Reduction in Myocardial Infarction Admissions in Liverpool after the Smoking Ban: Potential Socio-Economic Implications for Policymaking

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ARTICLE SUMMARY

Article Focus

- Smoke-free legislation appears to show a clear link with improved cardiovascular health over time, however there are very few studies looking at longer term trends or at the politically sensitive topic of its effects on socioeconomic inequalities.
- Liverpool has among the highest rates of smoking and heart disease nationally, as well as high levels of social and economic inequalities, thus representing a key area in which to investigate the effects of the smoking ban on both health and health inequalities.
- Trends and trend changes were analysed in the data for all MI and CHD admissions in Liverpool 2004-2012, including by sex and socio-economic status, and directly standardised to the European Standard Population.

Key Messages:

- Smoke-free legislation can result in a rapid improvement in cardiovascular health at the population level, with a short lag time.
- This improvement appears to be sustained even many years after the implementation of smoke-free legislation.
- There is clear potential for reductions in both absolute and relative socioeconomic health inequalities following implementation of smoke-free legislation.

Strengths and Limitations:

Strengths

- An inclusive, accurate data set through strict and specific data collection criteria was used (from mandatorily collected Hospital Episodes Statistics data for Liverpool), ensuring identification of almost all relevant data cases minimising selection bias.
- A relatively long period of time before and after the smoking ban (2004-2012) compared to other studies, allowing a longer trend analysis.
- Using a trend analysis method allowed the relating of periods of trend change to the smoking ban 'index event' in a more unbiased and objective way as compared to qualitative or visual trend interpretation.

Limitations

- Data quality issues meant that older HES data before 2004 was not suitable to be included in this or other research studies on HES data of this type.
- The time-series study design only measures associations and considers changes in trends over time, however it does not by design identify causal relationships.
- Small population groups after stratifying by socioeconomic status led to wide confidence intervals. A follow-up study examining the Merseyside aims to rectify this by including a larger population while still sharing similar health characteristics such as deprivation and smoking rates.

ABSTRACT

Objectives – To analyse trends and trend changes in MI and CHD admissions, to investigate the effects of the 2007 smoke free legislation on these trends, and to consider the policy implications of any findings.

Design –Interrupted time-series analysis using Joinpoint regression to assess changes in age-specific trends on 56,995 CHD admissions from 2004-12 (by sex and socio-economic status).

Setting – Liverpool (city).

Participants –HES data on all 56,995 admissions for CHD in Liverpool between 2004 and 2012 (ICD-10 codes I20 to I25 coded as an admission diagnosis within the defined dates).

Primary and Secondary Outcome Measures – Trend gradient and change points (by trend regression analysis) in age-standardised MI admissions in Liverpool between 2004-2012; by sex and by socio-economic status. Secondary analysis on CHD admissions.

Results – A significant and sustained reduction was seen in MI admissions in Liverpool beginning within one year of the smoking ban. Comparing 2005/2006 and 2010/2011, the age-adjusted rates for MI admissions fell by 42% *(39%-45%)* (41.6% in men and by 42.6% in women). These reductions appeared consistent across all socioeconomic groups. Interestingly, admission rates for total CHD (including mild to severe angina) increased by 10% *(8%–12%)*.

Conclusions – A dramatic reduction in myocardial infarction admissions in Liverpool has been observed coinciding with the smoking ban in 2007. Furthermore, benefits were apparent across the socioeconomic spectrum. Health inequalities were not widened and may even have reduced. The rapid effects observed with this top-down, environmental policy may further increase its value to policymakers. [247 Words]

Introduction

Smoking is the leading cause of preventable death in the UK[1], particularly for cardiovascular disease[2]; the UK prevalence of smoking was around 22% UK in 2007 representing some 13.7 million smokers[3]. Furthermore, strong socioeconomic inequalities were apparent with the smoking rates being around 14% in the most affluent groups and 34% in the most deprived[4].

A body of evidence now exists demonstrating that smoke-free legislation achieving comprehensive bans is highly effective in reducing exposure to second hand smoke[5].

It is important to generate evidence for public health interventions where possible, especially as in many cases other traditional ways of gathering evidence such as randomized controlled trials are often not feasible[6]. Lawrence et al in 2011 describe a "global research neglect" of population health interventions in the field of tobacco control, and a tendency for smoking cessation research to favour individual- over population-based approaches[6].

Liverpool ranks among the worst cities in the UK in terms of heart disease; socio-economic status; smoking prevalence[7 8], and healthcare costs associated with smoking[7]. Population level interventions, such as smoking bans in public places, might reduce health inequalities. There is thus great potential for a study to evaluate the smoking ban in this city, both in terms of health outcomes and, crucially, in differential effects by socioeconomic status.

Methods

Mortality and Morbidity statistics

All admissions for patients aged 16 and over in Liverpool from January 2004 to April 2012 with an International Classification of Diseases diagnosis code from I20 to I22 for coronary heart disease were extracted from the HES database by Liverpool PCT Health Intelligence staff. This data was presented anonymised and secured on NHS hardware and networks only. Age-adjustment was performed using the direct method to the European standard population.

Socio-economic status data

The 30 wards of Liverpool were manually categorised into 3 groups of 10 wards each – i.e. the 10 most deprived, the 10 least deprived and the ten in the middle. To retain greater statistical power, smaller divisions such as individual wards were not used. Individual socio-economic status for the wards was estimated by geographical area using average socioeconomic rankings for the Lower Super Output Areas of Liverpool, as calculated by Liverpool City Council[9]. We then obtained data on CHD admissions by age, sex and socioeconomic status for the period 2004-2012.

Trend Analysis

Plots of the age-specific mortality rates were smoothed using 3 year moving averages. A Joinpoint regression was fitted to provide estimated annual percentage change and to detect points in time where significant changes in the trends occur (JOINPOINT software version 3.0)[10]. We used a Bayesian Information Criterion (BIC) approach to select the most parsimonious model that fits best the data. A maximum number of five joinpoints was allowed for estimations. For each annual percentage change estimate, we also calculated the corresponding 95% confidence interval (95% CI). We performed several Joinpoint regression analyses: one for sex specific age-adjusted CHD admission rates, one for sex specific age-adjusted MI admission rates, and one for deprivation specific age-adjusted myocardial infarction admission rates.

Rate ratios were also calculated for average rates for the first 2 calendar years of the study (before the smoking ban 2005 – 2006) with the last 2 years of the study (after the smoking ban 2010 – 2011).

Ethical Approval

The study was ethically approved through the national NHS ethical approval scheme, and through this approval was confirmed by the East Dulwich NHS R&D Ethics board.

Results

Sex specific age-adjusted CHD admission trends

Comparing ‘05-‘06 and ‘10-‘11, the age-adjusted CHD admission rates increased overall by **8%** in men and by **12%** in women (Table 1). The Joinpoint analysis identified several changes in the trend during the study period, although none were within 2 quarters of the smoking ban (i.e. appearing to correspond with the time around the smoking ban).

Sex specific age-adjusted myocardial infarction admission trends

Comparing ‘05-‘06 and ‘10-‘11, the age-adjusted rates specifically for Myocardial Infarction admissions decreased overall by 41.6% in men and by 42.6% in women (Table 2). The Joinpoint analysis identified a change in trend corresponding to Q4 2007. In men, this represented a change from Annual Percentage Change (APC) of **0.9%** (0.1 to 1.6) to APC **-**

9.8% (-15.5 to -3.7). For women, this was a change from APC 0.2% (-1.2 to 1.7) to APC **-4.2%** (-5.0 to -3.4). (Figure 1)

The rate-ratio comparing the first 2 years of the study (just before the smoking ban) and the final 2 years of the study was 0.58 *(0.54 – 0.61).*

Socioeconomic differentials in MI admission trends

Gender-specific figures were not analysed, as the denominators became too low to be robust.

For the 10 most deprived wards, MI admissions reduced by 45% (58.0 to 28.4) between '05-'06 and '10-'11. Joinpoint identified a trend change at 2007 Q4, representing a trend change from APC **2.8%** (1.0 to 4.6) to APC **-11.5%** (-17.0 to -5.6). (Figure 2)

For the 10 middle-ranked wards, MI admissions reduced by 42.3% (56.4 to 23.6) between '05-'06 and '10-'11. Joinpoint identified a trend change at 2007 Q4, representing a trend change from APC 0.9% (-1.9 to 0.2) to APC **-3.7%** (-4.3 to -3.1). (Figure 2)

For the 10 most affluent wards, MI admissions reduced by 38.6% (57.5 to 11.2) between '05-'06 and '10-'11. Joinpoint identified a trend change at 2008 Q1, representing a trend change from APC 0.7% (-0.6 to 2.1) to APC **-6.1%** (-8.7 to -3.5). (Figure 2)

The average **absolute risk difference** between the most and least deprived wards over the first 2 years of the data set was 69.8 MI admissions per 100,000 person-years. In contrast, the rate for the final 2 years was 32 MI admissions per 100,000 person-years (A rate ratio of 0.46, *95% CI of 0.044 to 4.76*).

The average **rate ratio** between the most and least deprived wards over the first 2 years of the data set was 1.38. In contrast, the relative difference for the final 2 years was 1.26 (A ratio of 0.91, *95% CI of 0.43 to 1.91*).

Discussion

Main findings

Myocardial infarction admissions in Liverpool showed a dramatic and statistically significant decline coinciding with the introduction of the smoking ban in July 2007, with a lag period of approximately 3-6 months. This decline was substantially greater than the underlying secular trend. In spite of a slight deceleration of the rate of decline in 2009, the decreasing rates have clearly continued until the end of 2012. This very substantial decrease in the rate was statistically significant.

In contrast, total coronary heart disease (CHD) admissions apparently increased by approximately 10% during the same period. There are several possible reasons for this discrepancy, including the greater difficulty in diagnosis or exclusion of angina chest pain, resulting in a higher number of false positives, false negatives or miscoding (e.g. mild or atypical chest pain). Myocardial infarctions, however, are more clearly diagnosed and include clearly defined clinical and diagnostic criteria (e.g. biochemical markers and specific ECG changes).

The short lag time was notable. As in similar studies elsewhere the introduction of smoke-free legislation rapidly resulted in reduced admissions for acute MIs[11]. In spite of a slight deceleration of the rate of decline in 2009, our data nonetheless also suggest that a smoking ban may have a sustained and long term effect, consistent with previous systematic reviews[12]. Sims et al in 2010 found that smoke-free legislation in England reduced emergency admissions from myocardial infarction by 2.4% over a 15 month follow up period[13]. Further research will be necessary to ascertain whether the greater effect was seen in the findings of our study compared to other national studies is because of unique characteristics of the Liverpool demographic (higher baseline rates of heart disease/smoking; higher rates of deprivation) or some other environmental or statistical phenomenon. Interestingly, one study[14], found a declining trend in MI in England beginning well before 2007 (their study going back to 2002) and appears to show a steady linear decrease in MI admissions from 2002 to 2010, with no changes in the speed of decline around the time of the implementation of the smoking ban. Their study aggregated data for England using Hospital Episode Statistics “incident” cases of MI (i.e. new cases) – all MI events within a 30-day window are only considered once; whereas in our study all events are considered including multiple heart attacks in single individuals. A possible explanation could be that the smoking ban has a greater specific effect in reducing repeat or relapse MIs but not greatly reducing the number of ‘first’ MIs.

Few studies have examined the effect of socioeconomic status on health gains following smoking bans[15]. Our findings appear to suggest a reduction in all socioeconomic groups, and crude figures suggest a possible reduction in both absolute inequalities (differences) and relative inequalities (ratios), albeit not statistically significant. The trend across socioeconomic groups appears to suggest a possible greater favourable effect in more deprived demographics, and this might also explain the greater effect of the smoking ban in Liverpool compared to other populations.

Strengths and limitations

The main strength of this study was an inclusive, accurate data set through strict and specific data collection criteria over a period of 8 years. In addition using mandatorily collected HES data, all relevant data cases are likely to have been identified, minimising a potential source of selection bias.

Finally, using a trend analysis method such as Joinpoint regression allowed the relating of periods of trend change to the smoking ban 'index event' in a more unbiased and objective way as compared to qualitative or visual trend interpretation.

As with any other study, our analysis has several limitations. First, data quality issues prevented the use of older HES data before 2004. This meant that extremely long secular or cyclical trends may have been missed. Second, time-series study design only measures associations and considers changes in trends over time, rather than identifying causal relationships. What it can say is that there is a dramatic and statistically significant drop in the trends of myocardial infarction rates in Liverpool corresponding with the time of the smoking ban, and that reduced rates have subsequently been maintained. The use of methodological techniques such as controls was also not feasible – the smoking ban was implemented in all English regions simultaneously.

The small number of Liverpool cases analysed resulted in wide confidence intervals. We would emphasise that any inferences should be cautious, and emphasizing the urgent need for future research, particularly sub-analysis (e.g. by socioeconomic characteristics). Replicating these analyses in larger populations (Merseyside, which as a region, shares similar health characteristics such as deprivation and smoking rates) may therefore be valuable.

Public Health Implications

The implementation of the smoking ban was part of a national strategy to improve the health of the population, especially through reducing second-hand smoke exposure. The results from studies such as this may directly influence decisions regarding implementation of future, similar health legislation aimed at the population level.

