DATA REPORT

Ten year follow-up of the impact of Scottish smoke-free legislation on acute myocardial infarction

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Introduction

Worldwide, 181 countries have ratified the WHO's Framework Convention on Tobacco Control and become Parties to the convention,[1] and 1.5 billion people in 55 countries are now protected by comprehensive smoke-free legislation.[2] Smoke-free legislation has been associated with many health benefits but the most extensively researched has been myocardial infarction. Thirty one studies, covering legislation in 47 jurisdictions, produced a pooled relative risk reduction of 12%.[3] Many employed simple before and after comparisons, and most had follow-up to only 1-2 years following legislation.

In Scotland, the Smoking, Health and Social Care Act prohibited smoking in all enclosed public and work places from March 2006. There was a 17% reduction in myocardial infarctions in the year following implementation; compared with a 4% decline in England where legislation had not been introduced.[4] The primary aim was to protect non-smokers from the harmful effects of secondhand smoke. However, the legislation was associated with a short-term increase in quit attempts and temporary reduction in smoking prevalence.[5] Hence, in the year following legislation, myocardial infarctions fell among current as well as non-smokers,[4] and it is not known whether the overall reduction in myocardial infarctions has been maintained long-term. This study uses interrupted time series analysis to investigate whether myocardial infarction incidence over the ten years following Scottish legislation differed from the underlying trend prior to legislation.

Methods

Because of the sensitive nature of the data and our access agreement with the data provider, requests to access the dataset, from researchers training in information governance, should be sent directly to eDRIS at NSS.Edris@nhs.net. Use of anonymised extracts of Scottish routine data for health research is covered by generic NHS ethics approval (East of Scotland Research Ethics Committee; reference 16/ES/0112) We used two Scotland-wide databases to ascertain incident myocardial infarctions in Scotland between 2000 and 2016 inclusive. The Scottish Morbidity Record 01 (SMR01) collects data on all admissions to Scottish hospitals including date and diagnosis. Death certificates record date and cause of death. Both systems use the International Classification of Diseases (ICD). We defined myocardial infarction as ICD9 410 or ICD10 I21. In order to include only incident cases, we linked admissions and deaths to previous SMR01 records between 1990 and 2016 and excluded any that were preceded by an admission for myocardial infarction in the previous ten years.

We derived age-, sex-stratified counts of myocardial infarction by month over the study period. Estimates of mid-year population were obtained from the National Records of Scotland website (https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-estimates/mid-year-population-estimates) and linear interpolation and extrapolation applied to provide monthly population counts stratified by age and sex. The myocardial infarction and population counts were combined to derive monthly incidence of myocardial infarction per 100,000 population for those <60 and ≥60 years of age. All monthly rates were standardised to a common month length using: (myocardial infarction count x 100,000 x 365.25) / (population x 12 x days in month).

We used an interrupted time series design and tested three models: step change only; slope change only; and step change followed by slope change. The best model was chosen based on minimising the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) statistics. All models were estimated using the natural log of incidence and coefficients converted to percentages using: $100*(\exp(\beta)-1)$.

Introduction of high sensitivity troponin assays during the post legislation period lowered the diagnostic threshold for myocardial infarction; producing an artefactual increase in incidence. To take account of this, we included a second step and slope change in the model. The new assay was introduced into clinical practice in Scotland across 2010, with the exact data varying by hospital.[6] To identify the most appropriate date, we subjected the monthly data to a series of structural break tests using the R and EViews statistical and econometric software packages. To account for autocorrelation and heteroskedasticity we used heteroskedasticity and autocorrelation consistent (HAC) Newey West standard errors, with a quadratic spectral kernel and automatic bandwidth selection, using the user-created "ivreg2" routine in Stata. This approach automatically adjusts the variance-covariance matrix for seasonality and autocorrelation and results in a more parsimonious model than would be obtained if the seasonality and autocorrelation were explicitly modelled using a SARMA (seasonal autoregressive moving average) errors model or sine-cosine and monthly dummy variables. Initial data cleaning was done using R and the main analyses using Stata v15.1.

