Smoke-free policies on population health outcomes

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K E Y   M E S S A G E S

1. Poisson regression models were constructed to examine the change in trends and seasonal variations in deaths and hospital admissions before and after implementation of smoke-free law in 2007.
2. After implementation of smoke-free law, the predicted impact on hospital admissions and mortality from ischaemic heart disease was in line with findings from around the world.
3. e relatively low impact on ischaemic heart disease admissions in Hong Kong compared with other countries might be due to the fact that Hong Kong allowed exemptions from smoke-free policy until mid 2009.
4. Further analyses of future data are useful to refine the precise benefit to health.

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Introduction

Second-hand smoke (SHS) is a toxic mixture of carcinogens and other chemicals that may lead to cancers, chronic lung disease, heart disease,[1] and stroke.[2] Acute exposure to SHS can have immediate health e ects, particularly in persons already compromised by chronic heart or lung diseases. In particular, risks of cardiovascular events may rise rapidly in response to relatively small exposures to SHS.[3] ese e ects might be identifiable in health care utilisation data.

On 27 October 2006, Hong Kong implemented a smoke-free law in indoor workplaces and public places to provide protection against SHS. On 1 January 2007, statutory no-smoking areas were extended to the indoor areas of all restaurant premises,

TABLE 1. Annual proportional change in hospital admission and mortality

Disease	Annual proportional changes in all ages (%) [95% CI]	
	Pre-intervention (1997-2006)	
	Hospital admission	Mortality
Outcome condition		
Ischaemic heart disease	2.94 (2.75 to 3.13)†	1.49 (1.12 to 1.86)†
Acute myocardial infarctions	1.64 (1.21 to 2.07)†	-1.20 (-1.70 to -0.70)†
Cerebrovascular	0.78 (0.58 to 0.97)†	-0.07 (-0.45 to 0.30)
Cardiovascular	0.84 (0.75 to 0.93)†	1.03 (0.80 to 1.26)†
Respiratory	-3.11 (-3.19 to -3.02)†	0.68 (0.40 to 0.95)†
Lung Cancer	-1.45 (-1.72 to -1.18)†	1.52 (1.14 to 1.90)†
All natural causes	-0.05 (-0.08 to -0.02)†	1.44 (1.32 to 1.57)†
Control condition		
Injury, poisoning and external causes	-4.66 (-4.76 to -4.55)†	-0.94 (-1.48 to -0.40)†
Cancer excluding lung cancer	1.01 (0.92 to 1.11)†	1.20 (0.96 to 1.45)†
Natural causes excluding cardiorespiratory	0.29 (0.26 to 0.32)†	1.94 (1.77 to 2.11)†
Other causes*	0.99 (0.94 to 1.04)†	1.61 (1.41 to 1.82)†

* Refer to ICD-9 (001-009, 140-161, 163-246, 280-294, 320-326, 520-629, 710-719)
† Significant at 5% level

indoor workplaces, public indoor places, and some public outdoor places. However, bars, bathhouses, nightclubs, clubs, massage establishments, and mahjong-tin kau premises were exempted until July 2009. e main aim of this legislation was to reduce exposure of workers to SHS. e likely impact of such legislation on health and health care costs was a concern.

We have calculated the cost of active and passive smoking in Hong Kong.[4] To estimate the immediate impact of smoke-free policies on health and costs, we need to monitor the changes in health-related variables over the early intervention period. e Hospital Authority Clinical Management System provides data on mortality and admissions to hospital. We used such data to examine the immediate impact of a reduction of exposure to SHS in the Hong Kong population following the workplace smoking ban. In examining the e ect of change in health-related variables following a change in population exposure to airborne toxins, we used statistical methods that had been used to identify the impact of reductions in sulfur dioxide as a result of switching to lower sulfur fuel.[5] In that study, because the intervention took place in 1990, only mortality data were available. e current study was able to make use of health care utilisation data as well.

is study was carried out as soon as feasible in order to provide timely information on the impact of the legislation. It aimed to examine the health e ects following the implementation of smoke-free workplaces in Hong Kong by (1) examining trends in deaths and admissions to hospital for conditions associated with passive smoking over the years prior to and immediately following implementation of the smoke-free policy on 1 January 2007, and (2) examining whether there was any discernable change in rates of deaths and admissions for these conditions that coincided with introduction of the policy after accounting for the underlying trends and impacts of other confounders.