From a policy perspective, these findings suggest that health policies need to continue to change from a focus towards incentives for short term clinical and individual interventions such as through QoF or pay-by-results schemes[16] to a focus on primary prevention strategies that both reduce disease by tackling risk factors[17] at a population level, as well as driving changes in societal perceptions and health behaviours. This is especially topical given the debate around various population-level proposals with public health implications such as alcohol unit pricing.

Furthermore, this study highlights the potential speed of return of health benefits gained from such wide-net population-level interventions. It adds to a growing body of evidence that substantial declines in mortality can happen rapidly after population-wide changes in risk factors such as diet or smoke-exposure[18 19]. Policy interventions which achieve population-wide changes – such as smoke-free legislation, or dietary reductions in salt or saturated fat – can be powerfully effective and cost-saving[20].

These structural, upstream interventions like widespread smoking ban adequately enforced and designed not only could result in large and rapid gains[12], but crucially could reduce inequalities[21], or at least not generate or aggravate them. However the evidence base is still sparse and more empirical evidence to support this hypothesis is needed[22]. Although such policies are often politically challenging, they are emerging as powerful options to reduce the increasing burden of non-communicable diseases.

In conclusion, a dramatic reduction in MI admissions in Liverpool has been observed coinciding with the smoking ban in 2007. This is consistent with results in other settings and populations. Furthermore, early data suggest that the effect is consistent across the socioeconomic spectrum. This legislation does not appear to widen health inequalities and may even reduce them. The rapid effects observed with this top-down, population-wide policy further emphasizes its potential value to Public Health policymakers.

Competing Interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Figures

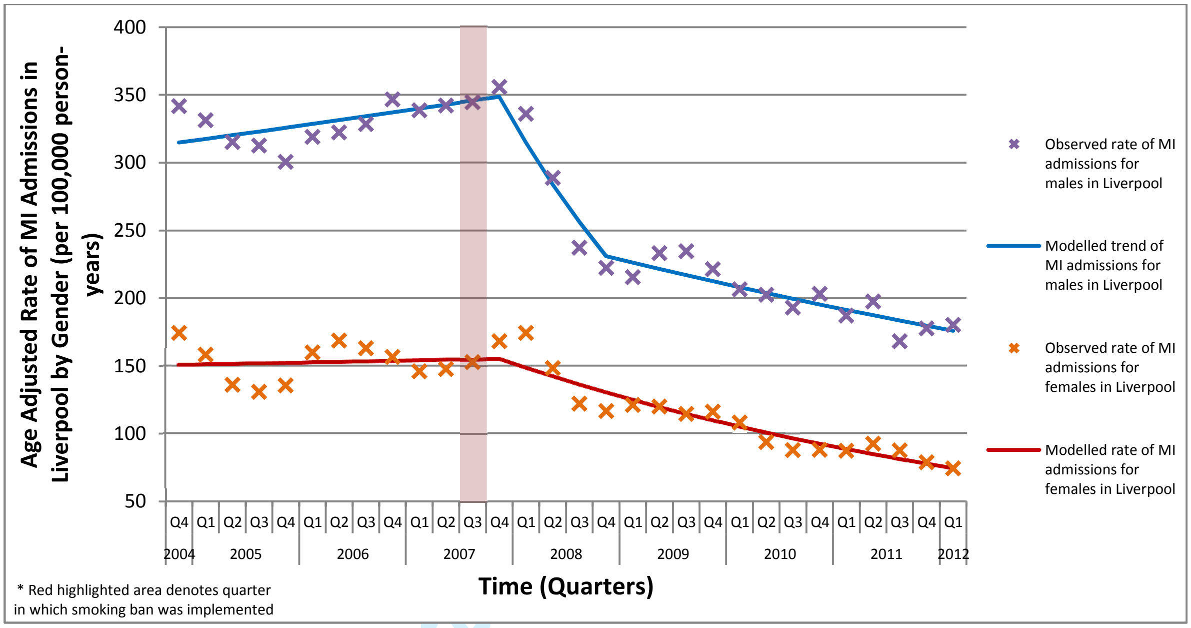

Figure 1 – Observed and modelled rates for all myocardial infarction admissions in Liverpool, 2004-2012, divided by gender.

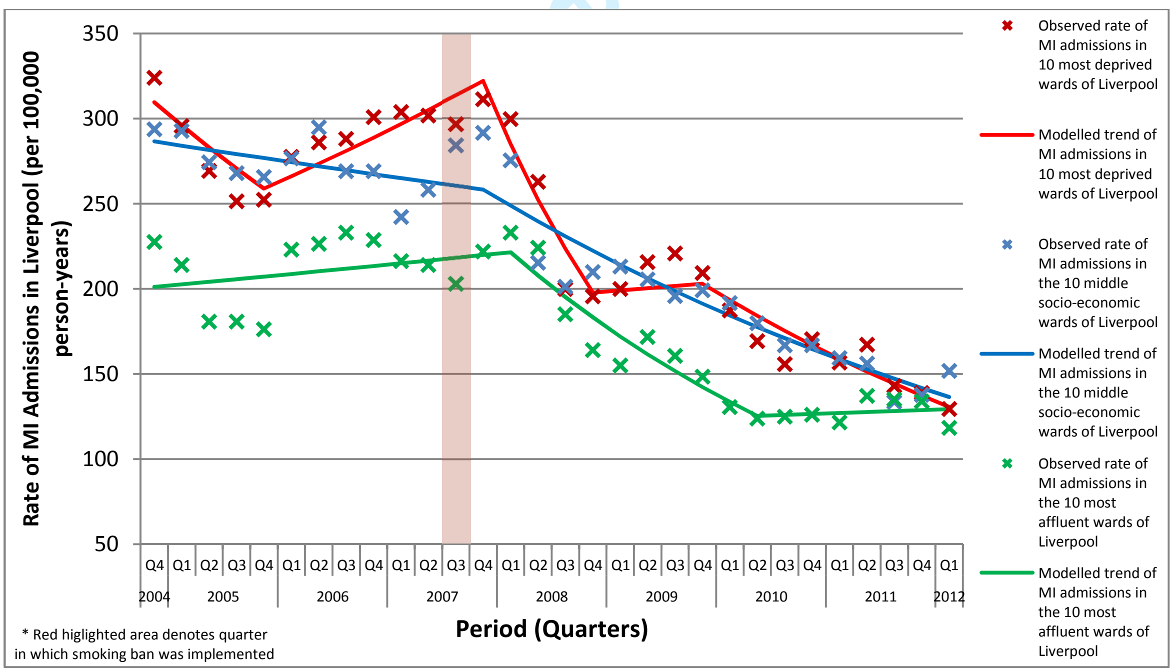

Figure 2 – Observed and modelled rates for all myocardial infarction admissions in Liverpool, 2004-2012, subdivided into three socioeconomic groupings (the 10 most deprived wards, the 10 middle-ranked wards and the 10 most affluent wards).

Tables

Table 1 – Descriptive data for all Coronary Heart Disease admissions in Liverpool between January 2004 and March 2012, including comparisons between 2005/2006 to 2010/2011.

	Population Characteristics 2004-2012		Crude Admissions			Age-adjusted rates per 100,000*		
	Frequency	**Percentage**	**2005-2006**	**2010-2011**	**Difference**	**2005-2006**	**2010-2011**	**Rate ratio**
Total	56995	100%	13434	15523	+2089	1696.7	2097.1	1.10 (1.08 – 1.12)
Male	30236	53.1%	7167	8271	+1104	2064.0	2235.4	1.08 (1.06 – 1.11)
Female	26759	46.9%	6267	7252	+985	1371.5	1542.2	1.12 (1.09 – 1.16)
16-19	11	<0.1%	2	3	+1	3.4	5.8	1.70
20-29	55	0.1%	15	12	-3	9.1	6.4	0.699
30-39	448	0.8%	127	87	-40	109.1	81.0	0.742
40-49	3526	6.2%	933	830	-103	763.5	707.0	0.926
50-59	9211	16.2%	2366	2339	-27	2351.9	2236.1	0.951
60-69	13647	23.9%	3290	3650	+360	4386.7	4632.0	1.06
70-79	17578	30.8%	4053	4883	+830	6622.6	8220.5	1.24
80+	12519	22.0%	2648	3719	+1071	8406.4	11068.5	1.32

* - Final age adjusted rates and confidence intervals calculated for total, male and female rates only. Age-specific rates and rate ratios are raw rates shown for reference.

Table 2 – Descriptive data for Myocardial Infarction admissions in Liverpool between January 2004 and March 2012, including comparisons between 2005/2006 to 2010/2011.

	Population Characteristics 2004-2012		Crude Admissions			Age-adjusted rates per 100,000*		
	Frequency	**Percentage**	**2005-2006**	**2005-2006**	**2005-2006**	**2005-2006**	**2010-2011**	**Rate ratio**
Total	6356	100%	1881	1089	-792	230.3	134.2	0.583 (0.549 – 0.618)
Male	3799	59.8%	1135	682	-453	325.3	190.0	0.584 (0.542 – 0.629)
Female	2557	40.2%	746	407	-339	148.7	85.3	0.574 (0.520 – 0.633)
16-19	2	<0.1%	0	0	0	0.0	0.0	-
20-29	11	0.2%	4	1	-3	2.4	0.5	0.219
30-39	91	1.4%	20	16	-4	17.2	14.9	0.867
40-49	488	7.7%	149	81	-68	121.9	69.0	0.566
50-59	1016	16.0%	286	221	-65	284.3	211.3	0.743
60-69	1376	21.6%	405	226	-179	540.0	286.8	0.531
70-79	1763	27.7%	531	291	-240	867.6	489.9	0.565
80+	1609	25.3%	486	253	-233	1542.9	753.0	0.488

* - Final age adjusted rates and confidence intervals calculated for total, male and female rates only. Age-specific rates and rate ratios are raw rates shown for reference.

Information Box

What is already known on this subject:

1. The global burden of tobacco-related disease is significant, as outlined in the WHO Framework Convention on Tobacco Control.
2. Smoke-free legislation appears to show a clear link with improved cardiovascular health over time.
3. However, there are very few studies looking at longer term trends or at the politically sensitive topic of its effects on socioeconomic inequalities.

What this study adds:

1. Smoke-free legislation can result in a rapid improvement in cardiovascular health at the population level, with a short lag time.
2. This improvement appears to be sustained even many years after the implementation of smoke-free legislation.
3. There is clear potential for reductions in both absolute and relative socioeconomic health inequalities following implementation of smoke-free legislation.

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Supplementary Information: Joinpoint regression data

A: Joinpoint regression trend analysis data for all CHD admissions in Liverpool between January 2004 and March 2012

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	1360.08	1387.92	
5	2005	**Q1**	1468.44	1404.04	
6		**Q2**	1380	1420.36	
7		**Q3**	1449.96	1436.88	Joinpoint 1
8		**Q4**	1490.68	1546.2	
9	2006	**Q1**	1739.36	1663.84	
10		**Q2**	1793.56	1790.44	
11		**Q3**	1878.52	1926.68	Joinpoint 2
12		**Q4**	1884.36	1904.04	
13	2007	**Q1**	1930.44	1881.68	
14		**Q2**	1861.52	1859.6	
15		**Q3**	1845.2	1837.76	
16		**Q4**	1800.76	1816.2	
17	2008	**Q1**	1820.88	1794.88	
18		**Q2**	1753.88	1773.8	
19		**Q3**	1735.48	1752.96	
20		**Q4**	1728.68	1732.4	Joinpoint 3
21	2009	**Q1**	1780.08	1765	
22		**Q2**	1815.48	1798.24	
23		**Q3**	1834.16	1832.12	
24		**Q4**	1852.64	1866.6	
25	2010	**Q1**	1879.88	1901.76	
26		**Q2**	1939.04	1937.56	
27		**Q3**	1963.68	1974.04	Joinpoint 4
28		**Q4**	1943.04	1906.88	
29	2011	**Q1**	1843.2	1842.04	
30		**Q2**	1788.04	1779.36	Joinpoint 5
31		**Q3**	1759.04	1787.8	
32		**Q4**	1792.32	1796.32	
33	2012	**Q1**	1817.36	1804.88	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	7	7	9
2	11	10	13
3	20	13	24
4	27	16	27
5	30	23	30

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	7	1.2	-2.4	4.9
2	7	11	7.6*	3.8	11.5
3	11	20	-1.2*	-1.9	-0.4
4	20	27	1.9*	0.6	3.1
5	27	30	-3.4	-10.1	3.8
6	30	33	0.5	-3.1	4.2

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.1775834	-4.9027658	
#2	1 Joinpoint(s)	30	4	26	0.0446991	-6.0555056	
#3	2 Joinpoint(s)	30	6	24	0.0354216	-6.0613904	
#4	3 Joinpoint(s)	30	8	22	0.0220611	-6.3081505	
#5	4 Joinpoint(s)	30	10	20	0.0130818	-6.6040016	
#6	5 Joinpoint(s)	30	12	18	0.0096519	-6.6813189	*

* = selected model

Final Selected Model
5 Joinpoint(s)

B: Joinpoint regression trend analysis data for male CHD admissions in Liverpool between January 2004 and March 2012

