched a series of tobacco control initiatives such as school-based anti-smoking programs and the 1997 Tobacco Hazards Prevention Act through which indoor places became partially smoke-free.[4] In 2002, the government levied tobacco taxes of NT$5 per pack and started the Outpatient Smoking Cessation Services.[5] During the period of 1990-2005, smoking prevalence among men aged 18 and older had declined from 59.4% to 40.0%.[6] Taiwan's Legislature ratified the WHO FCTC in 2005. Based on the FCTC recommendations,[7] an amendment to the Tobacco Hazards Prevention Act went into effect in 2009 (hereafter called the 2009 Act) to strengthen tobacco control measures by adding graphic warning labels on cigarette packages, extending smoke-free areas to almost all enclosed workplaces and public places, completely banning tobacco advertisements, promotion and sponsorship, as well as increasing tobacco taxes.

As a result of the 2009 Act, smoking prevalence among men aged 18 and older in Taiwan further decreased from 40.0% to 33.5% and exposure to passive smoking in workplaces decreased substantially from 33.2% to 18.2% between 2005 and 2011.[6, 8] Given this sizeable reduction in active and passive smoking, it is policy relevant to assess the current level of the costs of active and passive smoking-attributable illness, disability, and premature mortality, and to determine whether or not these costs have decreased.

Two previous studies estimated the cost of smoking in Taiwan in 2001. Using a prevalence-based approach, Yang et al. estimated that smoking contributed to US$398 million in excess medical expenditures and US$1,390 million in productivity loss from premature death among people aged 35 and older.[9] Using an incidence-based approach, Chung et al.[10] estimated that the present value of lifetime smoking-attributable medical costs among people aged 35 and older ranged from $291-$336 million depending on discount rate. There has been no study to update these cost estimates in Taiwan since 2001. Furthermore, none of studies on the cost of smoking in Taiwan and few of those in the literature have included any costs attributed to passive smoking, also known as secondhand smoke (SHS).

The main objective of this study is to assess the costs of the health effects of cigarette smoking and SHS exposure in Taiwan in 2010. This is the first attempt to quantify the economic costs of SHS exposure in Taiwan. This study will also provide an evaluation on the hypothesis that implementation of the 2009 Act was associated with decreases in economic costs of smoking and SHS exposure. Because of the similarity in tobacco epidemic and culture among East Asian countries, the findings of this study can be served as a valuable reference for understanding the economic benefits of tobacco control programs in the region.

METHODS

We considered three components of costs: direct costs of healthcare expenditures spent for treating tobacco-related diseases, indirect mortality costs measured by the value of lost productivity due to premature death, and indirect morbidity costs measured by the value of time lost from work due to tobacco-related illness. Prevalence-based, disease-specific cost-of-illness approach [11] was used to estimate the healthcare expenditures, workloss days, and deaths due to smoking-related diseases in 2010. We used an epidemiological population-attributable risk method [12] to determine the smoking-attributable fraction (SAF), which measures the proportion of expenditures, workloss days, or deaths that can be attributed to smoking, and applied it to the total measure. A SHS-attributable fraction (SAF^{SHS}) was estimated in a similar manner. Our analyses focused on adults aged 35 years and older.

Data sources

Population-based data from the annual Adult Smoking Behavior Survey (ASBS) were used to determine the prevalence of smoking and SHS exposure. The ASBS is a telephone interview survey collecting information on individual's demographic characteristics, cigarette smoking and quitting behavior, and SHS exposure from a nationally representative sample (around 16,000 per year) of non-institutionalized population aged 18 and older in Taiwan. Disease-specific inpatient and outpatient expenditures, and number of hospital inpatient days were obtained from the 2010 National Health Insurance (NHI) claims database. Taiwan's NHI, launched in 1995, is a mandatory single-payer social health insurance system administered by the government that provides universal healthcare coverage to virtually all citizens in Taiwan.

Population data came from the 2010 Population Census,[13] number of deaths for each disease from the 2010 Statistics of Causes of Death,[14] and life expectancy by age and gender from the 2010 life tables.[15] The age- and gender-specific employment rates and monthly earnings were obtained from the 2010 Report on the Manpower Utilization Survey.[16]

Smoking-related and SHS-associated diseases

We included 19 smoking-related diseases which showed significant association between cigarette smoking and mortality risk according to two large epidemiological studies conducted by Wen and colleagues in Taiwan.[17, 18] We considered 6 SHS-associated diseases: lung cancer, ischemic heart disease, cerebravascular disease, chronic obstructive pulmonary disease, asthma, and breast cancer, and 3 SHS-associated causes of death: lung cancer, ischemic heart disease, and cerebravascular disease as reported by the California Environmental Protection Agency (EPA) [19] and World Health Organization (WHO).[20, 21] Details of these diseases and their diagnosis codes are listed in Table 1.

Table 1. Smoking-related disease, secondhand smoke (SHS)-associated disease and cause of death, and relative risk (RR) by disease and gender, Taiwan

Disease (ICD-9 code)	RR of Smoking-related death				RR of SHS-associated disease		RR of SHS-associated death	
	Male		Female					
	CS	FS	CS	FS	Male	Female	Male	Female
SMOKING-RELATED CAUSE OF DEATH								
All causes (001–998)	1.55	1.33	1.89	1.33				
Cancer								
Lip/oral cavity/pharynx (140–149)	2.60	1.96	–	–				
Esophagus (150)	3.18	2.31	15.57	6.40				
Stomach (151)	1.68	1.41	–	–				
Rectum (154)	2.06	1.64	–	–				
Liver/gallbladder/bile ducts (155–	1.46	1.28	5.03	2.49				
Lung (162)[a]	2.73	2.04	3.36	1.88	1.29	1.29	1.29	1.29
Cervix uteri (180)	–	–	5.78	2.77				
Cardiovascular disease								
Rheumatic HD (390-398)	–	–	9.43	4.13				
Ischemic HD (410–414)[a]	2.06	1.64	3.58	1.96	1.49	1.49	1.23	1.23
Cardiac arrest and other HD (420–	1.60	1.36	–	–				
Cerebrovascular disease (430–438)[a]	1.65	1.39	–	–	1.82	1.82	1.65	1.65
Respiratory disease								
Chronic bronchitis (491)	3.13	2.28	–	–				
Asthma (493)[b]	–	–	7.12	3.27	1.97	1.97		
Chronic Airway Obstruction (496)	2.65	1.99	–	–				
Digestive system disease								
Peptic ulcer, GI hemorrhage (531–	3.00	2.20	22.28	8.89				
Liver cirrhosis (571)	2.01	1.61	–	–				
Other smoking-related disease								
Diabetes mellitus (250)	1.51	1.31	–	–				
Kidney diseases (580–589)	2.23	1.74	–	–				
Accidents (800–949)	1.66	1.40	–	–				
OTHER SHS-ASSOCIATED DISEASE								
COPD (490–492, 496)					1.55	1.55		
Breast cancer (174)[c]					–	1.68		

Note. CS=current smoker; FS=former smoker; HD=heart disease; GI=gastrointestinal; COPD=chronic obstructive pulmonary disease.
[a]Also a SHS-associated disease and SHS-associated cause of death. [b]Also a SHS-associated disease.
[c]Only among premenopausal women younger than age 50.

Smoking-attributable fraction (SAF) and SHS-attributable fraction (SAF^{SHS})

We calculated the SAF for each component of costs by disease, gender, and age group (35-49, 50-64, and ≥ 65 years). Based on two fundamental data elements: smoking prevalence and relative risk (RR) of *disease-specific death* for smoking, the SAF for death measures can be calculated using the following epidemiological formula: [11, 12]

$$\mathrm{SAF_{ijk}} = \frac{\mathrm{P^C_{jk}}\left(\mathrm{RR^C_{ij}} - 1\right)}{\mathrm{P^N_{jk}} + \mathrm{P^C_{jk}} \times \mathrm{RR^C_{ij}} + \mathrm{P^F_{jk}} \times \mathrm{RR^F_{ij}}} + \frac{\mathrm{P^F_{jk}}\left(\mathrm{RR^F_{ij}} - 1\right)}{\mathrm{P^N_{jk}} + \mathrm{P^C_{jk}} \times \mathrm{RR^C_{ij}} + \mathrm{P^F_{jk}} \times \mathrm{RR^F_{ij}}} \quad (1)$$

where P^N, P^C, and P^F denote the prevalence of never, current, and former smokers, respectively; RR^F denotes the RR of *disease-specific death* for former smokers in comparison to never smokers, and similarly RR^C denotes the RR of *disease-specific death* for current smokers; the subscript i denotes disease, j denotes gender, and k denotes age group. The first term of Equation (1) is the SAF for current smokers, and the second term is the SAF for former smokers.

Prevalence rates of current smokers, former smokers, and never smokers among adults aged 35 and older were obtained from the ASBS data. The RR of death for smokers is defined as the ratio of the death rate for smokers to that for never smokers. The RR^C came from the epidemiological studies by Wen and colleagues.[17, 18]; however, the RR^F was not available.

While the two previous cost-of-smoking studies in Taiwan assumed that the RR^F equals 1 and thus the SAF for former smokers becomes zero (as illustrated by the second term of Equation (1) above),[9,10] we used an interpolation approach to derive the RR^F. First, because Wen and colleagues reported the RR of *all-cause death* for former smokers (RRA^F) and current smokers (RRA^C),[17, 18] we could calculate the excess risk of *all-cause death* for former smokers over never smokers as ($RRA^F - 1$) and for current smokers over never smokers as ($RRA^C - 1$). Second, assuming the ratio between the excess risk of *disease-specific death* for former smokers ($RR^F - 1$) and the excess risk of *disease-specific death* for current smokers ($RR^C - 1$) equals the ratio between the excess risk of *all-cause death* for former smokers and the excess risk of *all-cause death* for current smoker, we calculated ($RR^F - 1$) by multiplying ($RR^C - 1$) by the ratio between ($RRA^F - 1$) and ($RRA^C - 1$). Finally, the relative risk RR^F equals the excess risk ($RR^F - 1$) plus 1.

To estimate the SAF for healthcare costs, we assumed the RRs of *disease-specific illness* for current and former smokers are the same as those of *disease-specific death* for current and former smokers because of data limitation.

Similarly, based on two fundamental data elements: prevalence of SHS exposure and relative risk of *disease-specific death or illness* for SHS exposure, we calculated the SAF^{SHS} among nonsmokers for each component of costs by disease, gender, and age group as:

$$\mathrm{SAF}_{ijk}^{SHS} = \frac{P_{jk}^{SHS}\left(RR_{ij}^{SHS} - 1\right)}{P_{jk}^{SHS}\left(RR_{ij}^{SHS} - 1\right) + 1} \qquad (2)$$

where P^{SHS} denotes the prevalence of SHS exposure among nonsmokers, and RR^{SHS} is the relative risk of *disease-specific death or illness* for exposed nonsmokers compared to unexposed nonsmokers.

Prevalence rates of SHS exposure among nonsmokers aged 35 and older were obtained from the ASBS data. Nonsmokers include never and former smokers. SHS exposed nonsmokers were those who either answered 'yes' to the question: 'During the past week has anyone smoked in front of you at home?' or who were employed and worked in indoor settings and answered 'yes' to the question: 'During the past week has anyone smoked in front of you at your workplace?' The RR^{SHS} of *disease-specific death* and the RR^{SHS} of *disease-specific illness* were obtained from published sources as reported by the California EPA [19] and WHO.[20, 21]

Table 1 shows the relative risk of disease-specific death and illness for current smokers, former smokers, and SHS exposure.

Direct costs

Expenditures paid by the NHI for inpatient hospitalizations and outpatient visits were included as direct costs. Expenditures for prescribed medications during the hospitalizations or outpatient visits were included in the respective inpatient or outpatient expenditure categories. Outpatient visits comprised ambulatory care visits at outpatient or emergency departments of hospitals, and those at western medicine clinics. The smoking-attributable inpatient or outpatient expenditure for each subgroup stratified by disease, gender and age was calculated by multiplying the SAF by the total annual inpatient or outpatient expenditures for that subgroup.

The SHS-attributable inpatient or outpatient expenditure for each disease was derived by multiplying the SAF^{SHS} by the total annual inpatient or outpatient expenditures for that disease among nonsmokers. Because the NHI claims database does not contain individual's smoking status, it does not allow for distinguishing health expenditures for smokers from those for nonsmokers. We determined the amount of total inpatient (similarly, outpatient) expenditures for nonsmokers, INP^{NON}, using the following method as done by two recent studies.[20, 22]

$$INP^{NON}_{ijk} = (INP_{ijk} - INP_{ijk} \times SAF^{C}_{ijk}) \times (1 - P^{C}_{jk}) \qquad (3)$$

where INP is total annual inpatient expenditures among all individuals regardless of smoking status, P^C is the prevalence of current smokers, and SAF^C is the smoking-attributable fraction for current smokers as expressed by the first term of Equation (1).