Methods

is study was conducted from December 2006 to March 2009. e trends in deaths and admissions between the pre- (1997-2006) and post- (2007-2008) intervention periods were estimated and modelled, and changes between pre and post-intervention periods were calculated. Data on discharges from 31 acute hospitals collected by the Hospital Authority Clinical Management System were obtained for the following conditions: ischaemic heart disease (IHD) [ICD-9-CM 410-414], acute myocardial infarctions (AMI) [410], cerebrovascular disease (430-438), cardiovascular disease (390-459), respiratory disease (460-519), lung cancer (162), and all natural causes (001-799). Injury, poisoning and external causes (800-999, e800-e999), cancer excluding lung cancer (140-161, 163-239), natural causes excluding cardiovascular and respiratory disease (001-389, 520-799), and other causes (001-009,140-161, 163-246, 280-294, 320-326, 520-629, 710-719) were used as control conditions. e year 2003 was excluded in the model for admissions, as the admission trends changed during the outbreak of severe acute respiratory syndrome (SARS) in 2003. Information on deaths obtained from the Hong Kong Census

Annual proportional changes in all ages (%) [95% CI]		Relative change (%) [95% CI]	
Post-intervention (2007-2008)		From pre- to post-intervention	
Hospital admission	Mortality	Hospital admission	Mortality
-6.33 (-11.05 to -1.36)†	-0.63 (-4.61 to 3.50)	-9.00 (-13.59 to -4.17)†	-2.09 (-6.02 to 2.00)
1.81 (-9.46 to 14.49)	-2.76 (-8.64 to 3.50)	0.17 (-10.93 to 12.65)	-1.58 (-7.55 to 4.78)
-0.83 (-6.26 to 4.93)	1.71 (-2.70 to 6.33)	-1.59 (-6.99 to 4.12)	1.78 (-2.65 to 6.42)
-0.39 (-2.86 to 2.15)	1.38 (-1.22 to 4.05)	-1.22 (-3.68 to 1.30)	0.35 (-2.24 to 3.00)
-0.63 (-3.09 to 1.89)	1.27 (-1.73 to 4.36)	2.55 (0.01 to 5.16)†	0.59 (-2.40 to 3.67)
12.67 (4.28 to 21.74)†	-4.22 (-8.35 to 0.09)	14.33 (5.81 to 23.53)†	-5.65 (-9.73 to -1.39)†
2.25 (1.43 to 3.08)†	0.88 (-0.48 to 2.26)	2.30 (1.48 to 3.13)†	-0.55 (-1.90 to 0.81)
0.28 (-2.98 to 3.66)	-1.77 (-8.44 to 5.38)	5.18 (1.76 to 8.72)†	-0.84 (-7.58 to 6.41)
3.28 (0.66 to 5.97)†	1.04 (-1.72 to 3.87)	2.24 (-0.36 to 4.91)	-0.17 (-2.90 to 2.64)
3.17 (2.24 to 4.11)†	0.49 (-1.38 to 2.40)	2.87 (1.95 to 3.81)†	-1.42 (-3.27 to 0.46)
3.28 (1.96 to 4.62)†	1.22 (-1.07 to 3.57)	2.27 (0.96 to 3.59)†	-0.38 (-2.65 to 1.93)

TABLE 2. Seasonal variations in hospital admission and mortality

Disease	Seasonal variations in all ages (%) [95% CI]	
	Baseline (1997-2006)	
	Hospital admission	Mortality
Outcome condition		
Ischaemic heart disease	2.87 (2.21 to 3.52)†	21.12 (19.62 to 22.61)†
Acute myocardial infarctions	13.23 (11.71 to 14.75)†	19.05 (16.97 to 21.12)†
Cerebrovascular	4.21 (3.52 to 4.90)†	17.78 (16.25 to 19.31)†
Cardiovascular	5.49 (5.17 to 5.81)†	20.22 (19.30 to 21.15)†
Respiratory	12.62 (12.33 to 12.91)†	17.61 (16.48 to 18.74)†
Lung cancer	2.96 (2.02 to 3.91)†	2.43 (0.91 to 3.95)†
All natural causes	0.55 (0.45 to 0.65)†	11.65 (11.16 to 12.13)†
Control condition		
Injury, poisoning and external causes	3.26 (2.90 to 3.62)†	16.26 (14.03 to 18.48)†
Cancer excluding lung cancer	2.75 (2.42 to 3.08)†	1.06 (0.09 to 2.02)†
Natural causes excluding cardiorespiratory	2.21 (2.10 to 2.32)†	5.46 (4.80 to 6.13)†
Other causes*	1.04 (0.88 to 1.20)†	4.88 (4.06 to 5.70)†