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	Q4	1663.56	1705.52	
5	2005	Q1	1810.36	1728.8	
6		Q2	1722.04	1752.36	
7		Q3	1773.24	1776.24	Joinpoint 1
8		Q4	1807.4	1881.84	
9	2006	Q1	2079.2	1993.72	
10		Q2	2134.92	2112.28	
11		Q3	2246.84	2237.88	
12		Q4	2292.2	2370.92	Joinpoint 2
13	2007	Q1	2378.76	2325.52	
14		Q2	2262.84	2281	
15		Q3	2217.12	2237.32	
16		Q4	2190.36	2194.48	
17	2008	Q1	2214.12	2152.48	
18		Q2	2107	2111.24	
19		Q3	2041	2070.8	
20		Q4	2044.68	2031.16	Joinpoint 3
21	2009	Q1	2081.52	2076.2	
22		Q2	2125.4	2122.28	
23		Q3	2129.04	2169.32	
24		Q4	2224.52	2217.44	
25	2010	Q1	2248.32	2266.64	
26		Q2	2331.64	2316.92	Joinpoint 4
27		Q3	2297.88	2292.2	
28		Q4	2331	2267.76	
29	2011	Q1	2237.6	2243.6	
30		Q2	2202	2219.68	
31		Q3	2126.52	2196.04	
32		Q4	2159.92	2172.6	
33	2012	Q1	2205	2149.44	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	7	7	14
2	12	10	22
3	20	17	27
4	26	23	30

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	7	1.4	-2.4	5.3
2	7	12	5.9*	3.4	8.5
3	12	20	-1.9*	-2.9	-0.9
4	20	26	2.2*	0.5	4
5	26	33	-1.1*	-2.1	-0.1

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.160688	-5.0027413	
#2	1 Joinpoint(s)	30	4	26	0.0510979	-5.921716	
#3	2 Joinpoint(s)	30	6	24	0.0346614	-6.0830874	
#4	3 Joinpoint(s)	30	8	22	0.0182291	-6.4989481	
#5	4 Joinpoint(s)	30	10	20	0.0124632	-6.6524435	*
#6	5 Joinpoint(s)	30	12	18	0.0107624	-6.5724118	

* = selected model

Final Selected Model
4 Joinpoint(s)

C: Joinpoint regression trend analysis data for female CHD admissions in Liverpool between January 2004 and March 2012

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	1090.72	1107.16	
5	2005	**Q1**	1166.2	1114.92	
6		**Q2**	1073.24	1122.76	
7		**Q3**	1164.88	1130.68	Joinpoint 1
8		**Q4**	1209.24	1255.52	
9	2006	**Q1**	1438.08	1394.2	
10		**Q2**	1486.16	1548.16	Joinpoint 2
11		**Q3**	1551.8	1536.48	
12		**Q4**	1524.68	1524.88	
13	2007	**Q1**	1543.2	1513.36	
14		**Q2**	1516.92	1501.96	
15		**Q3**	1526.88	1490.64	
16		**Q4**	1462.04	1479.4	
17	2008	**Q1**	1470.52	1468.24	
18		**Q2**	1435.84	1457.16	
19		**Q3**	1457.08	1446.16	Joinpoint 3
20		**Q4**	1442.68	1469.44	
21	2009	**Q1**	1507	1493.12	
22		**Q2**	1534	1517.16	
23		**Q3**	1564.04	1541.6	
24		**Q4**	1520.8	1566.4	
25	2010	**Q1**	1555.8	1591.64	
26		**Q2**	1599.76	1617.24	
27		**Q3**	1674.68	1643.28	Joinpoint 4
28		**Q4**	1609.48	1574.64	
29	2011	**Q1**	1509.64	1508.88	
30		**Q2**	1439.6	1445.84	Joinpoint 5
31		**Q3**	1450.32	1460.48	
32		**Q4**	1481.28	1475.28	
33	2012	**Q1**	1489.68	1490.24	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	7	7	9
2	10	10	13
3	19	13	24
4	27	16	27
5	30	23	30

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	7	0.7	-2.7	4.2
2	7	10	11.0*	3.7	18.9
3	10	19	-0.8*	-1.5	0
4	19	27	1.6*	0.7	2.5
5	27	30	-4.2	-10.5	2.6
6	30	33	1	-2.4	4.5

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.2193499	-4.6915381	
#2	1 Joinpoint(s)	30	4	26	0.0561688	-5.8270977	
#3	2 Joinpoint(s)	30	6	24	0.0423014	-5.883894	
#4	3 Joinpoint(s)	30	8	22	0.0338982	-5.8786038	
#5	4 Joinpoint(s)	30	10	20	0.0202819	-6.1654891	
#6	5 Joinpoint(s)	30	12	18	0.0139677	-6.3117261	*

* = selected model

Final Selected Model

5 Joinpoint(s)

D: Joinpoint regression trend analysis data for all MI admissions in Liverpool between January 2004 and March 2012

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	251.12	224.72	
5	2005	**Q1**	238	226.64	
6		**Q2**	220.12	228.56	
7		**Q3**	214.12	230.52	
8		**Q4**	210.96	232.48	
9	2006	**Q1**	231.32	234.44	
10		**Q2**	239.76	236.44	
11		**Q3**	240	238.44	
12		**Q4**	245.84	240.48	
13	2007	**Q1**	235.4	242.52	
14		**Q2**	237.6	244.6	
15		**Q3**	241.96	246.68	
16		**Q4**	256.4	248.76	Joinpoint 1
17	2008	**Q1**	251.36	228.16	
18		**Q2**	215.36	209.28	
19		**Q3**	177.28	191.96	
20		**Q4**	167.84	176.04	Joinpoint 2
21	2009	**Q1**	167.28	171.24	
22		**Q2**	174.84	166.56	
23		**Q3**	172.48	162	
24		**Q4**	166.16	157.56	
25	2010	**Q1**	154.76	153.24	
26		**Q2**	144.32	149.04	
27		**Q3**	136.96	144.96	
28		**Q4**	142	140.96	
29	2011	**Q1**	133.64	137.12	
30		**Q2**	141.16	133.36	
31		**Q3**	124.88	129.72	
32		**Q4**	125.16	126.16	
33	2012	**Q1**	124.4	122.68	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	16	15	18
2	20	19	22

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	16	0.9*	0	1.7
2	16	20	-8.3*	-14.4	-1.7
3	20	33	-2.7*	-3.4	-2

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.3447671	-4.239337	
#2	1 Joinpoint(s)	30	4	26	0.1374797	-4.9319834	
#3	2 Joinpoint(s)	30	6	24	0.0733659	-5.3332537	*
#4	3 Joinpoint(s)	30	8	22	0.0647343	-5.2316754	
#5	4 Joinpoint(s)	30	10	20	0.0607942	-5.0677253	
#6	5 Joinpoint(s)	30	12	18	0.0837904	-4.5201547	

* = selected model

Final Selected Model
2 Joinpoint(s)

E: Joinpoint regression trend analysis data for male MI admissions in Liverpool between January 2004 and March 2012

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	341.8	314.84	
5	2005	**Q1**	331.4	317.52	
6		**Q2**	315.24	320.24	
7		**Q3**	312.64	323	
8		**Q4**	300.56	325.76	
9	2006	**Q1**	319.04	328.52	
10		**Q2**	322.24	331.32	
11		**Q3**	328.52	334.16	
12		**Q4**	346.76	337.04	
13	2007	**Q1**	338.56	339.92	
14		**Q2**	342.24	342.8	
15		**Q3**	344.4	345.72	
16		**Q4**	355.8	348.68	Joinpoint 1
17	2008	**Q1**	335.96	314.6	
18		**Q2**	288.68	283.84	
19		**Q3**	237.32	256.08	
20		**Q4**	222.4	231.04	Joinpoint 2
21	2009	**Q1**	215.44	226.24	
22		**Q2**	233.2	221.56	
23		**Q3**	234.76	216.96	
24		**Q4**	221.36	212.48	
25	2010	**Q1**	206.52	208.08	
26		**Q2**	202.56	203.76	
27		**Q3**	193.16	199.56	
28		**Q4**	203.12	195.4	
29	2011	**Q1**	187.08	191.36	
30		**Q2**	197.48	187.4	
31		**Q3**	168.28	183.52	
32		**Q4**	177.6	179.72	
33	2012	**Q1**	180.28	176	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	16	15	17
2	20	19	22

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	16	0.9*	0.1	1.6
2	16	20	-9.8*	-15.5	-3.7
3	20	33	-2.1*	-2.7	-1.4

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.3447511	-4.2393836	
#2	1 Joinpoint(s)	30	4	26	0.1752419	-4.6892922	
#3	2 Joinpoint(s)	30	6	24	0.0584975	-5.5597299	*
#4	3 Joinpoint(s)	30	8	22	0.048604	-5.5182611	
#5	4 Joinpoint(s)	30	10	20	0.0420249	-5.4369586	
#6	5 Joinpoint(s)	30	12	18	0.0668013	-4.746751	

* = selected model

Final Selected Model
2 Joinpoint(s)

F: Joinpoint regression trend analysis data for female MI admissions in Liverpool between January 2004 and March 2012

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	174.44	150.68	
5	2005	**Q1**	158.32	151.04	
6		**Q2**	136	151.4	
7		**Q3**	130.88	151.76	
8		**Q4**	135.56	152.12	
9	2006	**Q1**	159.96	152.52	
10		**Q2**	168.8	152.88	
11		**Q3**	162.96	153.24	
12		**Q4**	156.68	153.6	
13	2007	**Q1**	146.04	153.96	
14		**Q2**	147.6	154.32	
15		**Q3**	152.8	154.72	
16		**Q4**	168.24	155.08	Joinpoint 1
17	2008	**Q1**	174.44	148.56	
18		**Q2**	148.28	142.28	
19		**Q3**	122.12	136.28	
20		**Q4**	116.8	130.52	
21	2009	**Q1**	121.16	125.04	
22		**Q2**	120.04	119.76	
23		**Q3**	114.48	114.72	
24		**Q4**	116.2	109.88	
25	2010	**Q1**	108.28	105.24	
26		**Q2**	93.84	100.8	
27		**Q3**	87.84	96.56	
28		**Q4**	88.12	92.48	
29	2011	**Q1**	87.48	88.6	
30		**Q2**	92.56	84.84	
31		**Q3**	87.6	81.28	
32		**Q4**	78.92	77.84	
33	2012	**Q1**	74.32	74.56	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	16	13	19

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	16	0.2	-1.2	1.7
2	16	33	-4.2*	-5	-3.4

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.4528029	-3.9667492	
#2	1 Joinpoint(s)	30	4	26	0.1851368	-4.6343646	*
#3	2 Joinpoint(s)	30	6	24	0.1662321	-4.5153284	
#4	3 Joinpoint(s)	30	8	22	0.1626941	-4.3100946	
#5	4 Joinpoint(s)	30	10	20	0.1609003	-4.0944354	
#6	5 Joinpoint(s)	30	12	18	0.1824625	-3.7419288	

* = selected model

Final Selected Model

1 Joinpoint(s)

G: Joinpoint regression trend analysis data for MI admissions in Liverpool between January 2004 and March 2012 in the 10 most deprived wards of Liverpool

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	323.97	309.68	
5	2005	**Q1**	295.57	296.13	
6		**Q2**	269.28	283.16	
7		**Q3**	251.39	270.76	
8		**Q4**	252.45	258.91	Joinpoint 1
9	2006	**Q1**	277.69	266.09	
10		**Q2**	286.1	273.47	
11		**Q3**	288.21	281.05	
12		**Q4**	300.83	288.85	
13	2007	**Q1**	303.99	296.86	
14		**Q2**	301.88	305.09	
15		**Q3**	296.62	313.56	
16		**Q4**	311.35	322.25	Joinpoint 2
17	2008	**Q1**	299.78	285.24	
18		**Q2**	262.96	252.47	
19		**Q3**	199.85	223.47	
20		**Q4**	195.65	197.8	Joinpoint 3
21	2009	**Q1**	199.85	199.11	
22		**Q2**	215.63	200.44	
23		**Q3**	220.89	201.77	
24		**Q4**	209.32	203.11	Joinpoint 4
25	2010	**Q1**	187.23	193.4	
26		**Q2**	169.35	184.15	
27		**Q3**	155.67	175.35	
28		**Q4**	170.4	166.96	
29	2011	**Q1**	156.73	158.98	
30		**Q2**	167.25	151.38	
31		**Q3**	143.05	144.14	
32		**Q4**	138.85	137.25	
33	2012	**Q1**	129.38	130.69	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	8	8	17
2	16	12	21
3	20	16	25
4	24	20	29

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	8	-4.4*	-8.2	-0.4
2	8	16	2.8*	1	4.6
3	16	20	-11.5*	-17	-5.6
4	20	24	0.7	-5.6	7.4
5	24	33	-4.8*	-5.9	-3.7

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.4752184	-3.9184316	
#2	1 Joinpoint(s)	30	4	26	0.2078359	-4.5187106	
#3	2 Joinpoint(s)	30	6	24	0.1587246	-4.5615428	
#4	3 Joinpoint(s)	30	8	22	0.1214503	-4.6024615	
#5	4 Joinpoint(s)	30	10	20	0.0860639	-4.7201297	*
#6	5 Joinpoint(s)	30	12	18	0.0791676	-4.5769064	