Indirect mortality costs

For each subgroup stratified by gender and 5-year age group, we estimated the number of smoking-attributable deaths (SAD) for each disease by multiplying the SAF by the total number of deaths for that disease. The number of smoking-attributable years of potential life lost (YPLLs) was estimated by the product of the SAD and life expectancy remaining at the age of death. Smoking-attributable mortality cost was estimated by the product of the SAD and the present value of lifetime earnings (PVLEs) expected at the age of death. The PVLEs were calculated by gender and 5-year age groups based on a human capital approach developed by Max and colleagues.[23] A discount rate of 3% was used to convert the earnings into its current worth. A growth rate of 4%, which was approximately the average annual growth rate of gross domestic product (GDP) in Taiwan during 2005−2009, was used to take into account the potential growth of future earnings.

We estimated the number of SHS-attributable deaths, YPLLs, and mortality costs following the same approach as described for active smoking-attributable indirect mortality measures except that the estimation only focused on nonsmokers. Total number of deaths among nonsmokers was determined using the similar method as described for Equation (3).

Indirect morbidity costs

We defined smoking-attributable indirect morbidity cost as the value of time lost from work due to active or passive smoking-caused illness. The lost time from work is commonly measured by the number of workloss days;[23, 24] however, because the data on workloss days by disease were not available, we used inpatient days as a proxy. The smoking-attributable indirect morbidity cost for each subgroup stratified by disease, gender and age was calculated by the product of the SAF, total annual inpatient days for that group, the proportion of the population currently employed, and daily earnings among employed persons.

Likewise, the SHS-attributable indirect morbidity cost was estimated by multiplying the SAF^{SHS} by total annual inpatient days among nonsmokers, employment rate, and daily earnings. Total number of inpatient days among nonsmokers was determined using the similar method as described for Equations (3).

Sensitivity analysis

To evaluate whether or not implementation of the 2009 Act in Taiwan was associated with decreases in active and passive smoking-attributable costs, we simulated what would be the cost estimates in 2010 by assuming two scenarios: smoking prevalence and SHS exposure rates remained at the same levels as in 2008, and smoking prevalence and SHS exposure rates were at the mean value of the 2008 and 2010 levels. We also performed sensitivity analyses to see how sensitive our cost estimates are to different assumptions about the RR values and productivity growth rates.

RESULTS

In 2010, the total population of Taiwan was 23.2 million, with 12.4 million being adults aged 35 and older. The prevalence and SHS exposure rates among adults in 2008 and 2010 are shown in Table 2. Smoking prevalence rates among men were about 10 times as high as those among women: 33.9% versus 3.8% for current smoking, and 15.7% versus 1.5% for former smoking. The SHS exposure rates among nonsmokers were similar between men and women. From 2008 to 2010, the current smoking prevalence among men decreased by nearly 10% and SHS exposure among both genders decreased by 13%.

Table 2. Prevalence (%) of smoking and secondhand smoke (SHS) exposure by gender and age among adults aged 35 and older: Taiwan, 2008, 2010

	2008[a]			2010[a]		
	Smoking		SHS exposure[b]	Smoking		SHS exposure[b]
	CS	FS		CS	FS	
Total	**21.6**	**7.8**	**28.3**	**19.2**	**8.8**	**24.7**
Male	**37.5**	**14.0**	**28.2**	**33.9**	**15.7**	**24.1**
35-49	47.6	15.2	30.0	43.9	16.7	24.6
50-64	37.4	18.7	30.0	31.5	23.6	22.4
65+	29.1	26.8	17.0	19.5	30.1	12.9
Female	**4.8**	**1.2**	**28.3**	**3.8**	**1.5**	**25.2**
35-49	5.9	1.1	33.0	4.8	1.7	29.5
50-64	1.6	1.0	25.8	2.0	1.1	21.5
65+	1.9	1.0	13.8	1.3	1.0	13.2

Note. CS=current smoker; FS=former smoker.
[a] Source: Adult Smoking Behavior Survey in Taiwan.
[b] Percentage of nonsmokers who are exposed to secondhand smoke.

Table 3 shows the deaths and years of potential life lost attributed to smoking and SHS exposure by cause of death and gender. The three leading causes of smoking-attributable deaths among men were lung cancer, ischemic heart disease, and chronic airway obstruction, and among women were cancers of liver/gallbladder/bile ducks, lung cancer, and ischemic heart disease. The leading cause of SHS-associated deaths was stroke for both genders. There was a substantial gender difference in the number of active smoking-attributable deaths — 13,744 for men and 615 for women. SHS exposure almost equally affected both genders by contributing to 588 deaths among men and 556 deaths among women. They totaled 15,503 deaths, which comprised about 20% of the total 19-cause deaths (77,953) among persons aged 35+ and 11% of the total all-cause deaths (144,709) among persons aged 0+. The total smoking and SHS attributable deaths were responsible for 284,014 years of potential life lost, averaging 18.3 years per death.

Table 3. Smoking-Attributable Mortality (SAM) and Smoking-Attributable Years of Potential Life Lost (SAYPLL) by Cause of Death and Gender among Adults Aged 35 and Older: Taiwan, 2010

	Male		Female	
Cause of death	**SAM**	**SAYPLL**	**SAM**	**SAYPLL**
SMOKING-RELATED DEATH	**13,744**	**252,954**	**615**	**12,244**
Cancers				
Lip/oral cavity/pharynx	1,135	29,214	0	0
Esophagus	715	17,356	24	493
Stomach	310	5,102	0	0
Rectum	250	4,397	0	0
Liver/gallbladder/bile ducts	920	19,031	181	3,682
Lung	2,198	34,801	129	2,988
Cervix uteri	0	0	72	2,010
Cardiovascular diseases				
Rheumatic HD	0	0	11	212
Ischemic HD	1,467	23,279	124	1,802
Cardiac arrest and other HD	816	14,119	0	0
Cerebrovascular disease	1,225	19,805	0	0
Respiratory diseases				
Chronic bronchitis	47	518	0	0
Asthma	0	0	24	366
Chronic Airway Obstruction	1,253	12,928	0	0
Digestive system diseases				
Peptic ulcer, GI hemorrhage	160	2,350	51	689
Liver cirrhosis	1,065	28,538	0	0
Other diseases				
Diabetes mellitus	689	11,477	0	0
Kidney disease	677	9,831	0	0
Accidents	817	20,207	0	0
SHS-ASSOCIATED DATH	**588**	**9,407**	**556**	**9,409**
Lung cancer	131	2,078	117	2,584
Ischemic HD	104	1,652	86	1,222
Cerebrovascular disease	353	5,677	354	5,603
TOTAL	**14,332**	**262,361**	**1,172**	**21,653**

Note. HD=heart disease; GI=gastrointestinal; SHS=secondhand smoke.

Table 4 shows the total direct and indirect costs attributed to smoking and SHS exposure by gender, age, and disease. The total economic costs of smoking and SHS exposure in 2010 amounted to 1,668 million, including $828 million (50%) in direct costs, $818 million (49%) in indirect mortality costs, and $22 (1%) million in indirect morbidity costs. The share of the total costs was greater from active smoking (93%) than SHS exposure (7%), and greater for men (92%) than women (8%). The total economic costs averaged $72 per Taiwanese aged 0+ and $701 per smoker aged 35+. Based on Taiwan's total cigarette consumption of 1,894 million packs in 2010, the total economic costs averaged $0.88 per pack, about 43% the 2010 average retail price of cigarettes (NT$65 or US$2.05).[13]

Of the $828 million in direct healthcare costs, $104 million was spent for treating ischemic heart disease, $94 million for stroke, and $53 million for lung cancer. Outpatient expenditures amounted to $520 million (63%) while inpatient expenditures were $308 million (37%). Among the $22 million in indirect morbidity costs, $18.7 million was due to active smoking and $3.4 million was due to SHS exposure. The $818 million in mortality costs averaged $52,777 per death among the 15,503 premature deaths caused by smoking or SHS exposure.

Table 4. Total Economic Costs of Smoking and Secondhand Smoke (SHS) Exposure by Component of Costs, Gender, Age, and Disease for Adults Aged 35 and Older: Taiwan, 2010 (Unit: US$1,000)

	Direct costs			Indirect costs		Total economic costs
	Inpatient	Outpatient	Subtotal	Morbidity cost	Mortality cost	
Smoking	268,941	473,003	741,943	18,669	782,595	1,543,208
SHS exposure	39,179	46,894	86,073	3,407	35,610	125,090
Male	274,288	467,438	741,726	18,932	781,654	1,542,312
Female	33,832	52,458	86,290	3,144	36,551	125,985
35-49	61,319	114,908	176,228	10,797	462,239	649,264
50-64	106,579	204,427	311,006	9,601	260,569	581,176
65+	140,222	200,561	340,783	1,678	73,801	416,262
Lung cancer	21,191	31,552	52,743	1,249	86,729	140,721
Ischemic HD	66,157	38,128	104,285	1,615	62,728	168,628
Cerebrovascular	46,055	48,275	94,330	2,943	71,882	169,155
Other diseases[a]	174,717	401,942	576,659	16,270	596,866	1,189,795
Total	**308,120**	**519,896**	**828,016**	**22,076**	**818,205**	**1,668,298**

Note. HD=heart disease. Exchange rate of the Taiwanese Dollar against US$ = 31.642 in 2010.

[a] "Other" includes all the rest of smoking or SHS related diseases.

Sensitivity analysis

Table 5 shows that if the prevalence rates of smoking and SHS exposure in 2010 had remained at the same levels as in 2008, the toll of active and passive smoking-attributable losses would have been greater by additional 1,537 deaths and $107 million in total economic cost. If the prevalence rates of smoking and SHS exposure were at the mean values of the 2009 and 2010 levels, there would have additional 855 deaths and $59 million loss in total economic cost.

If we assumed the annual growth rate of productivity was 6% instead of 4%, total economic costs would be $177 million higher. If we used the RR values for those smoking-related diseases reported by the widely cited American study,[24,25] our estimates of active and passive smoking- attributable premature deaths and total economic costs would increase by 6,984 deaths and $506 million.

Table 5. Sensitivity Analysis of the Smoking and Secondhand Smoke (SHS) Attributable Mortality (SAM), Direct Healthcare Costs, and Total Economic Costs: Taiwan, 2010

	SAM		Direct costs		Total economic costs	
	No.	% of all deaths*	Amount (US$ million)	% of NHE	Amount (US$ million)	% of GDP
MAIN ANALYSIS	15,503	10.71	828	3.38	1,668	0.39
SENSITIVE ANALYSIS						
1. Smoking & SHS exposure prevalence						
Assume the levels in 2008	17,040	11.78	894	3.65	1,775	0.41
Assume the mean levels in 2008 & 2010	16,358	11.30	865	3.53	1,727	0.40
Assume the levels in 2001[a]	18,868	13.04	971	3.96	1,903	0.44
2. Growth rate in productivity						
Assume 6% instead of 4%	15,503	10.71	828	3.38	1,845	0.43
3. Relative risk						
Assume RRs for former smokers = 1	11,088	7.66	629	2.57	1,322	0.31
Assume published RRs in the US[b]	22,487	15.54	1,042	4.25	2,174	0.51

Note. NHE=National personal healthcare expenditure (US$24.5 billion in 2010); GDP=Gross Domestic Product (US$430.1 billion in 2010). Exchange rate of the Taiwanese Dollar against US$ = 31.642 in 2010.

* In 2010, the number of all-cause deaths among persons of all ages was 144,709.

[a] For SHS exposure, because data on 2001 rates were available, we used the 2008 SHS exposure rates as a proxy.

[b] See Table 12.1 in the 2014 US Surgeon General Report.[25]

DISCUSSION

The direct costs of smoking and SHS exposure for 2010 in Taiwan was $828 million, accounting for 3.4% of total personal healthcare expenditures in the nation. Smoking and SHS exposure also led to 15,503 premature deaths, 284,014 years of potential life lost, $818 million in indirect costs of productivity losses due to premature deaths, and $22 million in indirect costs of time lost from work due to tobacco-related illness. These costs totaled $1,668 million, representing 0.4% of Taiwan's gross domestic product (GDP) and averaging about $700 per adult smoker.

The proportion of the total costs of smoking and SHS exposure to GDP in Taiwan is smaller than those estimated for other East Asia countries, such as 0.7% for China,[26] and 0.6%-0.8% for South Korea.[27] One possible explanation is because of relatively lower smoking rates in Taiwan. Another explanation may be the underestimation of our direct cost estimates which were based on the NHI claims database. The NHI database only includes health expenditures paid by the NHI, but not copayments or out-of-pocket payments that were spent on non-NHI covered health services such as orthodontics, long-term care, and nursing home care. In 2010, the NHI expenditures only comprised 57% of Taiwan's personal health expenditures.[28] Furthermore, due to limited data accessibility, we only included the NHI spending on inpatient care and Western medicine outpatient care. Other NHI covered health services such as Chinese medicine outpatient care accounted for 16% of the NHI expenditures in 2010.[28] If copayments, out-of-pocket, and other NHI covered health expenditures are counted, our direct cost estimate could be considerably larger than $828 million.