* Refer to ICD-9 (001-009, 140-161, 163-246, 280-294, 320-326, 520-629, 710-719)
† Significant at 5% level

TABLE 3. Summary of relative changes from pre- to post-intervention in all ages in hospital admission and mortality

Disease	Relative changes in all ages (%) [95% CI]	
	Main model	
	Hospital admission	Mortality
Outcome conditions		
Ischaemic heart disease	-9.00 (-13.59 to -4.17)†	-2.09 (-6.02 to 2.00)
Acute myocardial infarctions	0.17 (-10.93 to 12.65)	-1.58 (-7.55 to 4.78)
Cerebrovascular	-1.59 (-6.99 to 4.12)	1.78 (-2.65 to 6.42)
Cardiovascular	-1.22 (-3.68 to 1.30)	0.35 (-2.24 to 3.00)
Respiratory	2.55 (0.01 to 5.16)†	0.59 (-2.40 to 3.67)
Lung Cancer	14.33 (5.81 to 23.53)†	-5.65 (-9.73 to -1.39)†
All natural causes	2.30 (1.48 to 3.13)†	-0.55 (-1.90 to 0.81)
Control conditions		
Injury, poisoning and external causes	5.18 (1.76 to 8.72)†	-0.84 (-7.58 to 6.41)
Cancer excluding lung cancer	2.24 (-0.36 to 4.91)	-0.17 (-2.90 to 2.64)
Natural causes excluding cardiovascular and respiratory	2.87 (1.95 to 3.81)†	-1.42 (-3.27 to 0.46)
Other causes*	2.27 (0.96 to 3.59)†	-0.38 (-2.65 to 1.93)

* Refer to ICD-9 (001-009, 140-161, 163-246, 280-294, 320-326, 520-629, 710-719)
† Significant at 5% level

Seasonal variations in all ages (%) [95% CI]			
Year 1 (2007)		Year 2 (2008)	
Hospital admission	Mortality	Hospital admission	Mortality
4.99 (3.15 to 6.83)†	9.45 (5.12 to 13.79)†	4.68 (2.88 to 6.47)†	20.86 (16.51 to 25.22)†
9.10 (4.75 to 13.45)†	8.94 (2.35 to 15.53)†	24.40 (20.10 to 28.70)†	21.61 (14.92 to 28.30)†
6.41 (4.41 to 8.41)†	13.18 (8.42 to 17.94)†	6.20 (4.23 to 8.16)†	15.19 (10.51 to 19.88)†
8.64 (7.72 to 9.56)†	12.80 (10.02 to 15.57)†	9.39 (8.51 to 10.26)†	15.59 (12.84 to 18.34)†
10.08 (9.19 to 10.97)†	13.62 (10.37 to 16.86)†	12.94 (12.07 to 13.81)†	20.01 (16.86 to 23.17)†
6.18 (3.48 to 8.88)†	3.17 (-1.45 to 7.79)	6.37 (3.84 to 8.91)†	1.97 (-2.76 to 6.69)
0.32 (0.04 to 0.61)†	8.65 (7.19 to 10.10)†	1.15 (0.88 to 1.43)†	10.70 (9.27 to 12.13)†
2.46 (1.31 to 3.62)†	11.19 (3.69 to 18.70)†	0.80 (-0.34 to 1.93)	11.38 (3.99 to 18.76)†
2.22 (1.32 to 3.12)†	1.77 (-1.18 to 4.72)	2.04 (1.17 to 2.91)†	2.75 (-0.17 to 5.66)
1.95 (1.64 to 2.27)†	4.90 (2.89 to 6.90)†	1.29 (0.99 to 1.60)†	4.84 (2.85 to 6.82)†
0.62 (0.17 to 1.08)†	4.80 (2.35 to 7.25)†	1.78 (1.34 to 2.21)†	4.91 (2.50 to 7.32)†