* = selected model

Final Selected Model
4 Joinpoint(s)

H: Joinpoint regression trend analysis data for MI admissions in Liverpool between January 2004 and March 2012 in the 10 middle socioeconomically-ranked wards of Liverpool

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	293.84	286.64	
5	2005	**Q1**	292.76	284.16	
6		**Q2**	274.48	281.72	
7		**Q3**	268	279.28	
8		**Q4**	265.84	276.88	
9	2006	**Q1**	276.64	274.48	
10		**Q2**	294.92	272.12	
11		**Q3**	269.08	269.76	
12		**Q4**	269.08	267.44	
13	2007	**Q1**	242.16	265.16	
14		**Q2**	258.32	262.84	
15		**Q3**	284.16	260.6	
16		**Q4**	291.68	258.36	Joinpoint 1
17	2008	**Q1**	275.56	248.84	
18		**Q2**	215.28	239.68	
19		**Q3**	201.28	230.84	
20		**Q4**	209.88	222.36	
21	2009	**Q1**	213.12	214.16	
22		**Q2**	205.6	206.28	
23		**Q3**	195.88	198.68	
24		**Q4**	199.12	191.36	
25	2010	**Q1**	191.6	184.32	
26		**Q2**	179.76	177.52	
27		**Q3**	166.84	171	
28		**Q4**	166.84	164.72	
29	2011	**Q1**	159.32	158.64	
30		**Q2**	156.08	152.8	
31		**Q3**	133.48	147.16	
32		**Q4**	137.76	141.76	
33	2012	**Q1**	151.76	136.52	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	16	12	18

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	16	-0.9	-1.9	0.2
2	16	33	-3.7*	-4.3	-3.1

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.220956	-4.6842427	
#2	1 Joinpoint(s)	30	4	26	0.1131469	-5.1267723	*
#3	2 Joinpoint(s)	30	6	24	0.1005679	-5.0178798	
#4	3 Joinpoint(s)	30	8	22	0.0900131	-4.9020117	
#5	4 Joinpoint(s)	30	10	20	0.0813158	-4.7768801	
#6	5 Joinpoint(s)	30	12	18	0.0764994	-4.6111912	

* = selected model

Final Selected Model
1 Joinpoint(s)

I: Joinpoint regression trend analysis data for MI admissions in Liverpool between January 2004 and March 2012 in the 10 most affluent wards of Liverpool

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	227.52	201.08	
5	2005	**Q1**	214.12	202.6	
6		**Q2**	180.68	204.12	
7		**Q3**	180.68	205.64	
8		**Q4**	176.2	207.16	
9	2006	**Q1**	223.08	208.72	
10		**Q2**	226.4	210.28	
11		**Q3**	233.12	211.84	
12		**Q4**	228.64	213.44	
13	2007	**Q1**	216.36	215.04	
14		**Q2**	214.12	216.64	
15		**Q3**	203	218.24	
16		**Q4**	221.96	219.88	
17	2008	**Q1**	233.12	221.52	Joinpoint 1
18		**Q2**	224.16	207.96	
19		**Q3**	185.16	195.2	
20		**Q4**	163.96	183.24	
21	2009	**Q1**	155.04	172.04	
22		**Q2**	171.76	161.48	
23		**Q3**	160.6	151.6	
24		**Q4**	148.32	142.32	
25	2010	**Q1**	130.48	133.6	
26		**Q2**	123.8	125.4	Joinpoint 2
27		**Q3**	124.92	125.96	
28		**Q4**	126.04	126.52	
29	2011	**Q1**	121.56	127.08	
30		**Q2**	137.2	127.64	
31		**Q3**	134.96	128.2	
32		**Q4**	133.84	128.76	
33	2012	**Q1**	118.24	129.32	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	17	13	19
2	26	20	29

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	17	0.7	-0.6	2.1
2	17	26	-6.1*	-8.7	-3.5
3	26	33	0.4	-2.9	3.9

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.5123481	-3.843202	
#2	1 Joinpoint(s)	30	4	26	0.2820797	-4.21327	
#3	2 Joinpoint(s)	30	6	24	0.1686568	-4.5008475	*
#4	3 Joinpoint(s)	30	8	22	0.1608549	-4.321464	
#5	4 Joinpoint(s)	30	10	20	0.1280593	-4.3227271	
#6	5 Joinpoint(s)	30	12	18	0.1257466	-4.1142046	

* = selected model

Final Selected Model
2 Joinpoint(s)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract ***Reduction in Myocardial Infarction Admissions in Liverpool after the Smoking Ban: Potential Socio-Economic Implications for Policymaking***
		√ (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	√ Explain the scientific background and rationale for the investigation being reported
Objectives	3	√ State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	√ Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection. ***Setting, dates, data collection described, the other items not applicable.***
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants ***Time trend study, section not applicable***
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case ***Time trend study, section not applicable***
Variables	7	√ Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.
Data sources/ measurement	8*	√**.** For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias. ***Explicitly addressed in the discussion section***
Study size	10	Explain how the study size was arrived at. ***Not applicable***
Quantitative variables	11	√ Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	√ (*a*) Describe all statistical methods, including those used to control for confounding
		√ (*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed ***Not applicable***
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed ***Not applicable*** *Case-control study*—If applicable, explain how matching of cases and controls was addressed ***Not applicable*** *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy ***Not applicable***
		(*e*) Describe any sensitivity analyses. ***Entire population of interest, not applicable***

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed ***Not applicable*** .
		(b) Give reasons for non-participation at each stage ***Not applicable***
		(c) Consider use of a flow diagram ***Not applicable***
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. ***Not applicable***
		(b) Indicate number of participants with missing data for each variable of interest ***Not applicable***
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) ***Not applicable***
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time ***Not applicable***
		Case-control study—Report numbers in each exposure category, or summary measures of exposure ***Not applicable***
		Cross-sectional study—Report numbers of outcome events or summary measures ***Not applicable***
Main results	16	√ (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		√ (*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period ***Not applicable***
Other analyses	17	√ Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	√ Summarise key results with reference to study objectives
Limitations	19	√ Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	√ Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results ***Not applicable***
Other information		
Funding	22	√Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Reduction in Myocardial Infarction Admissions in Liverpool after the Smoking Ban: Potential Socio-Economic Implications for Policymaking

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Title: Reduction in Myocardial Infarction Admissions in Liverpool after the Smoking Ban: Potential Socio-Economic Implications for Policymaking

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The findings and conclusions in this report are those of the authors and do not necessarily represent the views of Liverpool City Council or the University of Liverpool.

BMJ OPEN: ARTICLE SUMMARY

Article Focus

- Studies have shown a clear link between implementation of smoke-free legislation and improved cardiovascular health, however relatively few studies have examined the politically sensitive topic of its effects on socioeconomic inequalities.
- Liverpool has among the highest rates of smoking nationally, as well as high levels of social and economic inequalities, thus representing a key area in which to investigate the effects of the smoking ban on both health and health inequalities.
- Trends and trend changes were analysed in the data for all MI and CHD admissions in Liverpool 2004-2012, including by sex and socio-economic, and directly standardised to the European Standard Population.

Key Messages:

- Smoke-free legislation can result in rapid improvement in cardiovascular health at the population level.
- This improvement is sustained even many years after the implementation of smoke-free legislation.
- There is clear potential for reductions in both absolute and relative socioeconomic health inequalities following implementation of smoke-free legislation.

BMJ OPEN: Strengths and Limitations:

Strengths

- An inclusive, accurate data set through strict and specific data collections criteria was used (from mandatorily collected Hospital Episode Statistics data for Liverpool), ensuring identification of almost all relevant data cases minimising selection bias.
- A relatively long period of time before and after the smoking ban (2004-2012) compared to other studies, allowing a longer trend analysis.

Limitations

- Data quality issues meant that older HES data before 2004 was not suitable to be included in this or other research studies on HES data of this type.
- Small population groups after stratifying by socioeconomic status led to wide confidence intervals. A follow-up study examining the Merseyside county as a whole aims to rectify this by including a larger population while still sharing similar health characteristics such as deprivation and smoking rates.

ABSTRACT

Objectives – To analyse trends and trend changes in MI and CHD admissions, to investigate the effects of the 2007 smoke-free legislation on these trends, and to consider the policy implications of any findings.

Design –Setting - Liverpool (city), UK.

Participants – HES data on all 56,995 admissions for CHD in Liverpool between 2004 and 2012 (ICD codes I20 to I25 coded as an admission diagnosis within the defined dates).

Primary and Secondary Outcome Measures – Trend gradient and change points (by trend regressions analysis) in age-standardised MI admissions in Liverpool between 2004-2012; by sex and by socio-economic status. Secondary analysis on CHD admissions.

Results – A significant and sustained reduction was seen in MI admissions in Liverpool beginning within one year of the smoking ban. Comparing 2005/2006 and 2010/2011, the age-adjusted rates for MI admissions fell by 42% *(39%-45%)* (41.6% in men and by 42.6% in women). Trend analysis show that this is significantly greater than the background trend of decreasing admissions. These reductions appeared consistent across all socioeconomic groups. Interestingly, admission rates for total CHD (including mild to severe angina) increased by 10% *(8%–12%)*.

Conclusions – A dramatic reduction in myocardial infarction admissions in Liverpool has been observed coinciding with the smoking ban in 2007. Furthermore, benefits were apparent across the socioeconomic spectrum. Health inequalities were not affected and may even have been reduced. The rapid effects observed with this top-down, environmental policy may further increase its value to policymakers. [247 words]

Introduction

Smoking is the leading cause of preventable death in the United Kingdom[1], particularly for cardiovascular disease[2]; the UK prevalence of smoking was around 22% UK in 2007 representing some 13.7 million smokers[3]. Furthermore, strong socioeconomic inequalities were apparent with the smoking rates being around 14% in the most affluent groups and 34% in the most deprived[4].

The World Health Organisation (WHO) suggested smoke-free legislation as one of the key strategies to reduce the adverse impact tobacco has on health [5]. Smoke-free legislation in England was enacted on 1 July 2007 which made it illegal to smoke in any enclosed public or work space.

A body of evidence now exists demonstrating that smoke-free legislation is highly effective in reducing exposure to second hand smoke[6].

It is important to generate evidence for public health interventions where possible, especially as in many cases other traditional ways of gathering evidence such as randomized controlled trials are often not feasible[7]. Lawrence et al in 2011 describe a "global research neglect" of population health interventions in the field of tobacco control, and a tendency for smoking cessation research to favour individual- over population-based approaches[7].

Liverpool (pop: ~450,000) ranks among the worst-performing cities in the UK in terms of heart disease; socio-economic status; smoking prevalence[8,9], and healthcare costs associated with smoking[8]. Population level interventions, such as smoking bans in public places, may potentially reduce health inequalities. There is thus great potential for a study to evaluate the smoking ban in this city, both in terms of health outcomes and, crucially, in differential effects by socioeconomic status.

Methods

Mortality and Morbidity statistics

All admissions for patients aged 16 and over in Liverpool from January 2004 to April 2012 with an International Classification of Diseases diagnosis code from I20 to I25 for coronary heart disease were extracted from the Hospital Episode Statistics (HES)[fn1] database by Liverpool Primary Care Trust (PCT)[fn2] Health Intelligence staff. This data was presented anonymised and secured on official health-service hardware and networks only.

Although we do not think that out-of-area healthcare use of this diagnosis was significant, we were not able to analyse this in detail.

Unfortunately the HES data that was available at the time did not allow us to link smoking status with the admissions, so we were not able to consider this in the analysis.

Age-adjustment was performed using the direct method to the European standard population.

Socio-economic status data

The 30 wards of Liverpool were manually categorised into 3 groups of 10 wards each – i.e. the 10 most deprived, the 10 least deprived and the ten in the middle. To retain greater statistical power, smaller divisions such as individual wards were not used. Individual socio-economic status for the wards was estimated by geographical area using average socioeconomic rankings for the Lower Super Output Areas of Liverpool, as calculated by Liverpool City Council[10].

[fn1] Hospital Episode Statistics (HES) is a secure records-based data system containing details of all admissions, outpatient appointments and A&E attendances at NHS hospitals in England, collected during a patient's time in hospital. More information is available at: http://www.hscic.gov.uk/hes

[fn2] At the time of the study period Primary Care Trusts (PCTs) were the main organisational and commissioning units in the English National Health System, including commissioning primary care and the majority of secondary care services.

We then obtained data on Coronary Heart Disease (CHD) admissions by age, sex and socioeconomic status for the period 2004-2012.

Trend Analysis

A preliminary analysis of the time plots of the age-adjusted mortality rates was carried out to detect patterns such as trend or seasonality patterns.

Plots of the age-specific mortality rates were smoothed using 3-periodmoving averages, to help reduce the exaggerated effect that outlying points can have on man trend analysis models when these points are very close to either end of the study period A Joinpoint regression was fitted to provide estimated annual percentage change and to detect points in time where significant changes in the trends occur (JOINPOINT software version 3.0)[11]. We used a Bayesian Information Criterion (BIC) approach to select the most parsimonious model that fits best the data. A maximum number of five joinpoints was allowed for estimations. For each annual percentage change estimate, we also calculated the corresponding 95% confidence interval (95% CI). We performed several Joinpoint regression analyses: one for sex specific age-adjusted CHD admission rates, one for sex specific age-adjusted Myocardial Infarction (MI) admission rates, and one for deprivation specific age-adjusted MI admission rates.