A previous study in Taiwan [9] also included the same 19 smoking-related diseases and used the same data source for relative risks. They estimated that active smoking caused 233,223 years of potential life lost (YPLLs) and $467 million (after converting into 2010 constant dollars) in direct healthcare costs in 2001. Our corresponding estimates in 2010 were 284,014 years and $818 million. These larger estimates seem contrary to the fact that smoking prevalence among adults aged 35 and older had decreased substantially among men from 48.0% to 33.9% and among women from 4.7% to 3.8% during 2001−2010. However, there is a caveat. Yang et al.[9] assumed the relative risk of disease-specific death for former smokers equal to 1 and thus assumed the smoking-attributable mortality and healthcare costs for former smokers were zero. If we made the same assumption while holding all other parameters constant, our 2010 estimates for YPLLs and direct healthcare costs would become 197,887 years and $544 million. The new 2010 estimate for YPLLs is 15% smaller than the 2001 estimate,[9] which is consistent with the declining smoking prevalence trend. The new 2010 estimate for smoking-attributable direct costs is 16% larger than the 2001 estimate,[9] which could occur because Taiwan's personal health expenditures rose by almost 40% in real term during 2001-2010.[28]

This study indicates that Taiwan's National Health Insurance spent $828 million — 6% of their budget — in 2010 to cover the excess healthcare expenditures caused by smoking and SHS exposure. These costs were borne by all Taiwan residents including never smokers who paid for insurance premium. Increasing cigarette taxes will help to offset the external costs of smoking imposed by smokers on others.

Tobacco control programs are costly, but the benefits of tobacco control programs are substantial. Several recent studies have shown that the 2009 Act in Taiwan was associated with a reduction in adolescent smoking [29] and SHS exposure,[8] and an increase in adult cessation rates.[30] Assuming a half of the reduction in adult smoking prevalence and SHS exposure during 2008−2010 was driven by the 2009 Act, our sensitivity analysis results show that there was a saving in avoided smoking and SHS attributable financial losses by $59 million a year in 2010 alone.

This study makes several contributions. First, we considered the economic impact of SHS exposure among adults aged 35+. Our results indicated that the SHS-attributable medical costs, indirect morbidity costs, and indirect mortality costs were not negligible — equaling 12%, 18%, and 5% of the levels of the active smoking-attributable direct medical costs, indirect morbidity costs, and indirect mortality costs, respectively. Thus, not including the impact of SHS exposure would underestimate the true burden of smoking. Second, we took into consideration smoking-attributable costs for former smokers. Former smokers often quit smoking because they have developed smoking-related illness. Although the risks of heart attack and stroke falls quickly within the first five years after quitting,[31] the risks of other tobacco-related diseases for former smokers takes longer time to reverse. Therefore, assuming the RRs for former smokers equal to 1 may underestimate the economic costs of smoking when the prevalence of former smokers, especially recent quitters, is high.

This study has several limitations. First, we did not consider costs of SHS exposure among children and young adults under age 35, and nor the costs due to health problems of newborns caused by maternal smoking such as low birth weight.[31] Second, in estimating indirect morbidity costs, we did not count opportunity costs of relatives or informal caregivers who took care of patients with smoking-related diseases, and productivity losses due to smoking-caused disability other than inpatient days. Third, we used the relative risk of death as a proxy for the relative risk of illness to estimate the smoking-attributable healthcare costs. Fourth, we derived the relative risk of disease-specific death for former smokers using an interpolation approach. Future research is needed to more accurately quantify the relative risk of disease-specific mortality for former smokers in Taiwan. Lastly, we evaluated the impact of the 2009 Act on smoking-attributable costs based on sensitivity analyses. Further research is needed to determine the marginal effect of the 2009 Act on smoking prevalence while controlling for other confounding factors.

Although smoking prevalence and SHS exposure in Taiwan have declined in recent years, they still impose a huge financial loss. Thus, sustained tobacco control efforts to encourage people to quit smoking, prevent smoking uptake by children and young adults, and protect all people from SHS exposure are needed.

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Contributorship: HYS laid out the analytical framework, supervised all the steps of data analysis, and revised the manuscript critically for important intellectual content. YWW drafted the manuscript particularly on the method parts and helped to review and interpret the results. LCC helped obtain all the data and conducted the analyses for this study. YWT conceptualized the research idea, obtained the funding, drafted the manuscript and helped interpret the results. All authors reviewed and approved the final manuscript.

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CHEERS Checklist
Items to include when reporting economic evaluations of health interventions

The **ISPOR CHEERS Task Force Report**, *Consolidated Health Economic Evaluation Reporting Standards (CHEERS)—Explanation and Elaboration: A Report of the ISPOR Health Economic Evaluations Publication Guidelines Good Reporting Practices Task Force*, provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

Section/item	Item No	Recommendation	Reported on page No/ line No
Title and abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	page 1, line1
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	page 2
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	pp 4-5. p.5, para 2 & P. 6, para2
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	p4, line 7
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	page 4, para 2
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	p4, para 3
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	N/A
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	p6, para 2 & p7 para 1
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	p14, para 1
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	p6 para 3, p7 para 1
Measurement of effectiveness	11a	*Single study-based estimates:* Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	N/A

	11b	*Synthesis-based estimates:* Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	N/A
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	pp. 6-7
Estimating resources and costs	13a	*Single study-based economic evaluation:* Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	pp. 10-15
	13b	*Model-based economic evaluation:* Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	N/A
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	Tables 4-5
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	p7 para 1 & p8
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	p11 para 1-2 7-8
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	p11 & p15 para 3
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	Tables 1-2
Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	N/A
Characterising uncertainty	20a	*Single study-based economic evaluation:* Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact	P22

		of methodological assumptions (such as discount rate, study perspective).	& Table 5
	20b	*Model-based economic evaluation:* Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	N/A
Characterising heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	pp. 24-25
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	p29
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	p29

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

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The Costs of Smoking and Secondhand Smoke Exposure in Taiwan: A Prevalence-Based Annual Cost Approach

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The Costs of Smoking and Secondhand Smoke Exposure in Taiwan: A Prevalence-Based Annual Cost Approach

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ABSTRACT

Objectives: To assess the costs of the health effects of cigarette smoking and secondhand smoke (SHS) exposure to society.

Design: Prevalence-based, disease-specific cost-of-illness study. We used an epidemiological population-attributable risk method to determine the costs that can be attributed to smoking and SHS exposure.

Setting: Taiwan.

Participants: All adult population aged 35 and older.

Primary outcome measures: Direct costs of healthcare expenditures spent for treating tobacco-related diseases, indirect mortality costs measured by the value of lost productivity due to tobacco-related premature deaths, and indirect morbidity costs measured by the value of time lost from work due to tobacco-related illness.

Results: In 2010, direct costs of smoking and SHS exposure amounted to US$828 million, accounting for 3.4% of Taiwan's total personal healthcare expenditures. Smoking and SHS exposure also contributed to 15,555 premature deaths — corresponding to a loss of 284,765 years of life and US$820 million in productivity — and US$22 million in indirect morbidity costs. These direct and indirect costs totaled US$1,670 million, representing 0.4% of Taiwan's gross domestic product (GDP) and averaging about US$720 per adult smoker. The share of the total costs was greater from active smoking (92%) than SHS exposure (8%), and greater for men (92%) than women (8%).

Conclusions: Smoking and SHS exposure impose a huge financial loss in Taiwan. Sustained tobacco control efforts to encourage people to quit smoking, prevent smoking uptake by children and young adults, and protect all people from SHS exposure are needed.

Strengths and limitations of this study

- Little is known about the economic costs of secondhand smoke (SHS) exposure in East Asian countries. This is the first study to assess the health effects of smoking by taking into account the economic impact of SHS exposure in Taiwan.
- This study provides evidence on the economic effect of the recent reduction in smoking prevalence and SHS exposure on healthcare costs and productivity losses to the Taiwan society, as a result of implementing a comprehensive tobacco control program in 2009.
- Only adults aged 35 and older were included in the study.
- The relative risks of healthcare cost for smokers are assumed to be the same as the relative risks of death for smokers because of data limitation.

INTRODUCTION

East Asia is the world's largest tobacco epidemic region, consuming nearly half of total global cigarette consumption.[1] Although all East Asian countries ratified the WHO Framework Convention on Tobacco Control (FCTC) in 2004 or 2015, a recent assessment study [2] revealed that the majority of countries in East Asia lagged behind in implementing the FCTC recommended tobacco control programs according to WHO's MPOWER (Monitoring, Protect, Offer, Warn, Enforcement and Raise) criteria.[3] As of 2010, 37−53% of adult men in East Asia were current smokers and more than 46% of men were exposed to passive smoking at workplaces.[2] To enhance the incentives to implement the promises of the ratified FCTC to reduce the tobacco epidemic in East Asia, update evidence on the economic costs due to active and passive smoking-caused illness, disability, and premature mortality in this region is imperative.

Taiwan is regarded as a model in East Asia in tobacco control.[2] During 1960s and 1970s, smoking prevalence among Taiwanese aged 35 and above exceeded 75% for men and 8–12% for women.[4] In 1987, Taiwan's cigarette market was forced to open to foreign brands, leading to a 6% jump in adult male smoking and a 13% jump in youth smoking within three years.[4] As a consequence, the government launched a series of tobacco control initiatives such as school-based anti-smoking programs and the 1997 Tobacco Hazards Prevention Act through which indoor workplaces and public places became partially smoke-free. [5] In 2002, the government levied a tobacco tax amounting to five New Taiwan Dollars (NT$) per pack and started the Outpatient Smoking Cessation Services. [5] During the period of 1990-2005, smoking prevalence among men aged 18 and older had declined from 59.4% to 40.0%.[5] Taiwan's Legislature ratified the WHO FCTC in 2005. Based on the FCTC recommendations,[6] an amendment to the Tobacco Hazards Prevention Act went into effect in 2009 (hereafter called the 2009 Act) to strengthen existing tobacco control measures by adding graphic warning labels on cigarette packages, extending smoke-free areas to almost all enclosed workplaces and public places, completely banning tobacco advertisements, promotion and sponsorship, as well as increasing tobacco taxes.

As a result of the 2009 Act, smoking prevalence among men aged 18 and older in Taiwan further decreased from 40.0% to 33.5% and exposure to passive smoking in workplaces decreased substantially from 33.2% to 18.2% between 2005 and 2011.[5, 7] Given this sizeable reduction in active and passive smoking, it is policy relevant to assess the current level of the costs of active and passive smoking-attributable illness, disability, and premature mortality, and to determine whether or not these costs have decreased.

Two previous studies estimated the cost of smoking in Taiwan. Using a prevalence-based approach, Yang et al. estimated that in 2001 smoking contributed to US$398 million in excess medical expenditures and US$1,390 million in productivity loss from premature death among people aged 35 and older in Taiwan.[8] Using an incidence-based approach, Chung et al.[9] estimated that the present value of lifetime smoking-attributable medical costs among people aged 35 and older ranged from US$291-$336 million depending on discount rate for the year 2001 in Taiwan. There has been no study to update these cost estimates in Taiwan since 2001. Furthermore, none of studies on the cost of smoking in Taiwan and few of those in the literature have included any health costs attributed to passive smoking, also known as secondhand smoke (SHS).

The main objective of this study is to assess the costs of the health effects of cigarette smoking and SHS exposure in Taiwan in 2010. This is the first attempt to quantify the economic costs of SHS exposure in Taiwan. This study will also provide an evaluation on the hypothesis that implementation of the 2009 Act was associated with decreases in economic costs of smoking and SHS exposure. Because of the similarity in tobacco epidemic and culture among East Asian countries, the findings of this study can be served as a valuable reference for understanding the economic benefits of tobacco control programs in the region.

METHODS

We considered three components of costs: direct costs of healthcare expenditures spent for treating tobacco-related diseases, indirect mortality costs measured by the value of lost productivity due to premature death, and indirect morbidity costs measured by the value of time lost from work due to tobacco-related illness. Prevalence-based, disease-specific cost-of-illness approach [10] was used to estimate the healthcare expenditures, workloss days, and deaths due to smoking-related diseases in 2010. We used an epidemiological population-attributable risk method [11] to determine the smoking-attributable fraction (SAF), which measures the proportion of expenditures, workloss days, or deaths that can be attributed to smoking, and applied it to the total measure. A SHS-attributable fraction (SAF^{SHS}) was estimated in a similar manner. Our analyses focused on adults aged 35 years and older.

Data sources

Population-based data from the annual Adult Smoking Behavior Survey (ASBS) were used to determine the prevalence of smoking and SHS exposure. The ASBS is a telephone interview survey collecting information on individual’s demographic characteristics, cigarette smoking and quitting behavior, and SHS exposure from a nationally representative sample (around 16,000 per year) of non-institutionalized population aged 18 and older in Taiwan. Disease-specific inpatient and outpatient expenditures, and number of hospital inpatient days were obtained from the 2010 National Health Insurance (NHI) claims database. Taiwan's NHI, launched in 1995, is a mandatory single-payer social health insurance system administered by the government that provides universal healthcare coverage to virtually all citizens in Taiwan.