Relative changes in all ages (%) [95% CI]				
SARS	Air pollutants		Hospital beds and smoking prevalence	
Hospital admission	Hospital admission	Mortality	Hospital admission	Mortality
-5.56 (-10.39 to -0.46)†	-7.39 (-12.48 to -2.01)†	-2.13 (-6.35 to 2.27)	-9.65 (-14.22 to -4.84)†	-2.17 (-6.10 to 1.92)
7.22 (-4.84 to 20.82)	0.22 (-11.96 to 14.08)	-0.84 (-7.29 to 6.05)	-3.92 (-14.60 to 8.09)	-1.71 (-7.67 to 4.65)
-0.75 (-6.28 to 5.10)	-2.43 (-8.29 to 3.81)	2.16 (-2.62 to 7.17)	-2.41 (-7.78 to 3.27)	1.77 (-2.66 to 6.41)
0.64 (-1.90 to 3.25)	0.27 (-2.46 to 3.09)	0.72 (-2.07 to 3.58)	-1.78 (-4.23 to 0.73)	0.29 (-2.29 to 2.93)
2.39 (-0.19 to 5.03)	3.08 (0.27 to 5.96)†	0.45 (-2.76 to 3.77)	2.78 (0.22 to 5.40)†	0.29 (-2.70 to 3.36)
14.05 (5.42 to 23.38)†	17.52 (7.96 to 27.94)†	-4.98 (-9.39 to -0.35)†	14.68 (6.11 to 23.94)†	-5.63 (-9.71 to -1.37)†
3.18 (2.34 to 4.03)†	3.85 (2.94 to 4.77)†	-0.57 (-2.02 to 0.90)	1.78 (0.96 to 2.61)†	-0.61 (-1.96 to 0.75)
3.65 (0.23 to 7.19)†	7.45 (3.63 to 11.42)†	2.07 (-5.38 to 10.11)	5.29 (1.85 to 8.84)†	-0.97 (-7.71 to 6.26)
1.53 (-1.09 to 4.22)	5.53 (2.60 to 8.54)†	-0.44 (-3.37 to 2.58)	2.89 (0.27 to 5.59)†	-0.15 (-2.88 to 2.66)
3.79 (2.83 to 4.74)†	4.55 (3.52 to 5.59)†	-1.69 (-3.67 to 0.33)	2.24 (1.31 to 3.17)†	-1.41 (-3.25 to 0.47)
4.00 (2.64 to 5.37)†	3.42 (1.97 to 4.88)†	-0.67 (-3.10 to 1.82)	1.80 (0.49 to 3.13)†	-0.38 (-2.64 to 1.94)

and Statistics Department for the pre- and post-intervention periods were used to examine mortality for the conditions described above (ICD-10 codes were used in recent years and matched with equivalent ICD-9 codes).

Poisson regression models were used to examine trends in admissions and deaths from 1997 to 2008. Weekly admission and death counts were used as the dependent variables, adjusted with background variables of temperature, humidity, and cycle of seasonality as independent variables to capture the main seasonal variation each year. The regression model was initially fitted for periods of 10 years pre-intervention and 2 years post-intervention separately to estimate the average annual proportional change in admissions and deaths in the pre- and post-intervention periods.

For the relative change in trend between the pre and post-intervention periods, we created a dummy variable (which defined the pre-intervention period as 0 and the post period as 1) and added it as an independent variable in the Poisson models. The coefficient for the variable represented the relative change and the effect of the intervention could be shown in terms of average annual reductions in mortality and admissions.

A measure of proportional change (amplitude) in admissions and deaths was used to examine the seasonal variations to the overall mean in the pre- and post-intervention periods. We fitted a Poisson regression model with deaths or discharges against a pair of trigonometric functions (α sine, β cosine). The estimated coefficients were used to calculate the amplitude of the seasonal curve in terms of sine and cosine in which $\lambda = \sqrt{\alpha^2 + \beta^2}$, with 95% confidence intervals (CI). This amplitude (λ) represented the proportional changes in admissions and deaths in either warm or cool seasons from the relative mean. By comparing the parameters for the 10-year baseline period to the years after the intervention, we were able to evaluate the change in seasonal cycles for each condition that might be associated with the intervention.