Rate ratios were also calculated for average rates for the first 2 calendar years of the study (before the smoking ban 2005 – 2006) with the last 2 years of the study (after the smoking ban 2010 – 2011). Although background, secular trends were not factored into the calculations at this time, it allows the results to be seen in context of other studies which have presented results as 'percentage decreases'[12]. However, we emphasise the importance of the complete trend analysis figures to provide a full context for the data.

As an alternative methodology, we fitted ARIMA models[13] to sex and deprivation specific MI admission rates. ARIMA preliminary analysis, model selection and model fitting were undertaken using the Time Series Modeller procedure of SPSS 20. Smoking ban policy was included in the models as an event variable where a value of 1 indicates times at which the dependent series were expected to be affected by the smoking policy ban. Finally, we used the Ljung-Box tests to assess the suitability of the models.

Ethical Approval

The study was ethically approved through the official National Health Service (NHS) ethical approval scheme, and through this approval was confirmed by the East Dulwich NHS Research & Development Ethics board.

Results

Sex specific age-adjusted CHD admission trends

Comparing '05-'06 and '10-'11, the age-adjusted CHD admission rates increased overall by **8%** in men and by **12%** in women (Table 1). The Joinpoint analysis identified several changes in the trend during the study period, although none were within 2 quarters of the smoking ban (i.e. appearing to correspond with the time around the smoking ban).

Sex specific age-adjusted myocardial infarction admission trends

Comparing '05-'06 and '10-'11, the age-adjusted rates specifically for Myocardial Infarction admissions decreased overall by 41.6% in men and by 42.6% in women (Table 2). The Joinpoint analysis identified a change in trend corresponding to Q4 2007. In men, this represented a change from Annual Percentage Change (APC) of **0.9%** (0.1 to 1.6) to APC **-9.8%** (-15.5 to -3.7). For women, this was a change from APC 0.2% (-1.2 to 1.7) to APC **-4.2%** (-5.0 to -3.4). (Figure 1)

The rate-ratio comparing the first 2 years of the study (just before the smoking ban) and the final 2 years of the study was 0.58 *(0.54 – 0.61).*

Socioeconomic differentials in MI admission trends

Gender-specific figures were not analysed, as the denominators became too low to be robust.

For the 10 most deprived wards, MI admissions reduced by 45% (58.0 to 28.4) between '05-'06 and '10-'11. Joinpoint identified a trend change at 2007 Q4, representing a trend change from APC **2.8%** (1.0 to 4.6) to APC **-11.5%** (-17.0 to -5.6). (Figure 2)

For the 10 middle-ranked wards, MI admissions reduced by 42.3% (56.4 to 23.6) between '05-'06 and '10-'11. Joinpoint identified a trend change at 2007 Q4, representing a trend change from APC 0.9% (-1.9 to 0.2) to APC **-3.7%** (-4.3 to -3.1). (Figure 2)

For the 10 most affluent wards, MI admissions reduced by 38.6% (57.5 to 11.2) between '05-'06 and '10-'11. Joinpoint identified a trend change at 2008 Q1, representing a trend change from APC 0.7% (-0.6 to 2.1) to APC **-6.1%** (-8.7 to -3.5). (Figure 2)

The average **absolute risk difference** between the most and least deprived wards over the first 2 years of the data set was 69.8 MI admissions per 100,000 person-years. In contrast, the rate for the final 2 years was 32 MI admissions per 100,000 person-years (A rate ratio of 0.46, *95% CI of 0.044 to 4.76*).

The average **rate ratio** between the most and least deprived wards over the first 2 years of the data set was 1.38. In contrast, the relative difference for the final 2 years was 1.26 (A ratio of 0.91, *95% CI of 0.43 to 1.91*).

ARIMA analysis

There is a statistically significant decreasing effect of smoking ban policy for men, delayed by 3 points on time (e.g. three quarters) found in the MI admissions for males, most deprived wards and the middle-ranked wards (Table 3). Surprisingly the middle-ranked wards seem to be more affected by the smoking ban than the most deprived wards.

The Ljung-Box tests (Table 4)**Error! Reference source not found.** indicate a reasonable good fit of the models (with the exemption of the model for the most affluent wards).

More details of the ARIMA methodology can be found in Tables 3 and 4.

Discussion

Main findings

Myocardial infarction admissions in Liverpool showed a dramatic and statistically significant decline coinciding with the introduction of the smoking ban in July 2007. This decline was substantially greater than the underlying secular trend. In spite of a slight deceleration of the rate of decline in 2009, the decreasing rates have clearly continued until the end of 2012. This very substantial decrease in the rate was statistically significant. Even when bearing in mind some background secular trends, the reduction in numbers of admissions by over 40% is still striking.

In contrast, total coronary heart disease (CHD) admissions apparently increased by approximately 10% during the same period. There are several possible reasons for this discrepancy, including the greater difficulty in diagnosis or exclusion of angina chest pain, resulting in a higher number of false positives, false negatives or miscoding (e.g. mild or atypical chest pain). Myocardial infarctions, however, are more clearly diagnosed and include clearly defined clinical and diagnostic criteria (e.g. biochemical markers and specific ECG changes).

The rapid effect of the smoke-free legislation on MI admissions was notable. As in similar studies elsewhere the introduction of smoke-free legislation rapidly resulted in reduced admissions for acute MIs[14]. Despite a slight reduction in the rate of decline in 2009, our data still suggests that the smoking ban has a sustained and long term effect, which is consistent with previous systematic reviews[15].

Sims et al in 2010 found that smoke-free legislation in England reduced emergency admissions from myocardial infarction by 2.4% over a 15 month follow up period[12]. Further research will be necessary to ascertain whether the greater effect was seen in the findings of our study compared to other national studies is because of unique characteristics of the Liverpool demographic (higher baseline rates of heart disease/smoking; higher rates of deprivation) or some other environmental or statistical phenomenon. Interestingly, one study[16], found a declining trend in MI in England beginning well before 2007 (their study going back to 2002) and appears to show a steady linear decrease in MI admissions from 2002 to 2010, with no changes in the speed of decline around the time of the implementation of the smoking ban. Their study aggregated data for England using Hospital Episode Statistics “incident” cases of MI (i.e. new cases) – all MI events within a 30-day window are only considered once; whereas in our study all events are considered including multiple heart attacks in single individuals. A possible explanation could be that the smoking ban has a greater specific effect in reducing repeat or relapse MIs but not greatly reducing the number of 'first' MIs.

Relatively few studies have examined the effect of socioeconomic status on health gains following smoking bans[17], however our findings do agree with the conclusions of Dinno & Glantz's study in 2009 which explored this. Examining the effects of smoke-free legislation smoking behaviour, they compared effects across racial/ethnic backgrounds and household income and found that smoke-free legislation does appear to benefit all socio-economic and race/ethnic groups equally [18]. Our crude figures suggest a possible reduction in both absolute inequalities (differences) and relative inequalities (ratios), albeit not yet at a statistically significant level. The trend across socioeconomic groups appears to suggest a possible greater favourable effect in more deprived demographics, and this might also explain the greater effect of the smoking ban in Liverpool compared to other populations.

In addition, the ARIMA results are broadly consistent with the joinpoint analysis: both lend support that the smoking ban policy as population level intervention does not increase inequalities. Moreover, as the results of the ARIMA analysis pointed out, it has the potential to reduce inequalities.

Strengths and limitations

The main strength of this study was an inclusive, accurate data set through strict and specific data collection criteria over a period of 8 years. In addition using mandatorily collected HES data, all relevant data cases are likely to have been identified, minimising a potential source of selection bias.

As with any other study, our analysis has several limitations. First, data quality issues prevented the use of older HES data before 2004. This meant that extremely long secular or cyclical trends may have been missed. What it can say is that there is a dramatic and statistically significant drop in the trends of myocardial infarction rates in Liverpool corresponding with the time of the smoking ban, and that reduced rates have subsequently been maintained. The use of methodological techniques such as controls was also not feasible – the smoking ban was implemented in all English regions simultaneously.

The small number of Liverpool cases analysed resulted in wide confidence intervals. We would emphasise that any inferences should be cautious, and emphasizing the urgent need for future research, particularly sub-analysis (e.g. by socioeconomic characteristics). Replicating these analyses in larger populations (Merseyside, which as a region, shares similar health characteristics such as deprivation and smoking rates) may therefore be valuable.

Also the ARIMA results should be take cautiously since there is some evidence that suggests ARIMA models do not perform well in small samples[19]. The sample size could also mask the real effect of the smoking ban. From this perspective, Joinpoint regression seems to be a more adequate and robust methodology to explore the effect of smoking policy ban.

Public Health Implications

The implementation of the smoking ban was part of a national strategy to improve the health of the population, especially through reducing second-hand smoke exposure. The results from studies such as this may directly influence decisions regarding implementation of future, similar health legislation aimed at the population level.

From a policy perspective, these findings suggest that health policies need to continue to change from a focus towards incentives for short term clinical and individual interventions such as through QoF or pay-by-results schemes[20] to a focus on primary prevention strategies that both reduce disease by tackling risk factors[21] at a population level, as well as driving changes in societal perceptions and health behaviours. This is especially topical given the debate around various population-level proposals with public health implications such as alcohol unit pricing.

Furthermore, this study highlights the potential speed of return of health benefits gained from such wide-net population-level interventions. It adds to a growing body of evidence that substantial declines in mortality can happen rapidly after population-wide changes in risk factors such as diet or smoke-exposure[22,23]. Policy interventions which achieve population-wide changes related to CHD and smoking can be powerfully effective and cost-saving[24].

These structural, upstream interventions like widespread smoking ban adequately enforced and designed not only could result in large and rapid gains[15], but crucially could reduce inequalities[25], or at least not generate or aggravate them. However the evidence base is still sparse and more empirical evidence to support this hypothesis is needed[26]. Evaluation of these individual policy interventions is important to determine their effectiveness, document the case for extending programmes to other jurisdictions, to aid in refining programme implementation, and to monitor the possibility of inadvertent consequences. Although such policies and their evaluations are often politically challenging, they are emerging as powerful options to reduce the increasing burden of non-communicable diseases.

In conclusion, a dramatic reduction in MI admissions in Liverpool has been observed coinciding with the smoking ban in 2007. This is consistent with results in other settings and populations. Furthermore, early data suggest that the effect is consistent across the socioeconomic spectrum. This legislation does not appear to affect health inequalities and may even reduce them. The rapid effects observed with this top-down, population-wide policy further emphasizes its potential value to Public Health policymakers.

Competing Interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Contributorship

Dr Andrew Liu: Main researcher, providing the main contribution for the paper overall.

Dr Maria Guzman Castillo: Provided substantial contribution via ARIMA modelling and writing of relevant paragraphs.

Prof Simon Capewell: Provided substantial contribution to interpretation of data, and review & revision of article drafts and key points especially regarding smoking behaviour, cardiovascular disease science, CVD epidemiology and implications on health equity.

John Lucy: Provided substantial contribution to conception, interpretation of data, and review & revision of article drafts and key points especially regarding local authority and public health policy and strategy.

Dr Martin O'Flaherty: Main supervisor for research, with substantial contributions to all of: conception and design, analysis and interpretation of data, critically reviewing and revising the drafts and key points.

Final approval of the version for publication was agreed between all authors.

Data sharing

No unpublished data shared externally. Researchers have access to manuscript but no additional unpublished data.

Figures

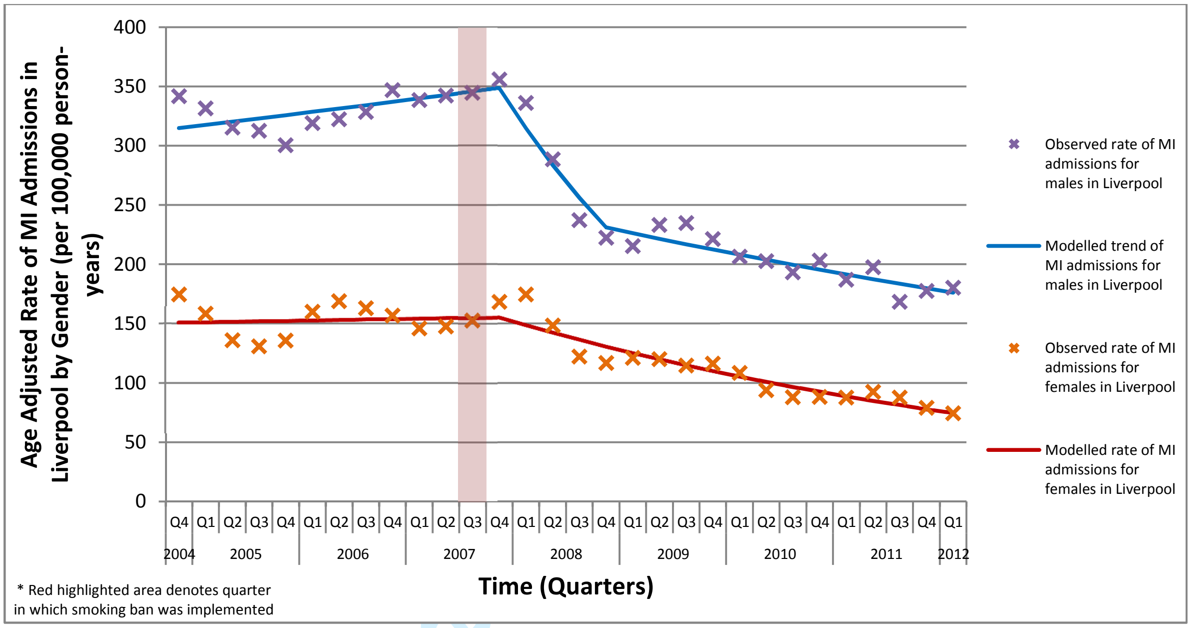

Figure 1 – Observed and modelled rates for all myocardial infarction admissions in Liverpool, 2004-2012, divided by gender.