Population data came from the 2010 Population Census,[12] number of deaths for each disease from the 2010 Statistics of Causes of Death,[13] and life expectancy by age and gender from the 2010 life tables.[14] The age- and gender-specific employment rates and monthly earnings were obtained from the 2010 Report on the Manpower Utilization Survey.[15]

Smoking-related and SHS-associated diseases

We included 19 smoking-related diseases which were identified to have a significant association between cigarette smoking and mortality risk by two large epidemiological studies conducted in Taiwan.[16, 17] We considered six SHS-associated diseases: lung cancer, ischemic heart disease, cerebravascular disease, chronic obstructive pulmonary disease, asthma, and breast cancer, and four SHS-associated causes of death: lung cancer, ischemic heart disease, cerebravascular disease, and asthma as reported by the California Environmental Protection Agency (EPA) [18] and World Health Organization (WHO).[19, 20] Details of these diseases and their diagnosis codes are listed in Table 1.

Table 1. Smoking-related disease, secondhand smoke (SHS)-associated disease and cause of death, and relative risk (RR) by disease and gender, Taiwan

	RR of Smoking-related death				RR of SHS-associated disease		RR of SHS-associated cause of death	
	Male		Female					
Disease (ICD-9 code)	CS	FS	CS	FS	Male	Female	Male	Female
SMOKING-RELATED CAUSE OF DEATH								
All causes (001–998)	1.55	1.33	1.89	1.33				
Cancer								
Lip/oral cavity/pharynx (140–149)	2.60	1.96	–	–				
Esophagus (150)	3.18	2.31	15.57	6.40				
Stomach (151)	1.68	1.41	–	–				
Rectum (154)	2.06	1.64	–	–				
Liver/gallbladder/bile ducts (155–	1.46	1.28	5.03	2.49				
Lung (162)[a]	2.73	2.04	3.36	1.88	1.29	1.29	1.29	1.29
Cervix uteri (180)	–	–	5.78	2.77				
Cardiovascular disease								
Rheumatic HD (390-398)	–	–	9.43	4.13				
Ischemic HD (410–414)[a]	2.06	1.64	3.58	1.96	1.49	1.49	1.23	1.23
Cardiac arrest and other HD (420–	1.60	1.36	–	–				
Cerebrovascular disease (430–438)[a]	1.65	1.39	–	–	1.82	1.82	1.65	1.65
Respiratory disease								
Chronic bronchitis (491)	3.13	2.28	–	–				
Asthma (493)[a]	–	–	7.12	3.27	1.97	1.97	1.97	1.97
Chronic Airway Obstruction (496)	2.65	1.99	–	–				
Digestive system disease								
Peptic ulcer, GI hemorrhage (531–	3.00	2.20	22.28	8.89				
Liver cirrhosis (571)	2.01	1.61	–	–				
Other smoking-related disease								
Diabetes mellitus (250)	1.51	1.31	–	–				
Kidney diseases (580–589)	2.23	1.74	–	–				
Accidents (800–949)	1.66	1.40	–	–				
OTHER SHS-ASSOCIATED DISEASE								
COPD (490–492, 496)					1.55	1.55		
Breast cancer (174)[b]					–	1.68		

Note. CS=current smoker; FS=former smoker; HD=heart disease; GI=gastrointestinal; COPD=chronic obstructive pulmonary disease.

[a]Also a SHS-associated disease and SHS-associated cause of death. [b]Only among premenopausal women younger than age 50.

Smoking-attributable fraction (SAF) and SHS-attributable fraction (SAF^{SHS})

We calculated the SAF for each component of costs by disease, gender, and age group (35-49, 50-64, and ≥ 65 years). Based on two fundamental data elements: smoking prevalence and relative risk (RR) of *disease-specific death* for smoking, the SAF for death measures can be calculated using the following epidemiological formula: [10, 11]

$$SAF_{ijk} = \frac{P^C_{jk}\left(RR^C_{ij} - 1\right)}{P^N_{jk} + P^C_{jk} \times RR^C_{ij} + P^F_{jk} \times RR^F_{ij}} + \frac{P^F_{jk}\left(RR^F_{ij} - 1\right)}{P^N_{jk} + P^C_{jk} \times RR^C_{ij} + P^F_{jk} \times RR^F_{ij}} \quad (1)$$

where P^N, P^C, and P^F denote the prevalence of never, current, and former smokers, respectively; RR^C (or RR^F) denotes the RR of disease-specific death for current (or former) smokers in comparison to never smokers; the subscript i denotes disease, j denotes gender, and k denotes age group. Note that $(RR^C - 1)$ denotes the excess risk of disease-specific death for current smokers over never smokers, and similarly, $(RR^F - 1)$ denotes the excess risk of disease-specific death for former smokers over never smokers. The first term of Equation (1) is the SAF for current smokers, and the second term is the SAF for former smokers.

Prevalence rates of current smokers, former smokers, and never smokers among adults aged 35 and older were obtained from the ASBS data. The RR of death for smokers is defined as the ratio of the death rate for smokers to that for never smokers. Given the huge body of scientific evidence that smokers have a greater risk of mortality compared with never smokers, the RR should be greater than 1 and the excess risk should be greater than zero. The disease-specific relative risks for current smokers (RR^C) specific among Taiwanese adults were taken from the two aforementioned epidemiological studies in Taiwan.[16, 17]; however, the disease-specific relative risks for former smokers (RR^F) were not available in published sources. Instead of adopting the assumption that the RR^F equal 1 and forcing the SAF for former smokers to becomes zero as other studies have done,[8, 9] we derived a proxy measure for the RR^F based on the assumption that the ratio between the excess risk for former smokers and the excess risk for current smokers is the same for any disease-specific death and all-cause death. Fortunately, in the same data sources which provided the disease-specific RR^C, the all-cause relative risk for current smokers (RRA^C) and the all-cause relative risk for former smokers (RRA^F) were also provided.[16, 17] Based on these relative risk data and our assumption, we estimated the disease-specific relative risks for former smokers via the following calculation: $(RR^C - 1) \times (RRA^F - 1) / (RRA^C - 1) + 1$.

To estimate the SAF for healthcare costs, we assumed the RRs of disease-specific healthcare cost for current and former smokers are the same as those of disease-specific death for current and former smokers because of data limitation.

Similarly, based on two fundamental data elements: prevalence of SHS exposure and relative risk of disease-specific death or illness for SHS exposure, we calculated the SAF^{SHS} among nonsmokers for each component of costs by disease, gender, and age group as:

$$SAF_{ijk}^{SHS} = \frac{P_{jk}^{SHS}\left(RR_{ij}^{SHS} - 1\right)}{P_{jk}^{SHS}\left(RR_{ij}^{SHS} - 1\right) + 1} \qquad (2)$$

where P^{SHS} denotes the prevalence of SHS exposure among nonsmokers, and RR^{SHS} is the relative risk of disease-specific death or illness for exposed nonsmokers compared to unexposed nonsmokers.

Prevalence rates of SHS exposure among nonsmokers aged 35 and older were obtained from the ASBS data. Nonsmokers include never and former smokers. SHS exposed nonsmokers were either those who either answered 'yes' to the question: 'During the past week has anyone smoked in front of you at home?' or those who were employed and worked in indoor settings and answered 'yes' to the question: 'During the past week has anyone smoked in front of you at your workplace?' The RR^{SHS} of disease-specific death and the RR^{SHS} of disease-specific illness were obtained from published sources as reported by the California EPA [18] and WHO.[19, 20]

The relative risks for each disease and each cause of death for current smokers, former smokers, and SHS exposure are shown in Table 1.

Direct costs

Expenditures paid by the NHI for inpatient hospitalizations and outpatient visits were included as direct costs. Expenditures for prescribed medications during the hospitalizations or outpatient visits were included in the respective inpatient or outpatient expenditure categories. Outpatient visits comprised ambulatory care visits at outpatient or emergency departments of hospitals, and those at western medicine clinics. The smoking-attributable inpatient or outpatient expenditure for each subgroup stratified by disease, gender and age was calculated by multiplying the SAF by the total annual inpatient or outpatient expenditures for that subgroup.

The SHS-attributable inpatient or outpatient expenditure for each disease was derived by multiplying the SAF^{SHS} by the total annual inpatient or outpatient expenditures for that disease among nonsmokers. Because the NHI claims database does not contain individual's smoking status, it does not allow for distinguishing health expenditures for smokers from those for nonsmokers. We determined the amount of total inpatient (similarly, outpatient) expenditures for nonsmokers, INP^{NON}, using the following method as used by two recent studies. [19, 21]

$$INP_{ijk}^{NON} = (INP_{ijk} - INP_{ijk} \times SAF_{ijk}^{C}) \times (1 - P_{jk}^{C}) \qquad (3)$$

where INP is total annual inpatient expenditures among all individuals regardless of smoking status, P^C is the prevalence of current smokers, and SAF^C is the smoking-attributable fraction for current smokers as expressed by the first term of Equation (1).

Indirect mortality costs

For each subgroup stratified by gender and 5-year age group, we estimated the number of smoking-attributable deaths (SAD) for each disease by multiplying the SAF by the total number of deaths for that disease. The number of smoking-attributable years of potential life lost (YPLLs) was estimated by the product of the SAD and life expectancy remaining at the age of death. Smoking-attributable mortality cost was estimated by the product of the SAD and the present value of lifetime earnings (PVLEs) expected at the age of death. The PVLEs were calculated by gender and 5-year age groups based on a human capital approach developed by Max and colleagues.[22] A discount rate of 3% was used to convert the earnings into its current worth. A growth rate of 4%, which was approximately the average annual growth rate of gross domestic product (GDP) in Taiwan during 2005−2009, was used to take into account the potential growth of future earnings.

We estimated the number of SHS-attributable deaths, YPLLs, and mortality costs following the same approach as described for active smoking-attributable indirect mortality measures except that the estimation only focused on nonsmokers. Total number of deaths among nonsmokers was determined using the similar method as described for Equation (3).

Indirect morbidity costs

We defined smoking-attributable indirect morbidity cost as the value of time lost from work due to active or passive smoking-caused illness. The lost time from work is commonly measured by the number of workloss days;[23] however, because the data on workloss days by disease were not available, we used inpatient days as a proxy. The smoking-attributable indirect morbidity cost for each subgroup stratified by disease, gender and age was calculated by the product of the SAF, total annual inpatient days for that group, the proportion of the population currently employed, and daily earnings among employed persons.

Likewise, the SHS-attributable indirect morbidity cost was estimated by multiplying the SAF^{SHS} by total annual inpatient days among nonsmokers, employment rate, and daily earnings. Total number of inpatient days among nonsmokers was determined using the similar method as described for Equations (3).

Sensitivity analysis

To evaluate whether or not implementation of the 2009 Act in Taiwan was associated with decreases in active and passive smoking-attributable costs, we simulated what would be the cost estimates in 2010 by assuming two scenarios: smoking prevalence and SHS exposure rates remained at the same levels as in 2008, and smoking prevalence and SHS exposure rates were at the mean value of the 2008 and 2010 levels. We also performed sensitivity analyses to see how sensitive our cost estimates are to different assumptions about the RR values and productivity growth rates.

RESULTS

In 2010, the total population of Taiwan was 23.2 million. Among the 12.4 million adults aged 35 and older, 2.3 million were current smokers. The smoking prevalence and SHS exposure rates by gender and age in 2008 and 2010 are shown in Table 2. In 2010, smoking prevalence rates among men were about 10 times as high as those among women: 33.9% versus 3.8% for current smoking, and 15.7% versus 1.5% for former smoking. The SHS exposure rates among nonsmokers were similar between men and women. From 2008 to 2010, the current smoking prevalence among men decreased by nearly 10% and SHS exposure among both genders decreased by 13%.

Table 2. Prevalence (%) of smoking and secondhand smoke (SHS) exposure by gender and age among adults aged 35 and older: Taiwan, 2008 and 2010

	2008[a]			2010[a]		
	Smoking		SHS exposure[b]	Smoking		SHS exposure[b]
	CS	FS		CS	FS	
Total	**21.6**	**7.8**	**28.3**	**19.2**	**8.8**	**24.7**
Male	**37.5**	**14.0**	**28.2**	**33.9**	**15.7**	**24.1**
35-49	47.6	15.2	30.0	43.9	16.7	24.6
50-64	37.4	18.7	30.0	31.5	23.6	22.4
65+	29.1	26.8	17.0	19.5	30.1	12.9
Female	**4.8**	**1.2**	**28.3**	**3.8**	**1.5**	**25.2**
35-49	5.9	1.1	33.0	4.8	1.7	29.5
50-64	1.6	1.0	25.8	2.0	1.1	21.5
65+	1.9	1.0	13.8	1.3	1.0	13.2

Note. CS=current smoker; FS=former smoker.
[a] Source: Adult Smoking Behavior Survey in Taiwan.
[b] Percentage of nonsmokers who are exposed to secondhand smoke in the home or at the workplace.