Results

Over the 17-year study period (2000-2016), there were 117,161 incident myocardial infarctions: 84,217 hospitalisations and 32,944 pre-hospital deaths in Scotland (population 5.2 million). Of the myocardial infarctions, 27,882 occurred in those <60 years and 89,279 in those ≥60 years. Men accounted for 71,144 (60.7%) overall: 21,176 (75.9%) of those <60 years of age and 49,968 (56.0%) of those ≥60 years. Among those ≥60 years, the step change model was the best fit (Table 1). The implementation of legislation was followed by a 13.41% (95% CI 6.53%, 19.78%) step reduction in myocardial infarction incidence overall; slightly lower in men (95% CI -13.17%, 95% CI -19.11%, -6.78%) than women (-13.95%, 95% CI -20.94%, -6.33%) but statistically significant in both (Figure 1). Among those aged <60 years, the best fit was a step and slope change model. It only reached statistical significance among women who had an 18.28% (95% CI 9.57%, 26.15%) step reduction at the time of legislation, but a subsequent increase in slope of 0.70% (0.44%, 0.97%) relative to the underlying trend.

Discussion

Myocardial infarction incidence was declining in Scotland prior to 2006, but there was an additional step reduction at the time that smoke-free legislation was implemented in both women and older men. The benefit has persisted to ten years follow-up among people aged ≥60 years, but not among younger people.

The most recent meta-analysis identified 31 studies; 21 from the Americas; 9 from Europe and 1 from New Zealand.[3] Together, they covered legislation introduced between 1991 and 2010 in 47 jurisdictions and produced a pooled reduction of 12%. The majority made simple before and after comparisons using up to 1-2 years follow-up. The longest follow-up study applied time-series analysis to hospitalisations for myocardial infarction from eight years before to five years after introduction of comprehensive smoke-free legislation in Prince Edward Island, Canada (population 143,000), and reported a 5.92% step reduction followed by a non-significant 0.07% reduction in slope.[7] Inclusion was not restricted to incident hospitalisations and pre-hospital deaths were not included.

A strength of our study was the inclusion of all events nationwide; thereby avoiding selection bias. A general population of 5.2 million and study population of 117,161 myocardial infarctions, increased our power to undertake sub-group analyses. Including both hospital admissions and pre-hospital deaths avoided any bias due to temporal changes in clinical practice, severity or prognosis. We previously showed secondhand smoke exposure impacts on myocardial infarction survival[8] as well as incidence. By excluding people who had a myocardial infarction in the previous ten years, we could be sure that any change was due to legislation impacting on incidence not prognosis. We used routine data but they are subjected to regular quality assurance checks. Smoking status is not recorded. Therefore, we were unable to distinguish between reductions in non-smokers, current smokers or both.

As with any natural experiment, extraneous changes and interventions can occur over the study period. The introduction of high-sensitivity troponin assays lowered the diagnostic threshold. We were able to include this in the model and showed it did not account for all the increase in incidence from 2006 in younger people. Lack of data on changes in weather and pollution were a limitation and should be included in future studies. However, the most plausible explanation for the recent rise in myocardial infarction among younger people is increasing incidence of adiposity and, subsequently, type 2 diabetes. Data from the Scottish National Diabetes Register have shown that, between 2004 and 2013, the incidence of type 2 diabetes remained stable overall but: declined in older men and women; remained stable in young women; and increased in young men.[9] This pattern may explain our finding that legislation has not impacted significantly on younger men and its initial impact in younger women has not persisted. This finding suggests that adiposity and type 2 diabetes may now have superseded smoking as the major driver of the trend in myocardial infarction among younger patients. However, this does not justify complacency in ongoing effects at tobacco control.