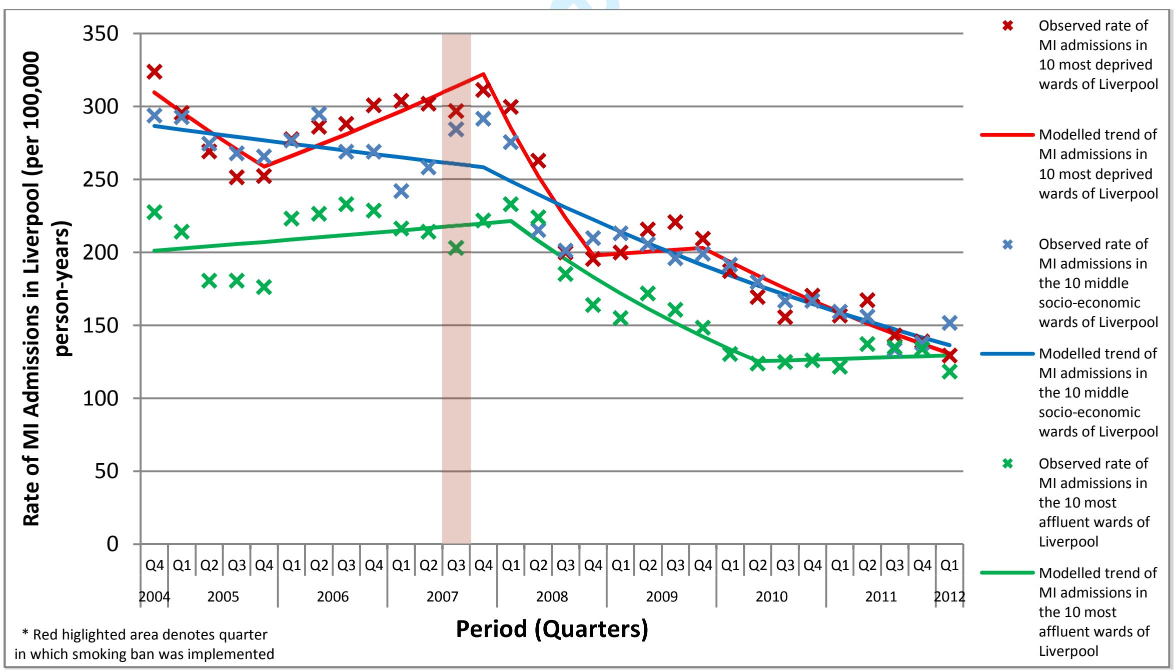

Figure 2 – Observed and modelled rates for all myocardial infarction admissions in Liverpool, 2004-2012, subdivided into three socioeconomic groupings (the 10 most deprived wards, the 10 middle-ranked wards and the 10 most affluent wards).

Tables

Table 1 – Descriptive data for all Coronary Heart Disease admissions in Liverpool between January 2004 and March 2012, including comparisons between 2005/2006 to 2010/2011.

	Population Characteristics 2004-2012		Crude Admissions			Age-adjusted rates per 100,000*		
	Frequency	Percentage	2005-2006	2010-2011	Difference	2005-2006	2010-2011	Rate ratio
Total	56995	100%	13434	15523	+2089	1696.7	2097.1	1.10 (1.08 – 1.12)
Male	30236	53.1%	7167	8271	+1104	2064.0	2235.4	1.08 (1.06 – 1.11)
Female	26759	46.9%	6267	7252	+985	1371.5	1542.2	1.12 (1.09 – 1.16)
16-19	11	<0.1%	2	3	+1	3.4	5.8	1.70
20-29	55	0.1%	15	12	-3	9.1	6.4	0.699
30-39	448	0.8%	127	87	-40	109.1	81.0	0.742
40-49	3526	6.2%	933	830	-103	763.5	707.0	0.926
50-59	9211	16.2%	2366	2339	-27	2351.9	2236.1	0.951
60-69	13647	23.9%	3290	3650	+360	4386.7	4632.0	1.06
70-79	17578	30.8%	4053	4883	+830	6622.6	8220.5	1.24
80+	12519	22.0%	2648	3719	+1071	8406.4	11068.5	1.32

* - Final age adjusted rates and confidence intervals calculated for total, male and female rates only. Age-specific rates and rate ratios are raw rates shown for reference.

Table 2 – Descriptive data for Myocardial Infarction admissions in Liverpool between January 2004 and March 2012, including comparisons between 2005/2006 to 2010/2011.

	Population Characteristics 2004-2012		Crude Admissions			Age-adjusted rates per 100,000*		
	Frequency	Percentage	2005-2006	2005-2006	2005-2006	2005-2006	2010-2011	Rate ratio
Total	6356	100%	1881	1089	-792	230.3	134.2	0.583 (0.549 – 0.618)
Male	3799	59.8%	1135	682	-453	325.3	190.0	0.584 (0.542 – 0.629)
Female	2557	40.2%	746	407	-339	148.7	85.3	0.574 (0.520 – 0.633)
16-19	2	<0.1%	0	0	0	0.0	0.0	-
20-29	11	0.2%	4	1	-3	2.4	0.5	0.219
30-39	91	1.4%	20	16	-4	17.2	14.9	0.867
40-49	488	7.7%	149	81	-68	121.9	69.0	0.566
50-59	1016	16.0%	286	221	-65	284.3	211.3	0.743
60-69	1376	21.6%	405	226	-179	540.0	286.8	0.531
70-79	1763	27.7%	531	291	-240	867.6	489.9	0.565
80+	1609	25.3%	486	253	-233	1542.9	753.0	0.488

* - Final age adjusted rates and confidence intervals calculated for total, male and female rates only. Age-specific rates and rate ratios are raw rates shown for reference

Table 3 – Arima model parameters

Model	Parameter		Estimate	SE	t	Sig.
Males[A]	Independent variable (three period delay)	Lag 0	-11.81	3.23	-3.65	0.00
		Lag 1	12.85	3.23	3.97	0.00
Females [AB]	AR	Lag 1	0.75	0.16	4.72	0.00
		Lag 2	-0.57	0.16	-3.62	0.00
Most deprived wards [AC]	Independent variable (three period delay)	Lag 0	-43.65	18.32	-2.38	0.03
Middle-ranked wards[A]	Independent variable (three period delay)	Lag 0	-60.28	13.70	-4.40	0.00
Most affluent wards [AD]	Constant		-0.02	0.02	-1.37	0.18

[A] Difference order 1
[B] Square transformation
[C] Seasonal Difference order 1
[D] Natural log transformation

Table 4 – Models goodness of fit: Ljung-Box test

Model	Ljung-Box Q(18)		
	Statistics	DF	Sig.
Males	18.77	18.00	0.41
Females	12.35	16.00	0.72
Most deprived wards	24.86	18.00	0.13
Middle-ranked wards	19.42	18.00	0.37
Most affluent wards	31.87	18.00	0.02

Information Box

What is already known on this subject:

1. The global burden of tobacco-related disease is significant, as outlined in the WHO Framework Convention on Tobacco Control.
2. Smoke-free legislation appears to show a clear link with improved cardiovascular health over time.
3. However, there are relatively few studies looking at the politically sensitive topic of its effects on socioeconomic inequalities.

What this study adds:

1. Smoke-free legislation can result in a rapid improvement in cardiovascular health at the population level.
2. This improvement appears to be sustained even many years after the implementation of smoke-free legislation.
3. There is clear potential for a reduction in both absolute and relative socioeconomic health inequalities following implementation of smoke-free legislation.

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1

Title: Reduction in Myocardial Infarction Admissions in Liverpool after the Smoking Ban: Potential Socio-Economic Implications for Policymaking

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BMJ OPEN: ARTICLE SUMMARY

Article Focus

- Smoke-free legislation appears to show a clear link with improved cardiovascular health over time, however there are very few studies looking at longer term trends or at Studies have shown a clear link between implementation of smoke-free legislation and improved cardiovascular health, however relatively few studies have examined the politically sensitive topic of its effects on socioeconomic inequalities.
- Liverpool has among the highest rates of smoking nationally, as well as high levels of social and economic inequalities, thus representing a key area in which to investigate the effects of the smoking ban on both health and health inequalities.
- Trends and trend changes were analysed in the data for all MI and CHD admissions in Liverpool 2004-2012, including by sex and socio-economic, and directly standardised to the European Standard Population.

Key Messages:

- Smoke-free legislation can result in rapid improvement in cardiovascular health at the population level.
- This improvement appears to beis sustained even many years after the implementation of smoke-free legislation.
- There is clear potential for reductions in both absolute and relative socioeconomic health inequalities following implementation of smoke-free legislation.

BMJ OPEN: Strengths and Limitations:

Strengths

- An inclusive, accurate data set through strict and specific data collections criteria was used (from mandatorily collected Hospital Episode Statistics data for Liverpool), ensuring identification of almost all relevant data cases minimising selection bias.
- A relatively long period of time before and after the smoking ban (2004-2012) compared to other studies, allowing a longer trend analysis.
- ~~Using a trend analysis method allowed the relating of periods of trend change to the smoking ban 'index event' in a more unbiased and objective way as compared to qualitative or visual trend interpretation.~~

Limitations

- Data quality issues meant that older HES data before 2004 was not suitable to be included in this or other research studies on HES data of this type.
- ~~The time-series study design only measures associations and considers changes in trends over time, however it does not by design identify causal relationships.~~
- Small population groups after stratifying by socioeconomic status led to wide confidence intervals. A follow-up study examining the Merseyside county as a whole aims to rectify this by including a larger population while still sharing similar health characteristics such as deprivation and smoking rates.

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ABSTRACT

Objectives – To analyse trends and trend changes in MI and CHD admissions, to investigate the effects of the 2007 smoke-free legislation on these trends, and to consider the policy implications of any findings.

Design – Interrupted time-series analysis using Joinpoint regression to assess changes in age-specific trends on 56,995 CHD admissions from 2004-2012 (by sex and socioeconomic status).

Setting - Liverpool (city), UK.

Participants – HES data on all 56,995 admissions for CHD in Liverpool between 2004 and 2012 (ICD codes I20 to I25 coded as an admission diagnosis within the defined dates).

Primary and Secondary Outcome Measures – Trend gradient and change points (by trend regressions analysis) in age-standardised MI admissions in Liverpool between 2004-2012; by sex and by socio-economic status. Secondary analysis on CHD admissions.

Results – A significant and sustained reduction was seen in MI admissions in Liverpool beginning within one year of the smoking ban. Comparing 2005/2006 and 2010/2011, the age-adjusted rates for MI admissions fell by 42% *(39%-45%)* (41.6% in men and by 42.6% in women). Trend analysis show that this is significantly greater than the background trend of decreasing admissions. These reductions appeared consistent across all socioeconomic groups. Interestingly, admission rates for total CHD (including mild to severe angina) increased by 10% *(8%–12%)*.

Conclusions – A dramatic reduction in myocardial infarction admissions in Liverpool has been observed coinciding with the smoking ban in 2007. Furthermore, benefits were apparent across the socioeconomic spectrum. Health inequalities were not widened affected and may

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even have been reduced. The rapid effects observed with this top-down, environmental policy may further increase its value to policymakers. [247 words]

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Introduction

Smoking is the leading cause of preventable death in the United Kingdom[1], particularly for cardiovascular disease[2]; the UK prevalence of smoking was around 22% UK in 2007 representing some 13.7 million smokers[3]. Furthermore, strong socioeconomic inequalities were apparent with the smoking rates being around 14% in the most affluent groups and 34% in the most deprived[4].

The World Health Organisation (WHO) suggested smoke-free legislation as one of the key strategies to reduce the adverse impact tobacco has on health [5]. Smoke-free legislation in England was enacted on 1 July 2007 which made it illegal to smoke in any enclosed public or work space.

A body of evidence now exists demonstrating that smoke-free legislation ~~achieving comprehensive bans~~ is highly effective in reducing exposure to second hand smoke[6].

It is important to generate evidence for public health interventions where possible, especially as in many cases other traditional ways of gathering evidence such as randomized controlled trials are often not feasible[7]. Lawrence et al in 2011 describe a “global research neglect” of population health interventions in the field of tobacco control, and a tendency for smoking cessation research to favour individual- over population-based approaches[7].