Table 3 shows the deaths and years of potential life lost attributed to smoking and SHS exposure by cause of death and gender. The three leading causes of smoking-attributable deaths among men were lung cancer, ischemic heart disease, and chronic airway obstruction, and among women were cancers of liver/gallbladder/bile ducks, lung cancer, and ischemic heart disease. The leading cause of SHS-associated deaths was stroke for both genders. There was a substantial gender difference in the number of active smoking-attributable deaths — 13,744 for men and 615 for women. SHS exposure almost equally affected both genders by contributing to 613 deaths among men and 583 deaths among women. Smoking and SHS exposure contributed to a total of 15,555 deaths, which comprised about 20% of the total 19-cause deaths (77,953) among persons aged 35+ and 11% of the total all-cause deaths (144,709) among persons aged 0+. They were responsible for 284,755 years of potential life lost, averaging 18.3 years per death.

Table 3. Total Deaths, Smoking-Attributable Mortality (SAM), and Smoking-Attributable Years of Potential Life Lost (SAYPLL) by Cause of Death and Gender among Adults Aged 35 and Older: Taiwan, 2010

	Male			Female		
Cause of death	Death[a]	SAM	SAYPLL	Death[a]	SAM	SAYPLL
SMOKING-RELATED DEATH	**49,563**	**13,744**	**252,954**	**28,390**	**615**	**12,244**
Cancers						
Lip/oral cavity/pharynx	2,705	1,135	29,214	338	0	0
Esophagus	1,455	715	17,356	106	24	493
Stomach	1,440	310	5,102	808	0	0
Rectum	827	250	4,397	522	0	0
Liver/gallbladder/bile ducts	5,663	920	19,031	2,516	181	3,682
Lung	5,388	2,198	34,801	2,724	129	2,988
Cervix uteri	0	0	0	687	72	2,010
Cardiovascular diseases						
Rheumatic HD	45	0	0	76	11	212
Ischemic HD	4,921	1,467	23,279	2,862	124	1,802
Cardiac arrest and other HD	4,141	816	14,119	3,200	0	0
Cerebrovascular disease	5,910	1,225	19,805	4,142	0	0
Respiratory diseases						
Chronic bronchitis	104	47	518	62	0	0
Asthma	261	0	0	242	24	366
Chronic Airway Obstruction	3,254	1,253	12,928	908	0	0
Digestive system diseases						
Peptic ulcer, GI hemorrhage	361	160	2,350	190	51	689
Liver cirrhosis	3,367	1,065	28,538	1,388	0	0
Other diseases						
Diabetes mellitus	4,043	689	11,477	4,139	0	0
Kidney disease	2,071	677	9,831	2.001	0	0
Accidents	3,604	817	20,207	1,479	0	0
SHS-ASSOCIATED DEATH		**613**	**9,768**		**583**	**9,799**
Lung cancer	5,388	131	2,078	2,724	117	2,584
Ischemic HD	4,921	104	1,652	2,862	86	1,222
Cerebrovascular disease	5,910	353	5,677	4,142	354	5,603
Asthma	261	25	361	242	27	390
TOTAL[b]	**49,563**	**14,357**	**262,722**	**28,390**	**1,198**	**22,043**

Note. HD=heart disease; GI=gastrointestinal; SHS=secondhand smoke.
[a] Number of deaths among people aged ≥ 35 regardless of their smoking and SHS exposure status.
[b] Total deaths from 19 smoking-related diseases which overlap with the four SHS-associated diseases.

Table 4 shows the total direct and indirect costs attributed to smoking and SHS exposure by gender, age, and disease. The total economic costs of smoking and SHS exposure in 2010 amounted to 1,670 million, including US$828 million (50%) in direct costs, US$820 million (49%) in indirect mortality costs, and US$22 (1%) million in indirect morbidity costs. The share of the total costs was greater from active smoking (92%) than SHS exposure (8%), and greater for men (92%) than women (8%). The total economic costs averaged US$72 per Taiwanese aged 0+ and US$718 per smoker aged 35+. Based on Taiwan's total cigarette consumption of 1,894 million packs in 2010, the total economic costs averaged US$0.88 per pack, about 43% the 2010 average retail price of cigarettes (NT$65 or US$2.05).[12]

Of the US$828 million in direct healthcare costs, US$104 million was spent for treating ischemic heart disease, US$94 million for stroke, and US$53 million for lung cancer. Outpatient expenditures amounted to US$520 million (63%) while inpatient expenditures were US$308 million (37%). Among the US$22 million in indirect morbidity costs, US$18.7 million was due to active smoking and US$3.4 million was due to SHS exposure. The US$820 million in mortality costs averaged US$52,688 per death among the 15,555 premature deaths caused by smoking or SHS exposure.

Table 4. Total Economic Costs of Smoking and Secondhand Smoke (SHS) Exposure by Component of Costs, Gender, Age, and Disease for Adults Aged 35 and Older: Taiwan, 2010 (Unit: US$1,000)

	Direct costs			Indirect costs		Total economic costs
	Inpatient	Outpatient	Subtotal	Morbidity cost	Mortality cost	
Smoking	268,941	473,003	741,943	18,669	782,595	1,543,208
SHS exposure	39,179	46,894	86,073	3,407	36,968	126,448
Male	274,288	467,438	741,726	18,932	782,515	1,543,173
Female	33,832	52,458	86,290	3,144	37,049	126,484
35-49	61,319	114,908	176,228	10,797	472,607	659,631
50-64	106,579	204,427	311,006	9,601	269,320	589,927
65+	140,222	200,561	340,783	1,678	77,637	420,098
Lung cancer	21,191	31,552	52,743	1,249	86,729	140,721
Ischemic HD	66,157	38,128	104,285	1,615	62,728	168,628
Cerebrovascular	46,055	48,275	94,330	2,943	71,882	169,155
Other diseases[a]	174,717	401,942	576,659	16,270	598,225	1,191,152
Total	**308,120**	**519,896**	**828,016**	**22,076**	**819,564**	**1,669,656**

Note. HD=heart disease. Exchange rate of the NT$ against US$1 = 31.642 in 2010.

[a] "Other" includes all the rest of smoking or SHS related diseases.

Sensitivity analysis

Table 5 shows that if the prevalence rates of smoking and SHS exposure in 2010 had remained at the same levels as in 2008, the toll of active and passive smoking-attributable losses would have been greater by additional 1,540 deaths and US$107 million in total economic cost. If the prevalence rates of smoking and SHS exposure were at the mean values of the 2009 and 2010 levels, there would have additional 883 deaths and US$59 million loss in total economic cost.

If we assumed the annual growth rate of productivity was 6% instead of 4%, total economic costs would be US$177 million higher. If we used the RR values for those smoking-related diseases reported by the widely cited American study,[24, 25] our estimates of active and passive smoking- attributable premature deaths and total economic costs would increase by 6,958 deaths and US$505 million.

Table 5. Sensitivity Analysis of Smoking and Secondhand Smoke (SHS) Attributable Mortality (SAM), Direct Healthcare Costs, and Total Economic Costs: Taiwan, 2010

	SAM		Direct costs		Total economic costs	
	No.	% of all deaths*	Amount (US$ million)	% of NHE	Amount (US$ million)	% of GDP
MAIN ANALYSIS	15,555	10.75	828	3.38	1,670	0.39
SENSITIVE ANALYSIS						
1. Smoking & SHS exposure prevalence						
Assume the levels in 2008	17,095	11.81	894	3.65	1,777	0.41
Assume the mean levels in 2008 & 2010	16,438	11.36	865	3.53	1,729	0.40
2. Growth rate in productivity						
Assume 6% instead of 4%	15,555	10.75	828	3.38	1,847	0.43
3. Relative risk						
Assume RRs for former smokers = 1	11,140	7.88	629	2.57	1,323	0.31
Assume published RRs in the U.S.[a]	22,513	15.56	1,042	4.25	2,175	0.51

Note. NHE=National personal healthcare expenditure (US$24.5 billion in 2010); GDP=Gross Domestic Product (US$430.1 billion in 2010). Exchange rate of the NT$ against US$ = 31.642 in 2010.

* In 2010, the number of all-cause deaths among people aged ≥ 0 was 144,709.

[a] See Table 12.1 in the 2014 U.S. Surgeon General Report.[25]

DISCUSSION

The direct costs of smoking and SHS exposure in Taiwan amounted to US$828 million and accounted for 3.4% of Taiwan's personal healthcare expenditures in 2010. Smoking and SHS exposure also led to 15,555 premature deaths, 284,755 years of potential life lost, US$820 million in indirect costs of productivity losses due to premature deaths, and US$22 million in indirect costs of time lost from work due to tobacco-related illness. These costs totaled US$1,670 million, representing 0.4% of Taiwan's gross domestic product (GDP) and averaging about US$720 per adult smoker.

The proportion of the total costs of smoking and SHS exposure to GDP in Taiwan is smaller than those estimated for other East Asia countries, such as 0.7% for China,[23] and 0.6%-0.8% for South Korea.[26] One possible explanation is because of relatively lower smoking rates in Taiwan. Another explanation may be the underestimation of our direct cost estimates which were based on the NHI claims database. The NHI database only includes health expenditures paid by the NHI, but not copayments or out-of-pocket payments that were spent on non-NHI covered health services such as orthodontics, long-term care, and nursing home care. In 2010, the NHI expenditures only comprised 57% of Taiwan's personal health expenditures.[27] Furthermore, due to limited data accessibility, we only included the NHI spending on inpatient care and Western medicine outpatient care. Other NHI covered health services such as Chinese medicine outpatient care accounted for 16% of the NHI expenditures in 2010.[27] If copayments, out-of-pocket, and other NHI covered health expenditures are counted, our direct cost estimate could be considerably larger than US$828 million.

Our estimated total costs of smoking and SHS exposure are very likely to be underestimated for several other reasons. First, we only included 19 diseases in the analyses of smoking-attributable costs. Smoking also causes many other diseases such as aortic aneurysm, atherosclerosis, pneumonia, Influenza, hip fractures, rheumatoid arthritis, periodontitis, nuclear cataract, and tuberculosis,[25] Because the RRs of these diseases for Taiwanese smokers were not available in public sources, we did not include them in our analyses. Without considering these diseases, our estimates almost certainly underestimate the true costs of smoking, Second, we did not include children and young adults under age 35 in the analyses of SHS-attributable costs. SHS exposure has been causally linked to adverse health effects on infants and children, including low birth weight, sudden infant death syndrome, middle ear disease, chronic respiratory symptoms, asthma, and attention deficit hyperactivity disorder [25, 28]. Third, we measured SHS exposure based on self-reported exposure in the home and workplace during the last week, but did not consider exposure that may have occurred in other public places or at an earlier time. It has been shown that self-reported SHS exposure greatly underestimates actual exposure assessed by the biomarker such as cotinine level.[29] Therefore, our estimated

SHS-attributable costs are most likely to be underestimated. Fourth, in estimating indirect morbidity costs, we did not count the opportunity costs of relatives or informal caregivers who took care of patients with smoking-related diseases, productivity losses due to smoking-caused disability other than inpatient days, and transportation expenses incurred during inpatient and outpatient visits for the treatment of smoking-related diseases.[23]

A previous study by Yang and Fann et al. [8] also included the same 19 smoking-related diseases and used the same data source for relative risks. They estimated that active smoking caused 233,223 years of potential life lost (YPLLs) and US$467 million (after converting into 2010 constant dollars) in excess healthcare costs for 2001. Our corresponding estimates for 2010 are 265,198 years and US$742 million. Even though adult smoking prevalence declined significantly during 2001−2010,[5] our 2010 estimates are larger than the 2001 estimates. One explanation is that Yang and Fann et al. assumed the disease-specific RRs for former smokers equal to 1, which implies former smokers have the same risk of death or illness as never smokers. This assumption would lead to underestimation of the smoking-attributable deaths and healthcare costs in 2001. Another explanation is that the total number of deaths from the 19 smoking-related diseases increased from 77,953 to 75,003 deaths and Taiwan's personal health expenditures rose by almost 40% in real term between 2001 and 2010.[13, 27]

This study indicates that Taiwan's National Health Insurance spent US$828 million — 6% of their budget — in 2010 to cover the excess healthcare expenditures caused by smoking and SHS exposure. These costs were borne by all Taiwan residents including never smokers who paid for insurance premium. Increasing cigarette taxes will help to offset the external costs of smoking imposed by smokers on others.

Tobacco control programs are costly. In 2009, the government of Taiwan spent US$15.7 million US dollars (or NT$520 million based on the 2009 exchange rate of NT$33.049 against US$1) on tobacco control programs.[30] However, the benefits of tobacco control programs are substantially larger. Several recent studies have shown that the 2009 Act in Taiwan was associated with a reduction in adolescent smoking [31] and SHS exposure,[7] and an increase in adult cessation rates.[32] Assuming a half of the reduction in adult smoking prevalence and SHS exposure during 2008−2010 was driven by the 2009 Act, our sensitivity analysis results show that there was a saving in avoided smoking and SHS attributable financial losses by US$59 million a year in 2010 alone.