Sources of funding

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Disclosures

None

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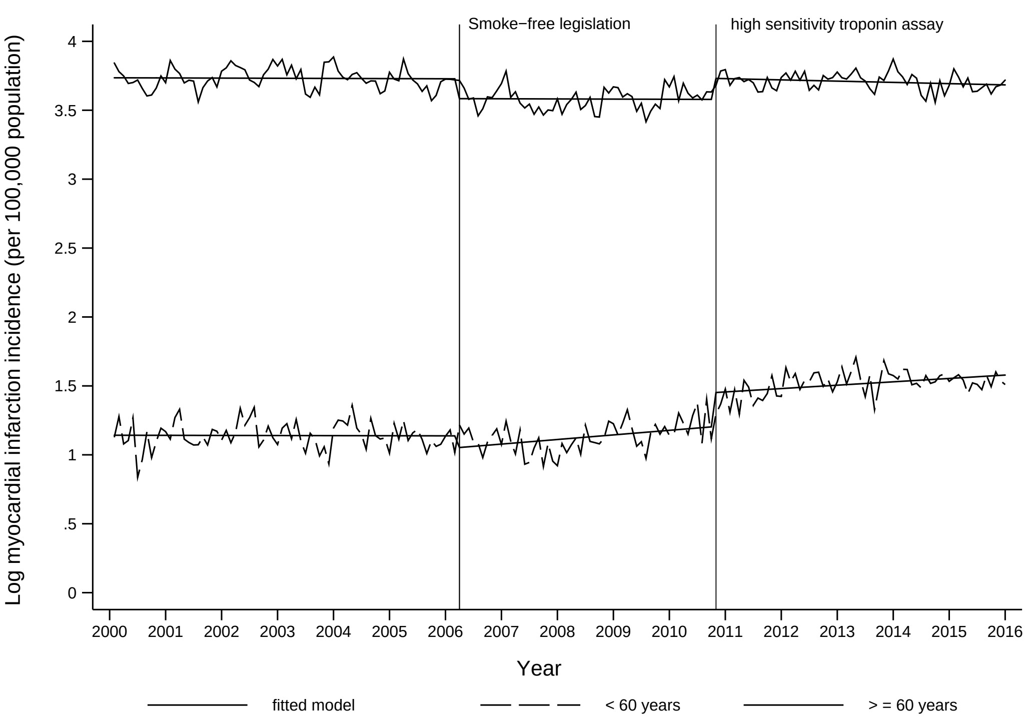
Table 1 Interrupted time series models of the effects of Scottish smoke-free legislation on the incidence of myocardial infarction

	Slope change only					Step change only			Step and slope changes				
	Pre legislation slope		Post legislation slope		AIC BIC	Step		AIC BIC	Step		Post legislation slope		AIC BIC
	% (95% CI)	P value	% (95% CI)	P value		% (95% CI)	P value		% (95% CI)	P value	% (95% CI)	P value	
>=60 yrs													
All	-0.16 (-0.31, -0.10)	0.037	-0.04 (-0.33, 0.26)	0.802	-418.8 -402.6	-13.41 (-19,78, -6.53)	<0.001	-448.5 -432.2	-13.99 (-19.22, -8.42)	<0.001	0.07 (-0.09, 0.24)	0.390	-447.5 -428.0
Men	-0.19 (-0.34, -0.03)	0.017	-0.009 (-0.31, 0.30)	0.955	-389.1 372.8	-13.17 (-19.11, -6.78)	<0.001	-408.5 -392.3	-13.98 (-19.90, -7.62)	<0.001	0.10 (0.001, 0.20)	0.047	-408.1 -388.6
Women	-0.14 (-0.29, 0.01)	0.607	-0.08 (-0.39, 0.23)	0.339	-325.1 -308.8	-13.95 (-20.94, -6.33)	0.001	-343.9 -327.6	-14.20 (-22.02, -5.60)	0.002	0.03 (-0.16, 0.22)	0.740	-342.0 -322.5
<60 yrs													
All	-0.08 (-0.20, 0.04)	0.194	0.22 (-0.015, 0.45)	0.066	-351.1 -334.8	-5.94 (-15.00, 4.08)	0.236	-349.0 -332.7	-8.37 (-17.25, 1.47)	0.093	0.28 (0.11, 0.46)	0.001	-355.9 -336.4
Men	-0.04 (-0.13, 0.06)	0.433	0.11 (-0.07, 0.28)	0.248	-324.4 -308.2	-4.17 (-11.19, 3.41)	0.272	-324.8 -308.5	-5.46 (-12.55, 2.20)	0.158	0.15 (-0.06, 0.35)	0.166	-324.9 -305.3
Women	-0.21 (-0.44, 0.02)	0.075	0.55 (0.09, 1.02)	0.019	-89.7 -73.4	-12.83 (-29.01, 7.05)	0.190	-85.1 -68.8	-18.28 (-26.15, -9.57)	<0.001	0.70 (0.44, 0.97)	<0.001	-97.1 -77.5

AIC Akaike Information Criterion; BIC Bayesian Information Criterion; CI confidence interval

Figure 1. Monthly Incidence of myocardial infarction over time by age


Smoke−free legislation
high sensitivity troponin assay
Log myocardial infarction incidence (per 100,000 population)
4
3.5
3
2.5
2
1.5
1
.5
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
fitted model
< 60 years
> = 60 years