Liverpool (pop: ~450,000) ranks among the worst-performing cities in the UK in terms of heart disease; socio-economic status; smoking prevalence[8,9], and healthcare costs associated with smoking[8]. Population level interventions, such as smoking bans in public places, ~~might~~ may potentially reduce health inequalities. There is thus great potential for a study to evaluate the smoking ban in this city, both in terms of health outcomes and, crucially, in differential effects by socioeconomic status.

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Methods

Mortality and Morbidity statistics

All admissions for patients aged 16 and over in Liverpool from January 2004 to April 2012 with an International Classification of Diseases diagnosis code from I20 to I225 for coronary heart disease were extracted from the Hospital Episode Statistics (HES)[fn1] database by Liverpool Primary Care Trust (PCT)[fn2] Health Intelligence staff. This data was presented anonymised and secured on official health-service hardware and networks only.

Although we do not think that out-of-area healthcare use of this diagnosis was significant, we were not able to analyse this in detail.

Unfortunately the HES data that was available at the time did not allow us to link smoking status with the admissions, so we were not able to consider this in the analysis.

Age-adjustment was performed using the direct method to the European standard population.

Socio-economic status data

The 30 wards of Liverpool were manually categorised into 3 groups of 10 wards each – i.e. the 10 most deprived, the 10 least deprived and the ten in the middle. To retain greater statistical power, smaller divisions such as individual wards were not used. Individual socio-economic status for the wards was estimated by geographical area using average socioeconomic rankings for the Lower Super Output Areas of Liverpool, as calculated by Liverpool City Council[10].

[fn1] Hospital Episode Statistics (HES) is a secure records-based data system containing details of all admissions, outpatient appointments and A&E attendances at NHS hospitals in England, collected during a patient's time in hospital. More information is available at: http://www.hscic.gov.uk/hes

[fn2] At the time of the study period Primary Care Trusts (PCTs) were the main organisational and commissioning units in the English National Health System, including commissioning primary care and the majority of secondary care services.

We then obtained data on Coronary Heart Disease (CHD) admissions by age, sex and socioeconomic status for the period 2004-2012.

Trend Analysis

A preliminary analysis of the time plots of the age-adjusted mortality rates was carried out to detect patterns such as trend or seasonality patterns.

Plots of the age-specific mortality rates were smoothed using 3-period year moving averages, to help reduce the exaggerated effect that outlying points can have on man trend analysis models when these points are very close to either end of the study period A Joinpoint regression was fitted to provide estimated annual percentage change and to detect points in time where significant changes in the trends occur (JOINPOINT software version 3.0)[11]. We used a Bayesian Information Criterion (BIC) approach to select the most parsimonious model that fits best the data. A maximum number of five joinpoints was allowed for estimations. For each annual percentage change estimate, we also calculated the corresponding 95% confidence interval (95% CI). We performed several Joinpoint regression analyses: one for sex specific age-adjusted CHD admission rates, one for sex specific age-adjusted Myocardial Infarction (MI) admission rates, and one for deprivation specific age-adjusted myocardial infarctionMI admission rates.

Rate ratios were also calculated for average rates for the first 2 calendar years of the study (before the smoking ban 2005 – 2006) with the last 2 years of the study (after the smoking ban 2010 – 2011). Although background, secular trends were not factored into the calculations at this time, it allows the results to be seen in context of other studies which have presented results as 'percentage decreases'[12]. However, we emphasise the importance of the complete trend analysis figures to provide a full context for the data.

As an alternative methodology, we fitted ARIMA models[13] to sex and deprivation specific MI admission rates. ARIMA preliminary analysis, model selection and model fitting were undertaken using the Time Series Modeller procedure of SPSS 20. Smoking ban policy was included in the models as an event variable where a value of 1 indicates times at which the dependent series were expected to be affected by the smoking policy ban. Finally, we used the Ljung-Box tests to assess the suitability of the models.

Ethical Approval

The study was ethically approved through the official National Health Service (NHS) ethical approval scheme, and through this approval was confirmed by the East Dulwich NHS Research & Development Ethics board.

Results

Sex specific age-adjusted CHD admission trends

Comparing '05-'06 and '10-'11, the age-adjusted CHD admission rates increased overall by **8%** in men and by **12%** in women (Table 1). The Joinpoint analysis identified several changes in the trend during the study period, although none were within 2 quarters of the smoking ban (i.e. appearing to correspond with the time around the smoking ban).

Sex specific age-adjusted myocardial infarction admission trends

Comparing '05-'06 and '10-'11, the age-adjusted rates specifically for Myocardial Infarction admissions decreased overall by 41.6% in men and by 42.6% in women (Table 2). The Joinpoint analysis identified a change in trend corresponding to Q4 2007. In men, this represented a change from Annual Percentage Change (APC) of **0.9%** (0.1 to 1.6) to APC **-**

9.8% (-15.5 to -3.7). For women, this was a change from APC 0.2% (-1.2 to 1.7) to APC **-4.2%** (-5.0 to -3.4). (Figure 1)

The rate-ratio comparing the first 2 years of the study (just before the smoking ban) and the final 2 years of the study was 0.58 *(0.54 – 0.61).*

Socioeconomic differentials in MI admission trends

Gender-specific figures were not analysed, as the denominators became too low to be robust.

For the 10 most deprived wards, MI admissions reduced by 45% (58.0 to 28.4) between '05-'06 and '10-'11. Joinpoint identified a trend change at 2007 Q4, representing a trend change from APC **2.8%** (1.0 to 4.6) to APC **-11.5%** (-17.0 to -5.6). (Figure 2)

For the 10 middle-ranked wards, MI admissions reduced by 42.3% (56.4 to 23.6) between '05-'06 and '10-'11. Joinpoint identified a trend change at 2007 Q4, representing a trend change from APC 0.9% (-1.9 to 0.2) to APC **-3.7%** (-4.3 to -3.1). (Figure 2)

For the 10 most affluent wards, MI admissions reduced by 38.6% (57.5 to 11.2) between '05-'06 and '10-'11. Joinpoint identified a trend change at 2008 Q1, representing a trend change from APC 0.7% (-0.6 to 2.1) to APC **-6.1%** (-8.7 to -3.5). (Figure 2)

The average **absolute risk difference** between the most and least deprived wards over the first 2 years of the data set was 69.8 MI admissions per 100,000 person-years. In contrast, the rate for the final 2 years was 32 MI admissions per 100,000 person-years (A rate ratio of 0.46, *95% CI of 0.044 to 4.76*).

The average **rate ratio** between the most and least deprived wards over the first 2 years of the data set was 1.38. In contrast, the relative difference for the final 2 years was 1.26 (A ratio of 0.91, *95% CI of 0.43 to 1.91*).

ARIMA analysis

There is a statistically significant decreasing effect of smoking ban policy for men, delayed by 3 points on time (e.g. three quarters) found in the MI admissions for males, most deprived wards and the middle-ranked wards (Table 3). Surprisingly the middle-ranked wards seem to be more affected by the smoking ban than the most deprived wards.

The Ljung-Box tests (Table 4)**Error! Reference source not found.** indicate a reasonable good fit of the models (with the exemption of the model for the most affluent wards).

More details of the ARIMA methodology can be found in Tables 3 and 4.

Discussion

Main findings

Myocardial infarction admissions in Liverpool showed a dramatic and statistically significant decline coinciding with the introduction of the smoking ban in July 2007. This decline was substantially greater than the underlying secular trend. In spite of a slight deceleration of the rate of decline in 2009, the decreasing rates have clearly continued until the end of 2012. This very substantial decrease in the rate was statistically significant. Even when bearing in mind some background secular trends, the reduction in numbers of admissions by over 40% is still striking.

In contrast, total coronary heart disease (CHD) admissions apparently increased by approximately 10% during the same period. There are several possible reasons for this discrepancy, including the greater difficulty in diagnosis or exclusion of angina chest pain, resulting in a higher number of false positives, false negatives or miscoding (e.g. mild or atypical chest pain). Myocardial infarctions, however, are more clearly diagnosed and include clearly defined clinical and diagnostic criteria (e.g. biochemical markers and specific ECG changes).

The ~~short lag~~rapid effect of the smoke-free legislation on MI admissions ~~time~~ was notable. As in similar studies elsewhere the introduction of smoke-free legislation rapidly resulted in reduced admissions for acute MIs[14]. ~~In spite of~~Despite a slight ~~deceleration of~~reduction in the rate of decline in 2009, our data ~~nonetheless also suggest that a smoking ban may have~~still suggests that the smoking ban has a sustained and long term effect, which is consistent with previous systematic reviews[15].

Sims et al in 2010 found that smoke-free legislation in England reduced emergency admissions from myocardial infarction by 2.4% over a 15 month follow up period[12]. Further research will be necessary to ascertain whether the greater effect was seen in the findings of our study compared to other national studies is because of unique characteristics of the Liverpool demographic (higher baseline rates of heart disease/smoking; higher rates of deprivation) or some other environmental or statistical phenomenon. Interestingly, one study[16], found a declining trend in MI in England beginning well before 2007 (their study going back to 2002)

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and appears to show a steady linear decrease in MI admissions from 2002 to 2010, with no changes in the speed of decline around the time of the implementation of the smoking ban. Their study aggregated data for England using Hospital Episode Statistics "incident" cases of MI (i.e. new cases) – all MI events within a 30-day window are only considered once; whereas in our study all events are considered including multiple heart attacks in single individuals. A possible explanation could be that the smoking ban has a greater specific effect in reducing repeat or relapse MIs but not greatly reducing the number of 'first' MIs.

Relatively few studies have examined the effect of socioeconomic status on health gains following smoking bans[17], however our findings do agree with the conclusions of Dinno & Glantz's study in 2009 which explored this. Examining the effects of smoke-free legislation smoking behaviour, they compared effects across racial/ethnic backgrounds and household income and found that smoke-free legislation does appear to benefit all socio-economic and race/ethnic groups equally [18]. Our findings appear to suggest a reduction in all socioeconomic groups, and crude figures suggest a possible reduction in both absolute inequalities (differences) and relative inequalities (ratios), albeit not yet at a statistically significant level. The trend across socioeconomic groups appears to suggest a possible greater favourable effect in more deprived demographics, and this might also explain the greater effect of the smoking ban in Liverpool compared to other populations.

In addition, the ARIMA results are broadly consistent with the joinpoint analysis: both lend support that the smoking ban policy as population level intervention does not increase inequalities. Moreover, as the results of the ARIMA analysis pointed out, it has the potential to reduce inequalities.

Strengths and limitations

The main strength of this study was an inclusive, accurate data set through strict and specific data collection criteria over a period of 8 years. In addition using mandatorily collected HES data, all relevant data cases are likely to have been identified, minimising a potential source of selection bias.

~~Finally, using a trend analysis method such as Joinpoint regression allowed the relating of periods of trend change to the smoking ban 'index event' in a more unbiased and objective way as compared to qualitative or visual trend interpretation.~~

As with any other study, our analysis has several limitations. First, data quality issues prevented the use of older HES data before 2004. This meant that extremely long secular or cyclical trends may have been missed. ~~Second, time series study design only measures associations and considers changes in trends over time, rather than identifying causal relationships.~~ What it can say is that there is a dramatic and statistically significant drop in the trends of myocardial infarction rates in Liverpool corresponding with the time of the smoking ban, and that reduced rates have subsequently been maintained. The use of methodological techniques such as controls was also not feasible – the smoking ban was implemented in all English regions simultaneously.

The small number of Liverpool cases analysed resulted in wide confidence intervals. We would emphasise that any inferences should be cautious, and emphasizing the urgent need for future research, particularly sub-analysis (e.g. by socioeconomic characteristics). Replicating these analyses in larger populations (Merseyside, which as a region, shares similar health characteristics such as deprivation and smoking rates) may therefore be valuable.

Also the ARIMA results should be take cautiously since there is some evidence that suggests ARIMA models do not perform well in small samples[19]. The sample size could also mask the real effect of the smoking ban. From this perspective, Joinpoint regression seems to be a more adequate and robust methodology to explore the effect of smoking policy ban.

Public Health Implications

The implementation of the smoking ban was part of a national strategy to improve the health of the population, especially through reducing second-hand smoke exposure. The results from studies such as this may directly influence decisions regarding implementation of future, similar health legislation aimed at the population level.

From a policy perspective, these findings suggest that health policies need to continue to change from a focus towards incentives for short term clinical and individual interventions such as through QoF or pay-by-results schemes[20] to a focus on primary prevention strategies that both reduce disease by tackling risk factors[21] at a population level, as well as driving changes in societal perceptions and health behaviours. This is especially topical given the debate around various population-level proposals with public health implications such as alcohol unit pricing.

Furthermore, this study highlights the potential speed of return of health benefits gained from such wide-net population-level interventions. It adds to a growing body of evidence that substantial declines in mortality can happen rapidly after population-wide changes in risk factors such as diet or smoke-exposure[22,23]. Policy interventions which achieve population-wide changes – such as smoke-free legislation, or dietary reductions in salt or saturated fat – related to CHD and smoking can be powerfully effective and cost-saving[24].