This study makes several contributions. First, our results indicated that the SHS-attributable medical costs, indirect morbidity costs, and indirect mortality costs among adults aged ≥ 35 were not negligible — equaling 12%, 18%, and 5% of the levels of the active smoking-attributable direct medical costs, indirect morbidity costs, and indirect mortality costs, respectively. Thus, not including the impact of SHS exposure would underestimate the true burden of smoking. Second, we developed an interpolation approach to measure the disease-specific RRs for former smokers in Taiwan to count smoking-attributable costs for former smokers. Smokers often quit smoking because they have developed smoking-related illness. Although the risks of heart attack and stroke falls quickly within the first five years after quitting,[33] the risks of other tobacco-related diseases takes longer time to reverse after quitting. Therefore, assuming the RRs for former smokers equal to 1 would certainly underestimate the costs of smoking when the prevalence of former smokers, especially recent quitters, is high.

This study is subject to some limitation. We used the relative risk of death as a proxy for the relative risk of healthcare utilization and expenditures to estimate the direct cost of smoking because of data limitation. Also, our measure for disease-specific RR for former smokers was based on the assumption that the ratio between the excess risk for former smokers and the excess risk for current smokers is the same for any disease-specific death and all-cause death. To test the validity of this, we applied this approach to the widely cited American RR data which consist of disease-specific and all-cause RRs for current and former smokers and are available in the internet-based SAMMEC software.[24] We found that our derived RRs for former smokers follow a consistent pattern with the actual RRs for former smokers across diseases, Nevertheless, epidemiological research is needed to more accurately quantify the disease-specific RRs for former smokers in Taiwan. Lastly, we obtained the RRs from previous epidemiological studies which followed up the vital status of two cohorts established prior to 1992 till 2000.[16, 17] Due to the changes in smoking behavior over time, the cohort of smokers today are likely different the cohort 20 years ago; therefore, these RR data may not reflect the true RRs of smokers in 2010. Indeed, the 2014 U.S. Surgeon General's Report has shown that today's cigarette smokers—both men and women—have a much higher risk for lung cancer and chronic obstructive pulmonary disease than smokers in the past.

Despite the limitations that certainly lead to underestimation of our estimated total economic costs of smoking and SHS exposure, we found that smoking still imposes a huge financial burden on Taiwanese society even though smoking prevalence and SHS exposure in Taiwan have declined in recent years. Thus, sustained tobacco control efforts to encourage people to quit smoking, prevent smoking uptake by children and young adults, and protect all people from SHS exposure are needed.

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The Costs of Smoking and Secondhand Smoke Exposure in Taiwan: A Prevalence-Based Annual Cost Approach

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ABSTRACT

Objectives: To assess the costs of the health effects of cigarette smoking and secondhand smoke (SHS) exposure to society.

Design: Prevalence-based, disease-specific cost-of-illness study. We used an epidemiological population-attributable risk method to determine the costs that can be attributed to smoking and SHS exposure.

Setting: Taiwan.

Participants: All adult population aged 35 and older.

Primary outcome measures: Direct costs of healthcare expenditures spent for treating tobacco-related diseases, indirect mortality costs measured by the value of lost productivity due to tobacco-related premature deaths, and indirect morbidity costs measured by the value of time lost from work due to tobacco-related illness.

Results: In 2010, direct costs of smoking and SHS exposure amounted to US$828 million, accounting for 3.4% of Taiwan's total personal healthcare expenditures. Smoking and SHS exposure also contributed to 15,555 premature deaths — corresponding to a loss of 284,765 years of life and US$820 million in productivity — and US$22 million in indirect morbidity costs. These direct and indirect costs totaled US$1,670 million, representing 0.4% of Taiwan's gross domestic product (GDP) and averaging about US$720 per adult smoker. The share of the total costs was greater from active smoking (92%) than SHS exposure (8%), and greater for men (92%) than women (8%).

Conclusions: Smoking and SHS exposure impose a huge financial loss in Taiwan. Sustained tobacco control efforts to encourage people to quit smoking, prevent smoking uptake by children and young adults, and protect all people from SHS exposure are needed.

Strengths and limitations of this study

- Little is known about the economic costs of secondhand smoke (SHS) exposure in East Asian countries. This is the first study to assess the health effects of smoking by taking into account the economic impact of SHS exposure in Taiwan.
- This study provides evidence on the economic effect of the recent reduction in smoking prevalence and SHS exposure on healthcare costs and productivity losses to the Taiwan society, as a result of implementing a comprehensive tobacco control program in 2009.
- Only adults aged 35 and older were included in the study.
- The relative risks of healthcare cost for smokers are assumed to be the same as the relative risks of death for smokers because of data limitation.

INTRODUCTION

East Asia is the world's largest tobacco epidemic region, consuming nearly half of total global cigarette consumption.[1] Although all East Asian countries ratified the WHO Framework Convention on Tobacco Control (FCTC) in 2004 or 2015, a recent assessment study [2] revealed that the majority of countries in East Asia lagged behind in implementing the FCTC recommended tobacco control programs according to WHO's MPOWER (Monitoring, Protect, Offer, Warn, Enforcement and Raise) criteria.[3] As of 2010, 37−53% of adult men in East Asia were current smokers and more than 46% of men were exposed to passive smoking at workplaces.[2] To enhance the incentives to implement the promises of the ratified FCTC to reduce the tobacco epidemic in East Asia, update evidence on the economic costs due to active and passive smoking-caused illness, disability, and premature mortality in this region is imperative.

Taiwan is regarded as a model in East Asia in tobacco control.[2] During 1960s and 1970s, smoking prevalence among Taiwanese aged 35 and above exceeded 75% for men and 8–12% for women.[4] In 1987, Taiwan's cigarette market was forced to open to foreign brands, leading to a 6% jump in adult male smoking and a 13% jump in youth smoking within three years.[4] As a consequence, the government launched a series of tobacco control initiatives such as school-based anti-smoking programs and the 1997 Tobacco Hazards Prevention Act through which indoor workplaces and public places became partially smoke-free. [5] In 2002, the government levied a tobacco tax amounting to five New Taiwan Dollars (NT$) per pack and started the Outpatient Smoking Cessation Services. [5] During the period of 1990-2005, smoking prevalence among men aged 18 and older had declined from 59.4% to 40.0%.[5] Taiwan's Legislature ratified the WHO FCTC in 2005. Based on the FCTC recommendations,[6] an amendment to the Tobacco Hazards Prevention Act went into effect in 2009 (hereafter called the 2009 Act) to strengthen existing tobacco control measures by adding graphic warning labels on cigarette packages, extending smoke-free areas to almost all enclosed workplaces and public places, completely banning tobacco advertisements, promotion and sponsorship, as well as increasing tobacco taxes.

As a result of the 2009 Act, smoking prevalence among men aged 18 and older in Taiwan further decreased from 40.0% to 33.5% and exposure to passive smoking in workplaces decreased substantially from 33.2% to 18.2% between 2005 and 2011.[5, 7] Given this sizeable reduction in active and passive smoking, it is policy relevant to assess the current level of the costs of active and passive smoking-attributable illness, disability, and premature mortality, and to determine whether or not these costs have decreased.

Two previous studies estimated the cost of smoking in Taiwan. Using a prevalence-based approach, Yang et al. estimated that in 2001 smoking contributed to US$398 million in excess medical expenditures and US$1,390 million in productivity loss from premature death among people aged 35 and older in Taiwan.[8] Using an incidence-based approach, Chung et al.[9] estimated that the present value of lifetime smoking-attributable medical costs among people aged 35 and older ranged from US$291-$336 million depending on discount rate for the year 2001 in Taiwan. There has been no study to update these cost estimates in Taiwan since 2001. Furthermore, none of studies on the cost of smoking in Taiwan and few of those in the literature have included any health costs attributed to passive smoking, also known as secondhand smoke (SHS).

The main objective of this study is to assess the costs of the health effects of cigarette smoking and SHS exposure in Taiwan in 2010. This is the first attempt to quantify the economic costs of SHS exposure in Taiwan. This study will also provide an evaluation on the hypothesis that implementation of the 2009 Act was associated with decreases in economic costs of smoking and SHS exposure. Because of the similarity in tobacco epidemic and culture among East Asian countries, the findings of this study can be served as a valuable reference for understanding the economic benefits of tobacco control programs in the region.

METHODS

We considered three components of costs: direct costs of healthcare expenditures spent for treating tobacco-related diseases, indirect mortality costs measured by the value of lost productivity due to premature death, and indirect morbidity costs measured by the value of time lost from work due to tobacco-related illness. Prevalence-based, disease-specific cost-of-illness approach [10] was used to estimate the healthcare expenditures, workloss days, and deaths due to smoking-related diseases in 2010. We used an epidemiological population-attributable risk method [11] to determine the smoking-attributable fraction (SAF), which measures the proportion of expenditures, workloss days, or deaths that can be attributed to smoking, and applied it to the total measure. A SHS-attributable fraction (SAF^{SHS}) was estimated in a similar manner. Our analyses focused on adults aged 35 years and older.

Data sources

Population-based data from the annual Adult Smoking Behavior Survey (ASBS) were used to determine the prevalence of smoking and SHS exposure. The ASBS is a telephone interview survey collecting information on individual's demographic characteristics, cigarette smoking and quitting behavior, and SHS exposure from a nationally representative sample (around 16,000 per year) of non-institutionalized population aged 18 and older in Taiwan. Disease-specific inpatient and outpatient expenditures, and number of hospital inpatient days were obtained from the 2010 National Health Insurance (NHI) claims database. Taiwan's NHI, launched in 1995, is a mandatory single-payer social health insurance system administered by the government that provides universal healthcare coverage to virtually all citizens in Taiwan.

Population data came from the 2010 Population Census,[12] number of deaths for each disease from the 2010 Statistics of Causes of Death,[13] and life expectancy by age and gender from the 2010 life tables.[14] The age- and gender-specific employment rates and monthly earnings were obtained from the 2010 Report on the Manpower Utilization Survey.[15]

Smoking-related and SHS-associated diseases

We included 19 smoking-related diseases which were identified to have a significant association between cigarette smoking and mortality risk by two large epidemiological studies conducted in Taiwan.[16, 17] We considered six SHS-associated diseases: lung cancer, ischemic heart disease, cerebravascular disease, chronic obstructive pulmonary disease, asthma, and breast cancer, and four SHS-associated causes of death: lung cancer, ischemic heart disease, cerebravascular disease, and asthma as reported by the California Environmental Protection Agency (EPA) [18] and World Health Organization (WHO).[19, 20] Details of these diseases and their diagnosis codes are listed in Table 1.

Table 1. Smoking-related disease, secondhand smoke (SHS)-associated disease and cause of death, and relative risk (RR) by disease and gender, Taiwan

Disease (ICD-9 code)	RR of Smoking-related death: Male CS	Male FS	Female CS	Female FS	RR of SHS-associated disease: Male	Female	RR of SHS-associated cause of death: Male	Female
SMOKING-RELATED CAUSE OF DEATH								
All causes (001–998)	1.55	1.33	1.89	1.33				
Cancer								
Lip/oral cavity/pharynx (140–149)	2.60	1.96	–	–				
Esophagus (150)	3.18	2.31	15.57	6.40				
Stomach (151)	1.68	1.41	–	–				
Rectum (154)	2.06	1.64	–	–				
Liver/gallbladder/bile ducts	1.46	1.28	5.03	2.49				
Lung (162)[a]	2.73	2.04	3.36	1.88	1.29	1.29	1.29	1.29
Cervix uteri (180)	–	–	5.78	2.77				
Cardiovascular disease								
Rheumatic HD (390-398)	–	–	9.43	4.13				
Ischemic HD (410–414)[a]	2.06	1.64	3.58	1.96	1.49	1.49	1.23	1.23
Cardiac arrest and other HD	1.60	1.36	–	–				
Cerebrovascular disease (430–438)[a]	1.65	1.39	–	–	1.82	1.82	1.65	1.65
Respiratory disease								
Chronic bronchitis (491)	3.13	2.28	–	–				
Asthma (493)[a]	–	–	7.12	3.27	1.97	1.97	1.97	1.97
Chronic Airway Obstruction (496)	2.65	1.99	–	–				
Digestive system disease								
Peptic ulcer, GI hemorrhage	3.00	2.20	22.28	8.89				
Liver cirrhosis (571)	2.01	1.61	–	–				
Other smoking-related disease								
Diabetes mellitus (250)	1.51	1.31	–	–				
Kidney diseases (580–589)	2.23	1.74	–	–				
Accidents (800–949)	1.66	1.40	–	–				
OTHER SHS-ASSOCIATED DISEASE								
COPD (490–492, 496)					1.55	1.55		
Breast cancer (174)[b]					–	1.68		

Note. CS=current smoker; FS=former smoker; HD=heart disease; GI=gastrointestinal; COPD=chronic obstructive pulmonary disease.

[a]Also a SHS-associated disease and SHS-associated cause of death. [b]Only among premenopausal women younger than age 50.