We validated our models by examining changes in admission or deaths from conditions, which were less likely to be affected by the smoking ban, such as injury and poisoning, and compared these with the changes in the outcome conditions. For sensitivity analyses, we also adjusted admission trends in pre- and post-SARS periods and tested the background variables including air pollutant concentrations, number of hospital beds, and smoking prevalence in order to identify whether their impact on hospital admissions and deaths might change our conclusions.

Results

After the introduction of the smoke-free law, the annual proportional change in hospital admissions for IHD in all ages dropped by 9% (Table 1). The seasonal peak in hospital admissions for respiratory disease in all ages was reduced from 12.6% to 10.1% in the first year after intervention; however, there was a rebound to 12.9% in the second year (Table 2). For mortality in all ages, only those died from lung cancer immediate dropped by 5.7% after the intervention (Table 1). However, the seasonal peak for deaths from IHD declined from 21.1% to 9.5% and for all natural causes from 11.7% to 8.7% (Table 2). The seasonal peak for deaths from AMI also reduced in the first year but the change was not significant. In the second year, an increase in the seasonal peak for IHD and AMI deaths to the pre-intervention level was observed (Table 2).

Results from the sensitivity analysis[6] are consistent with the main model (Table 3). An alternative model of the post-SARS period for admission was also tested. The changes in admission from pre- to post-intervention were consistent with the main model but the proportional changes in IHD and two of the control conditions became insignificant. This alternative model may add uncertainty to the results and therefore was not considered for use as the final model.

Discussion

Many studies have reported a decrease in cardiovascular disease after the implementation of smoke-free laws. In the present study, the annual proportional changes in mortality were significant in two conditions: lung cancer (which decreased among all ages) and all natural causes (which increased in the age-group of 40 to 64 years). The reduction in lung cancer deaths is difficult to attribute to the intervention due to the long latency in development of lung cancer, except by the development of earlier detection and better treatments. Also the increase in death rates among the age-group of 40 to 64 years is likely to be due to an increase in numbers of this age-group with an ageing population. We examined the data in another way by investigating the seasonal variations in numbers of deaths and found a significant decrease in the peak for IHD, AMI, cardiovascular, and cerebrovascular disease deaths for the 65+ age-group. However, all of these causes of death returned to previous levels the following year, except for cerebrovascular disease (which increased but not significantly). This kind of rebound after a reduction in peak mortality levels has been seen after other interventions, and has been explained as a delay in some deaths that were expected but occurred in the following high mortality season.

Our results showed an impact on hospital admissions for IHD that the rate was significantly lower after the intervention for all ages and the 65+ age-group. In all age-groups, where we expected an increase in admissions (as found for all causes), we actually had a decrease in admissions for IHD. For the seasonal variation in the number of admissions, there was a significant drop in admission due to respiratory diseases for all ages and the 65+ age-group. The drop might be related to a reduction in SHS exposure but it is difficult to confirm given the other patterns of admissions.

There were limitations in this study mainly related to data availability and complexity. In particular we only had 2 years of data after the intervention and there were a variety of seasonal trends and many factors affecting the data patterns. Therefore further data in later years are useful to confirm the trends identified here.

The disruption of the provision of hospital services due to SARS in 2003 should be taken into account in any analysis. It may have taken some time for admission trends to recover after 2003 and they may not mirror those before 2003. We have tried to adjust for this in our model and sensitivity analysis.

Finally, Hong Kong allowed exemptions to the smoke-free law and thus some of the population continued to be exposed to SHS till mid-2009. Further data in future years are useful to confirm whether the eventual imposition of smoke-free policies in all workplaces contributes to any further benefit in decreasing rates of IHD.

Conclusion

After the implementation of smoke-free policies in most workplaces in Hong Kong, the predicted impact on admissions to hospital and mortality from IHD was in line with findings from around the world. The drop of 9% in admissions for IHD in Hong Kong was on the low side compared with other countries. However, Hong Kong allowed exemptions from the smoke-free policy until mid-2009. Further analyses of future years' data may help to refine the precise benefit to health following amendments to the ordinance.

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