Smoking-attributable fraction (SAF) and SHS-attributable fraction (SAF^{SHS})

We calculated the SAF for each component of costs by disease, gender, and age group (35-49, 50-64, and ≥ 65 years). Based on two fundamental data elements: smoking prevalence and relative risk (RR) of *disease-specific death* for smoking, the SAF for death measures can be calculated using the following epidemiological formula: [10, 11]

$$SAF_{ijk} = \frac{P_{jk}^{C}\left(RR_{ij}^{C} - 1\right)}{P_{jk}^{N} + P_{jk}^{C} \times RR_{ij}^{C} + P_{jk}^{F} \times RR_{ij}^{F}} + \frac{P_{jk}^{F}\left(RR_{ij}^{F} - 1\right)}{P_{jk}^{N} + P_{jk}^{C} \times RR_{ij}^{C} + P_{jk}^{F} \times RR_{ij}^{F}} \quad (1)$$

where P^N, P^C, and P^F denote the prevalence of never, current, and former smokers, respectively; RR^C (or RR^F) denotes the RR of disease-specific death for current (or former) smokers in comparison to never smokers; the subscript i denotes disease, j denotes gender, and k denotes age group. Note that $(RR^C - 1)$ denotes the excess risk of disease-specific death for current smokers over never smokers, and similarly, $(RR^F - 1)$ denotes the excess risk of disease-specific death for former smokers over never smokers. The first term of Equation (1) is the SAF for current smokers, and the second term is the SAF for former smokers.

Prevalence rates of current smokers, former smokers, and never smokers among adults aged 35 and older were obtained from the ASBS data. The RR of death for smokers is defined as the ratio of the death rate for smokers to that for never smokers. Given the huge body of scientific evidence that smokers have a greater risk of mortality compared with never smokers, the RR should be greater than 1 and the excess risk should be greater than zero. The disease-specific relative risks for current smokers (RR^C) specific among Taiwanese adults were taken from the two aforementioned epidemiological studies in Taiwan.[16, 17]; however, the disease-specific relative risks for former smokers (RR^F) were not available in published sources. Instead of adopting the assumption that the RR^F equal 1 and forcing the SAF for former smokers to becomes zero as other studies have done,[8, 9] we derived a proxy measure for the RR^F based on the assumption that the ratio between the excess risk for former smokers and the excess risk for current smokers is the same for any disease-specific death and all-cause death. Fortunately, in the same data sources which provided the disease-specific RR^C, the all-cause relative risk for current smokers (RRA^C) and the all-cause relative risk for former smokers (RRA^F) were also provided.[16, 17] Based on these relative risk data and our assumption, we estimated the disease-specific relative risks for former smokers via the following calculation: $(RR^C - 1) \times (RRA^F - 1) / (RRA^C - 1) + 1$.

To estimate the SAF for healthcare costs, we assumed the RRs of disease-specific healthcare cost for current and former smokers are the same as those of disease-specific death for current and former smokers because of data limitation.

Similarly, based on two fundamental data elements: prevalence of SHS exposure and relative risk of disease-specific death or illness for SHS exposure, we calculated the SAF^{SHS} among nonsmokers for each component of costs by disease, gender, and age group as:

$$SAF_{ijk}^{SHS} = \frac{P_{jk}^{SHS}\left(RR_{ij}^{SHS} - 1\right)}{P_{jk}^{SHS}\left(RR_{ij}^{SHS} - 1\right) + 1} \qquad (2)$$

where P^{SHS} denotes the prevalence of SHS exposure among nonsmokers, and RR^{SHS} is the relative risk of disease-specific death or illness for exposed nonsmokers compared to unexposed nonsmokers.

Prevalence rates of SHS exposure among nonsmokers aged 35 and older were obtained from the ASBS data. Nonsmokers include never and former smokers. SHS exposed nonsmokers were either those who either answered 'yes' to the question: 'During the past week has anyone smoked in front of you at home?' or those who were employed and worked in indoor settings and answered 'yes' to the question: 'During the past week has anyone smoked in front of you at your workplace?' The RR^{SHS} of disease-specific death and the RR^{SHS} of disease-specific illness were obtained from published sources as reported by the California EPA [18] and WHO.[19, 20]

The relative risks for each disease and each cause of death for current smokers, former smokers, and SHS exposure are shown in Table 1.

Direct costs

Expenditures paid by the NHI for inpatient hospitalizations and outpatient visits were included as direct costs. Expenditures for prescribed medications during the hospitalizations or outpatient visits were included in the respective inpatient or outpatient expenditure categories. Outpatient visits comprised ambulatory care visits at outpatient or emergency departments of hospitals, and those at western medicine clinics. The smoking-attributable inpatient or outpatient expenditure for each subgroup stratified by disease, gender and age was calculated by multiplying the SAF by the total annual inpatient or outpatient expenditures for that subgroup.

The SHS-attributable inpatient or outpatient expenditure for each disease was derived by multiplying the SAF^{SHS} by the total annual inpatient or outpatient expenditures for that disease among nonsmokers. Because the NHI claims database does not contain individual's smoking status, it does not allow for distinguishing health expenditures for smokers from those for nonsmokers. We determined the amount of total inpatient (similarly, outpatient) expenditures for nonsmokers, INP^{NON}, using the following method as used by two recent studies. [19, 21]

$$INP_{ijk}^{NON} = (INP_{ijk} - INP_{ijk} \text{ x } SAF_{ijk}^{C}) \text{ x } (1 - P_{jk}^{C}) \qquad (3)$$

where INP is total annual inpatient expenditures among all individuals regardless of smoking status, P^C is the prevalence of current smokers, and SAF^C is the smoking-attributable fraction for current smokers as expressed by the first term of Equation (1).

Indirect mortality costs

For each subgroup stratified by gender and 5-year age group, we estimated the number of smoking-attributable deaths (SAD) for each disease by multiplying the SAF by the total number of deaths for that disease. The number of smoking-attributable years of potential life lost (YPLLs) was estimated by the product of the SAD and life expectancy remaining at the age of death. Smoking-attributable mortality cost was estimated by the product of the SAD and the present value of lifetime earnings (PVLEs) expected at the age of death. The PVLEs were calculated by gender and 5-year age groups based on a human capital approach developed by Max and colleagues.[22] A discount rate of 3% was used to convert the earnings into its current worth. A growth rate of 4%, which was approximately the average annual growth rate of gross domestic product (GDP) in Taiwan during 2005−2009, was used to take into account the potential growth of future earnings.

We estimated the number of SHS-attributable deaths, YPLLs, and mortality costs following the same approach as described for active smoking-attributable indirect mortality measures except that the estimation only focused on nonsmokers. Total number of deaths among nonsmokers was determined using the similar method as described for Equation (3).

Indirect morbidity costs

We defined smoking-attributable indirect morbidity cost as the value of time lost from work due to active or passive smoking-caused illness. The lost time from work is commonly measured by the number of workloss days;[23] however, because the data on workloss days by disease were not available, we used inpatient days as a proxy. The smoking-attributable indirect morbidity cost for each subgroup stratified by disease, gender and age was calculated by the product of the SAF, total annual inpatient days for that group, the proportion of the population currently employed, and daily earnings among employed persons.

Likewise, the SHS-attributable indirect morbidity cost was estimated by multiplying the SAF^{SHS} by total annual inpatient days among nonsmokers, employment rate, and daily earnings. Total number of inpatient days among nonsmokers was determined using the similar method as described for Equations (3).

Sensitivity analysis

To evaluate whether or not implementation of the 2009 Act in Taiwan was associated with decreases in active and passive smoking-attributable costs, we simulated what would be the cost estimates in 2010 by assuming two scenarios: smoking prevalence and SHS exposure rates remained at the same levels as in 2008, and smoking prevalence and SHS exposure rates were at the mean value of the 2008 and 2010 levels. We also performed sensitivity analyses to see how sensitive our cost estimates are to different assumptions about the RR values and productivity growth rates.

RESULTS

In 2010, the total population of Taiwan was 23.2 million. Among the 12.4 million adults aged 35 and older, 2.3 million were current smokers. The smoking prevalence and SHS exposure rates by gender and age in 2008 and 2010 are shown in Table 2. In 2010, smoking prevalence rates among men were about 10 times as high as those among women: 33.9% versus 3.8% for current smoking, and 15.7% versus 1.5% for former smoking. The SHS exposure rates among nonsmokers were similar between men and women. From 2008 to 2010, the current smoking prevalence among men decreased by nearly 10% and SHS exposure among both genders decreased by 13%.

Table 2. Prevalence (%) of smoking and secondhand smoke (SHS) exposure by gender and age among adults aged 35 and older: Taiwan, 2008 and 2010

	2008[a]			2010[a]		
	Smoking		SHS exposure[b]	Smoking		SHS exposure[b]
	CS	FS		CS	FS	
Total	**21.6**	**7.8**	**28.3**	**19.2**	**8.8**	**24.7**
Male	**37.5**	**14.0**	**28.2**	**33.9**	**15.7**	**24.1**
35-49	47.6	15.2	30.0	43.9	16.7	24.6
50-64	37.4	18.7	30.0	31.5	23.6	22.4
65+	29.1	26.8	17.0	19.5	30.1	12.9
Female	**4.8**	**1.2**	**28.3**	**3.8**	**1.5**	**25.2**
35-49	5.9	1.1	33.0	4.8	1.7	29.5
50-64	1.6	1.0	25.8	2.0	1.1	21.5
65+	1.9	1.0	13.8	1.3	1.0	13.2

Note. CS=current smoker; FS=former smoker.
[a] Source: Adult Smoking Behavior Survey in Taiwan.
[b] Percentage of nonsmokers who are exposed to secondhand smoke in the home or at the workplace.

Table 3 shows the deaths and years of potential life lost attributed to smoking and SHS exposure by cause of death and gender. The three leading causes of smoking-attributable deaths among men were lung cancer, ischemic heart disease, and chronic airway obstruction, and among women were cancers of liver/gallbladder/bile ducks, lung cancer, and ischemic heart disease. The leading cause of SHS-associated deaths was stroke for both genders. There was a substantial gender difference in the number of active smoking-attributable deaths — 13,744 for men and 615 for women. SHS exposure almost equally affected both genders by contributing to 613 deaths among men and 583 deaths among women. Smoking and SHS exposure contributed to a total of 15,555 deaths, which comprised about 20% of the total 19-cause deaths (77,953) among persons aged 35+ and 11% of the total all-cause deaths (144,709) among persons aged 0+. They were responsible for 284,755 years of potential life lost, averaging 18.3 years per death.

Table 3. Total Deaths, Smoking-Attributable Mortality (SAM), and Smoking-Attributable Years of Potential Life Lost (SAYPLL) by Cause of Death and Gender among Adults Aged 35 and Older: Taiwan, 2010

Cause of death	Male			Female		
	Death[a]	SAM	SAYPLL	Death[a]	SAM	SAYPLL
SMOKING-RELATED DEATH	**49,563**	**13,744**	**252,954**	**28,390**	**615**	**12,244**
Cancers						
Lip/oral cavity/pharynx	2,705	1,135	29,214	338	0	0
Esophagus	1,455	715	17,356	106	24	493
Stomach	1,440	310	5,102	808	0	0
Rectum	827	250	4,397	522	0	0
Liver/gallbladder/bile ducts	5,663	920	19,031	2,516	181	3,682
Lung	5,388	2,198	34,801	2,724	129	2,988
Cervix uteri	0	0	0	687	72	2,010
Cardiovascular diseases						
Rheumatic HD	45	0	0	76	11	212
Ischemic HD	4,921	1,467	23,279	2,862	124	1,802
Cardiac arrest and other HD	4,141	816	14,119	3,200	0	0
Cerebrovascular disease	5,910	1,225	19,805	4,142	0	0
Respiratory diseases						
Chronic bronchitis	104	47	518	62	0	0
Asthma	261	0	0	242	24	366
Chronic Airway Obstruction	3,254	1,253	12,928	908	0	0
Digestive system diseases						
Peptic ulcer, GI hemorrhage	361	160	2,350	190	51	689
Liver cirrhosis	3,367	1,065	28,538	1,388	0	0
Other diseases						
Diabetes mellitus	4,043	689	11,477	4,139	0	0
Kidney disease	2,071	677	9,831	2.001	0	0
Accidents	3,604	817	20,207	1,479	0	0
SHS-ASSOCIATED DEATH		**613**	**9,768**		**583**	**9,799**
Lung cancer	5,388	131	2,078	2,724	117	2,584
Ischemic HD	4,921	104	1,652	2,862	86	1,222
Cerebrovascular disease	5,910	353	5,677	4,142	354	5,603
Asthma	261	25	361	242	27	390
TOTAL[b]	**49,563**	**14,357**	**262,722**	**28,390**	**1,198**	**22,043**

Note. HD=heart disease; GI=gastrointestinal; SHS=secondhand smoke.

[a] Number of deaths among people aged ≥ 35 regardless of their smoking and SHS exposure status.

[b] Total deaths from 19 smoking-related diseases which overlap with the four SHS-associated diseases.

Table 4 shows the total direct and indirect costs attributed to smoking and SHS exposure by gender, age, and disease. The total economic costs of smoking and SHS exposure in 2010 amounted to 1,670 million, including US$828 million (50%) in direct costs, US$820 million (49%) in indirect mortality costs, and US$22 (1%) million in indirect morbidity costs. The share of the total costs was greater from active smoking (92%) than SHS exposure (8%), and greater for men (92%) than women (8%). The total economic costs averaged US$72 per Taiwanese aged 0+ and US$718 per smoker aged 35+. Based on Taiwan's total cigarette consumption of 1,894 million packs in 2010, the total economic costs averaged US$0.88 per pack, about 43% the 2010 average retail price of cigarettes (NT$65 or US$2.05).[12]

Of the US$828 million in direct healthcare costs, US$104 million was spent for treating ischemic heart disease, US$94 million for stroke, and US$53 million for lung cancer. Outpatient expenditures amounted to US$520 million (63%) while inpatient expenditures were US$308 million (37%). Among the US$22 million in indirect morbidity costs, US$18.7 million was due to active smoking and US$3.4 million was due to SHS exposure. The US$820 million in mortality costs averaged US$52,688 per death among the 15,555 premature deaths caused by smoking or SHS exposure.

Table 4. Total Economic Costs of Smoking and Secondhand Smoke (SHS) Exposure by Component of Costs, Gender, Age, and Disease for Adults Aged 35 and Older: Taiwan, 2010 (Unit: US$1,000)

	Direct costs			Indirect costs		Total economic costs
	Inpatient	Outpatient	Subtotal	Morbidity cost	Mortality cost	
Smoking	268,941	473,003	741,943	18,669	782,595	1,543,208
SHS exposure	39,179	46,894	86,073	3,407	36,968	126,448
Male	274,288	467,438	741,726	18,932	782,515	1,543,173
Female	33,832	52,458	86,290	3,144	37,049	126,484
35-49	61,319	114,908	176,228	10,797	472,607	659,631
50-64	106,579	204,427	311,006	9,601	269,320	589,927
65+	140,222	200,561	340,783	1,678	77,637	420,098
Lung cancer	21,191	31,552	52,743	1,249	86,729	140,721
Ischemic HD	66,157	38,128	104,285	1,615	62,728	168,628
Cerebrovascular	46,055	48,275	94,330	2,943	71,882	169,155
Other diseases[a]	174,717	401,942	576,659	16,270	598,225	1,191,152
Total	**308,120**	**519,896**	**828,016**	**22,076**	**819,564**	**1,669,656**

Note. HD=heart disease. Exchange rate of the NT$ against US$1 = 31.642 in 2010.

[a] "Other" includes all the rest of smoking or SHS related diseases.

Sensitivity analysis

Table 5 shows that if the prevalence rates of smoking and SHS exposure in 2010 had remained at the same levels as in 2008, the toll of active and passive smoking-attributable losses would have been greater by additional 1,540 deaths and US$107 million in total economic cost. If the prevalence rates of smoking and SHS exposure were at the mean values of the 2009 and 2010 levels, there would have additional 883 deaths and US$59 million loss in total economic cost.

If we assumed the annual growth rate of productivity was 6% instead of 4%, total economic costs would be US$177 million higher. If we used the RR values for those smoking-related diseases reported by the widely cited American study,[24, 25] our estimates of active and passive smoking- attributable premature deaths and total economic costs would increase by 6,958 deaths and US$505 million.

Table 5. Sensitivity Analysis of Smoking and Secondhand Smoke (SHS) Attributable Mortality (SAM), Direct Healthcare Costs, and Total Economic Costs: Taiwan, 2010

	SAM		Direct costs		Total economic costs	
	No.	% of all deaths*	Amount (US$ million)	% of NHE	Amount (US$ million)	% of GDP
MAIN ANALYSIS	15,555	10.75	828	3.38	1,670	0.39
SENSITIVE ANALYSIS						
1. Smoking & SHS exposure prevalence						
Assume the levels in 2008	17,095	11.81	894	3.65	1,777	0.41
Assume the mean levels in 2008 & 2010	16,438	11.36	865	3.53	1,729	0.40
2. Growth rate in productivity						
Assume 6% instead of 4%	15,555	10.75	828	3.38	1,847	0.43
3. Relative risk						
Assume RRs for former smokers = 1	11,140	7.88	629	2.57	1,323	0.31
Assume published RRs in the U.S.[a]	22,513	15.56	1,042	4.25	2,175	0.51

Note. NHE=National personal healthcare expenditure (US$24.5 billion in 2010); GDP=Gross Domestic Product (US$430.1 billion in 2010). Exchange rate of the NT$ against US$ = 31.642 in 2010.

* In 2010, the number of all-cause deaths among people aged ≥ 0 was 144,709.

[a] See Table 12.1 in the 2014 U.S. Surgeon General Report.[25]

DISCUSSION

The direct costs of smoking and SHS exposure in Taiwan amounted to US$828 million and accounted for 3.4% of Taiwan's personal healthcare expenditures in 2010. Smoking and SHS exposure also led to 15,555 premature deaths, 284,755 years of potential life lost, US$820 million in indirect costs of productivity losses due to premature deaths, and US$22 million in indirect costs of time lost from work due to tobacco-related illness. These costs totaled US$1,670 million, representing 0.4% of Taiwan's gross domestic product (GDP) and averaging about US$720 per adult smoker.

The proportion of the total costs of smoking and SHS exposure to GDP in Taiwan is smaller than those estimated for other East Asia countries, such as 0.7% for China,[23] and 0.6%-0.8% for South Korea.[26] One possible explanation is because of relatively lower smoking rates in Taiwan. Another explanation may be the underestimation of our direct cost estimates which were based on the NHI claims database. The NHI database only includes health expenditures paid by the NHI, but not copayments or out-of-pocket payments that were spent on non-NHI covered health services such as orthodontics, long-term care, and nursing home care. In 2010, the NHI expenditures only comprised 57% of Taiwan's personal health expenditures.[27] Furthermore, due to limited data accessibility, we only included the NHI spending on inpatient care and Western medicine outpatient care. Other NHI covered health services such as Chinese medicine outpatient care accounted for 16% of the NHI expenditures in 2010.[27] If copayments, out-of-pocket, and other NHI covered health expenditures are counted, our direct cost estimate could be considerably larger than US$828 million.

Our estimated total costs of smoking and SHS exposure are very likely to be underestimated for several other reasons. First, we only included 19 diseases in the analyses of smoking-attributable costs. Smoking also causes many other diseases such as aortic aneurysm, atherosclerosis, pneumonia, Influenza, hip fractures, rheumatoid arthritis, periodontitis, nuclear cataract, and tuberculosis,[25] Because the RRs of these diseases for Taiwanese smokers were not available in public sources, we did not include them in our analyses. Without considering these diseases, our estimates almost certainly underestimate the true costs of smoking, Second, we did not include children and young adults under age 35 in the analyses of SHS-attributable costs. SHS exposure has been causally linked to adverse health effects on infants and children, including low birth weight, sudden infant death syndrome, middle ear disease, chronic respiratory symptoms, asthma, and attention deficit hyperactivity disorder [25, 28]. Third, we measured SHS exposure based on self-reported exposure in the home and workplace during the last week, but did not consider exposure that may have occurred in other public places or at an earlier time. It has been shown that self-reported SHS exposure greatly underestimates actual exposure assessed by the biomarker such as cotinine level.[29] Therefore, our estimated

SHS-attributable costs are most likely to be underestimated. Fourth, in estimating indirect morbidity costs, we did not count the opportunity costs of relatives or informal caregivers who took care of patients with smoking-related diseases, productivity losses due to smoking-caused disability other than inpatient days, and transportation expenses incurred during inpatient and outpatient visits for the treatment of smoking-related diseases.[23]

A previous study by Yang and Fann et al. [8] also included the same 19 smoking-related diseases and used the same data source for relative risks. They estimated that active smoking caused 233,223 years of potential life lost (YPLLs) and US$467 million (after converting into 2010 constant dollars) in excess healthcare costs for 2001. Our corresponding estimates for 2010 are 265,198 years and US$742 million. Even though adult smoking prevalence declined significantly during 2001−2010,[5] our 2010 estimates are larger than the 2001 estimates. One explanation is that Yang and Fann et al. assumed the disease-specific RRs for former smokers equal to 1, which implies former smokers have the same risk of death or illness as never smokers. This assumption would lead to underestimation of the smoking-attributable deaths and healthcare costs in 2001. Another explanation is that the total number of deaths from the 19 smoking-related diseases increased from 77,953 to 75,003 deaths and Taiwan's personal health expenditures rose by almost 40% in real term between 2001 and 2010.[13, 27]

This study indicates that Taiwan's National Health Insurance spent US$828 million — 6% of their budget — in 2010 to cover the excess healthcare expenditures caused by smoking and SHS exposure. These costs were borne by all Taiwan residents including never smokers who paid for insurance premium. Increasing cigarette taxes will help to offset the external costs of smoking imposed by smokers on others.

Tobacco control programs are costly. In 2009, the government of Taiwan spent US$15.7 million US dollars (or NT$520 million based on the 2009 exchange rate of NT$33.049 against US$1) on tobacco control programs.[30] However, the benefits of tobacco control programs are substantially larger. Several recent studies have shown that the 2009 Act in Taiwan was associated with a reduction in adolescent smoking [31] and SHS exposure,[7] and an increase in adult cessation rates.[32] Assuming a half of the reduction in adult smoking prevalence and SHS exposure during 2008−2010 was driven by the 2009 Act, our sensitivity analysis results show that there was a saving in avoided smoking and SHS attributable financial losses by US$59 million a year in 2010 alone.

This study makes several contributions. First, our results indicated that the SHS-attributable medical costs, indirect morbidity costs, and indirect mortality costs among adults aged ≥ 35 were not negligible — equaling 12%, 18%, and 5% of the levels of the active smoking-attributable direct medical costs, indirect morbidity costs, and indirect mortality costs, respectively. Thus, not including the impact of SHS exposure would underestimate the true burden of smoking. Second, we developed an interpolation approach to measure the disease-specific RRs for former smokers in Taiwan to count smoking-attributable costs for former smokers. Smokers often quit smoking because they have developed smoking-related illness. Although the risks of heart attack and stroke falls quickly within the first five years after quitting,[33] the risks of other tobacco-related diseases takes longer time to reverse after quitting. Therefore, assuming the RRs for former smokers equal to 1 would certainly underestimate the costs of smoking when the prevalence of former smokers, especially recent quitters, is high.

This study is subject to some limitation. We used the relative risk of death as a proxy for the relative risk of healthcare utilization and expenditures to estimate the direct cost of smoking because of data limitation. Also, our measure for disease-specific RR for former smokers was based on the assumption that the ratio between the excess risk for former smokers and the excess risk for current smokers is the same for any disease-specific death and all-cause death. To test the validity of this, we applied this approach to the widely cited American RR data which consist of disease-specific and all-cause RRs for current and former smokers and are available in the internet-based SAMMEC software.[24] We found that our derived RRs for former smokers follow a consistent pattern with the actual RRs for former smokers across diseases, Nevertheless, epidemiological research is needed to more accurately quantify the disease-specific RRs for former smokers in Taiwan. Lastly, we obtained the RRs from previous epidemiological studies which followed up the vital status of two cohorts established prior to 1992 till 2000.[16, 17] Due to the changes in smoking behavior over time, the cohort of smokers today are likely different the cohort 20 years ago; therefore, these RR data may not reflect the true RRs of smokers in 2010. Indeed, the 2014 U.S. Surgeon General's Report has shown that today's cigarette smokers—both men and women—have a much higher risk for lung cancer and chronic obstructive pulmonary disease than smokers in the past.

Despite the limitations that certainly lead to underestimation of our estimated total economic costs of smoking and SHS exposure, we found that smoking still imposes a huge financial burden on Taiwanese society even though smoking prevalence and SHS exposure in Taiwan have declined in recent years. Thus, sustained tobacco control efforts to encourage people to quit smoking, prevent smoking uptake by children and young adults, and protect all people from SHS exposure are needed.

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CHEERS Checklist
Items to include when reporting economic evaluations of health interventions

The **ISPOR CHEERS Task Force Report**, *Consolidated Health Economic Evaluation Reporting Standards (CHEERS)—Explanation and Elaboration: A Report of the ISPOR Health Economic Evaluations Publication Guidelines Good Reporting Practices Task Force*, provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

Section/item	Item No	Recommendation	Reported on page No/ line No
Title and abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	page 1, lines 5-7
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	page 2
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	pp 4-5. P. 6, para2
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	p4, para 1
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	p4, para 2
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	p5, para 2
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	N/A
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	p6, para 2 & p7 para 1
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	p14, line 38
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	p6. line 57 & p7 para 1
Measurement of effectiveness	11a	*Single study-based estimates:* Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	N/A

	11b	*Synthesis-based estimates:* Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	N/A
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	pp. 7-8
Estimating resources and costs	13a	*Single study-based economic evaluation:* Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	pp. 10-15
	13b	*Model-based economic evaluation:* Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	N/A
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	Tables 4-5
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	p7 para 1 & p8
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	p11 para 1-2
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	p11 & p15 para 3 & p. 16, lines 4-10
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	Tables 1-2
Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	N/A
Characterising uncertainty	20a	*Single study-based economic evaluation:* Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact	P22

		of methodological assumptions (such as discount rate, study perspective).	& Table 5
	20b	*Model-based economic evaluation:* Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	N/A
Characterising heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	pp. 24-26 & pp.28-29
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	p30
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	p30

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

The **ISPOR CHEERS Task Force Report** provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* link or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

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