Field Code Changed

These structural, upstream interventions like widespread smoking ban adequately enforced and designed not only could result in large and rapid gains[15], but crucially could reduce inequalities[25], or at least not generate or aggravate them. However the evidence base is still sparse and more empirical evidence to support this hypothesis is needed[26]. Evaluation of these individual policy interventions is important to determine their effectiveness, document the case for extending programmes to other jurisdictions, to aid in refining programme implementation, and to monitor the possibility of inadvertent consequences. Although such policies and their evaluations are often politically challenging, they are emerging as powerful options to reduce the increasing burden of non-communicable diseases.

In conclusion, a dramatic reduction in MI admissions in Liverpool has been observed coinciding with the smoking ban in 2007. This is consistent with results in other settings and populations. Furthermore, early data suggest that the effect is consistent across the socioeconomic spectrum. This legislation does not appear to ~~widen~~ affect health inequalities and may even reduce them. The rapid effects observed with this top-down, population-wide policy further emphasizes its potential value to Public Health policymakers.

Competing Interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

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Figures

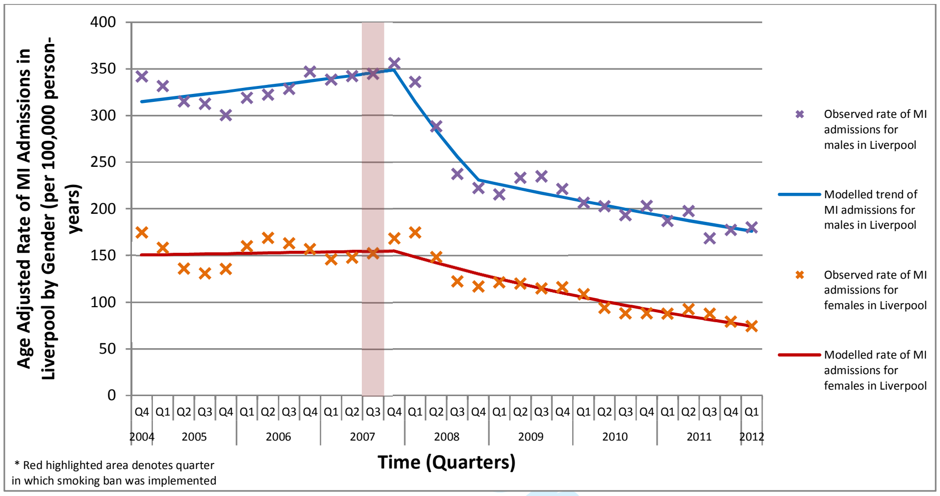

Figure 1 – Observed and modelled rates for all myocardial infarction admissions in Liverpool, 2004-2012, divided by gender.

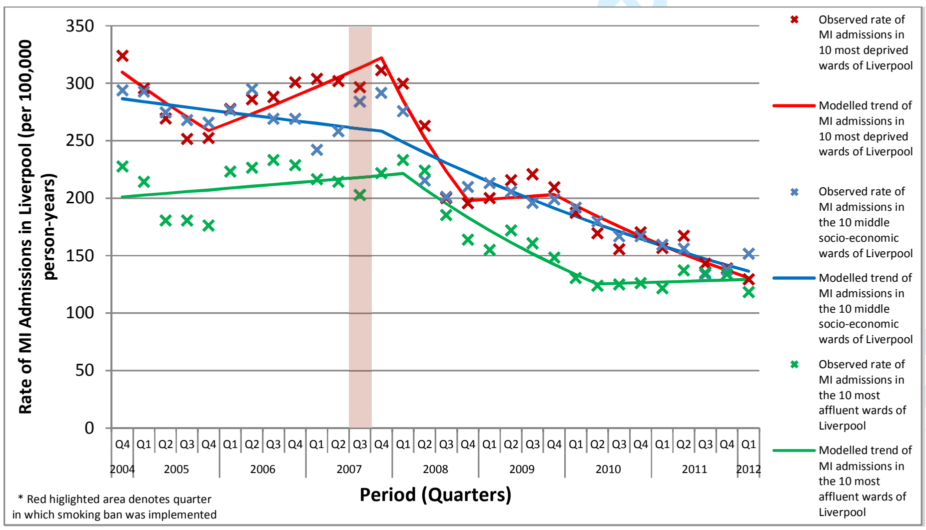

Figure 2 – Observed and modelled rates for all myocardial infarction admissions in Liverpool, 2004-2012, subdivided into three socioeconomic groupings (the 10 most deprived wards, the 10 middle-ranked wards and the 10 most affluent wards).

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Tables

Table 1 – Descriptive data for all Coronary Heart Disease admissions in Liverpool between January 2004 and March 2012, including comparisons between 2005/2006 to 2010/2011.

	Population Characteristics 2004-2012		Crude Admissions			Age-adjusted rates per 100,000*		
	Frequency	Percentage	2005-2006	2010-2011	Difference	2005-2006	2010-2011	Rate ratio
Total	56995	100%	13434	15523	+2089	1696.7	2097.1	1.10 (1.08 – 1.12)
Male	30236	53.1%	7167	8271	+1104	2064.0	2235.4	1.08 (1.06 – 1.11)
Female	26759	46.9%	6267	7252	+985	1371.5	1542.2	1.12 (1.09 – 1.16)
16-19	11	<0.1%	2	3	+1	3.4	5.8	1.70
20-29	55	0.1%	15	12	-3	9.1	6.4	0.699
30-39	448	0.8%	127	87	-40	109.1	81.0	0.742
40-49	3526	6.2%	933	830	-103	763.5	707.0	0.926
50-59	9211	16.2%	2366	2339	-27	2351.9	2236.1	0.951
60-69	13647	23.9%	3290	3650	+360	4386.7	4632.0	1.06
70-79	17578	30.8%	4053	4883	+830	6622.6	8220.5	1.24
80+	12519	22.0%	2648	3719	+1071	8406.4	11068.5	1.32

* - Final age adjusted rates and confidence intervals calculated for total, male and female rates only. Age-specific rates and rate ratios are raw rates shown for reference.

Table 2 – Descriptive data for Myocardial Infarction admissions in Liverpool between January 2004 and March 2012, including comparisons between 2005/2006 to 2010/2011.

	Population Characteristics 2004-2012		Crude Admissions			Age-adjusted rates per 100,000*		
	Frequency	Percentage	2005-2006	2005-2006	2005-2006	2005-2006	2010-2011	Rate ratio
Total	6356	100%	1881	1089	-792	230.3	134.2	0.583 (0.549 – 0.618)
Male	3799	59.8%	1135	682	-453	325.3	190.0	0.584 (0.542 – 0.629)
Female	2557	40.2%	746	407	-339	148.7	85.3	0.574 (0.520 – 0.633)
16-19	2	<0.1%	0	0	0	0.0	0.0	-
20-29	11	0.2%	4	1	-3	2.4	0.5	0.219
30-39	91	1.4%	20	16	-4	17.2	14.9	0.867
40-49	488	7.7%	149	81	-68	121.9	69.0	0.566
50-59	1016	16.0%	286	221	-65	284.3	211.3	0.743
60-69	1376	21.6%	405	226	-179	540.0	286.8	0.531
70-79	1763	27.7%	531	291	-240	867.6	489.9	0.565
80+	1609	25.3%	486	253	-233	1542.9	753.0	0.488

* - Final age adjusted rates and confidence intervals calculated for total, male and female rates only. Age-specific rates and rate ratios are raw rates shown for reference

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Table 3 – Arima model parameters

Model	Parameter		Estimate	SE	t	Sig.
Males[A]	Independent variable (three period delay)	Lag 0	-11.81	3.23	-3.65	0.00
		Lag 1	12.85	3.23	3.97	0.00
Females [AB]	AR	Lag 1	0.75	0.16	4.72	0.00
		Lag 2	-0.57	0.16	-3.62	0.00
Most deprived wards [AC]	Independent variable (three period delay)	Lag 0	-43.65	18.32	-2.38	0.03
Middle-ranked wards[A]	Independent variable (three period delay)	Lag 0	-60.28	13.70	-4.40	0.00
Most affluent wards [AD]	Constant		-0.02	0.02	-1.37	0.18

[A] Difference order 1
[B] Square transformation
[C] Seasonal Difference order 1
[D] Natural log transformation

Table 4 – Models goodness of fit: Ljung-Box test

Model	Ljung-Box Q(18)		
	Statistics	DF	Sig.
Males	18.77	18.00	0.41
Females	12.35	16.00	0.72
Most deprived wards	24.86	18.00	0.13
Middle-ranked wards	19.42	18.00	0.37
Most affluent wards	31.87	18.00	0.02

21

Information Box

What is already known on this subject:

1. The global burden of tobacco-related disease is significant, as outlined in the WHO Framework Convention on Tobacco Control.
2. Smoke-free legislation appears to show a clear link with improved cardiovascular health over time.
3. However, there are very relatively few studies looking at longer term trends or at the politically sensitive topic of its effects on socioeconomic inequalities.

What this study adds:

1. Smoke-free legislation can result in a rapid improvement in cardiovascular health at the population level, with a short lag time.
2. This improvement appears to be sustained even many years after the implementation of smoke-free legislation.
3. There is clear potential for a reduction in both absolute and relative socioeconomic health inequalities following implementation of smoke-free legislation.

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Supplementary Information: Joinpoint regression data

A: Joinpoint regression trend analysis data for all CHD admissions in Liverpool between January 2004 and March 2012

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	1360.08	1387.92	
5	2005	**Q1**	1468.44	1404.04	
6		**Q2**	1380	1420.36	
7		**Q3**	1449.96	1436.88	Joinpoint 1
8		**Q4**	1490.68	1546.2	
9	2006	**Q1**	1739.36	1663.84	
10		**Q2**	1793.56	1790.44	
11		**Q3**	1878.52	1926.68	Joinpoint 2
12		**Q4**	1884.36	1904.04	
13	2007	**Q1**	1930.44	1881.68	
14		**Q2**	1861.52	1859.6	
15		**Q3**	1845.2	1837.76	
16		**Q4**	1800.76	1816.2	
17	2008	**Q1**	1820.88	1794.88	
18		**Q2**	1753.88	1773.8	
19		**Q3**	1735.48	1752.96	
20		**Q4**	1728.68	1732.4	Joinpoint 3
21	2009	**Q1**	1780.08	1765	
22		**Q2**	1815.48	1798.24	
23		**Q3**	1834.16	1832.12	
24		**Q4**	1852.64	1866.6	
25	2010	**Q1**	1879.88	1901.76	
26		**Q2**	1939.04	1937.56	
27		**Q3**	1963.68	1974.04	Joinpoint 4
28		**Q4**	1943.04	1906.88	
29	2011	**Q1**	1843.2	1842.04	
30		**Q2**	1788.04	1779.36	Joinpoint 5
31		**Q3**	1759.04	1787.8	
32		**Q4**	1792.32	1796.32	
33	2012	**Q1**	1817.36	1804.88	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	7	7	9
2	11	10	13
3	20	13	24
4	27	16	27
5	30	23	30

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	7	1.2	-2.4	4.9
2	7	11	7.6*	3.8	11.5
3	11	20	-1.2*	-1.9	-0.4
4	20	27	1.9*	0.6	3.1
5	27	30	-3.4	-10.1	3.8
6	30	33	0.5	-3.1	4.2

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.1775834	-4.9027658	
#2	1 Joinpoint(s)	30	4	26	0.0446991	-6.0555056	
#3	2 Joinpoint(s)	30	6	24	0.0354216	-6.0613904	
#4	3 Joinpoint(s)	30	8	22	0.0220611	-6.3081505	
#5	4 Joinpoint(s)	30	10	20	0.0130818	-6.6040016	
#6	5 Joinpoint(s)	30	12	18	0.0096519	-6.6813189	*

* = selected model

Final Selected Model
5 Joinpoint(s)

B: Joinpoint regression trend analysis data for male CHD admissions in Liverpool between January 2004 and March 2012

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	1663.56	1705.52	
5	2005	**Q1**	1810.36	1728.8	
6		**Q2**	1722.04	1752.36	
7		**Q3**	1773.24	1776.24	Joinpoint 1
8		**Q4**	1807.4	1881.84	
9	2006	**Q1**	2079.2	1993.72	
10		**Q2**	2134.92	2112.28	
11		**Q3**	2246.84	2237.88	
12		**Q4**	2292.2	2370.92	Joinpoint 2
13	2007	**Q1**	2378.76	2325.52	
14		**Q2**	2262.84	2281	
15		**Q3**	2217.12	2237.32	
16		**Q4**	2190.36	2194.48	
17	2008	**Q1**	2214.12	2152.48	
18		**Q2**	2107	2111.24	
19		**Q3**	2041	2070.8	
20		**Q4**	2044.68	2031.16	Joinpoint 3
21	2009	**Q1**	2081.52	2076.2	
22		**Q2**	2125.4	2122.28	
23		**Q3**	2129.04	2169.32	
24		**Q4**	2224.52	2217.44	
25	2010	**Q1**	2248.32	2266.64	
26		**Q2**	2331.64	2316.92	Joinpoint 4
27		**Q3**	2297.88	2292.2	
28		**Q4**	2331	2267.76	
29	2011	**Q1**	2237.6	2243.6	
30		**Q2**	2202	2219.68	
31		**Q3**	2126.52	2196.04	
32		**Q4**	2159.92	2172.6	
33	2012	**Q1**	2205	2149.44	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	7	7	14
2	12	10	22
3	20	17	27
4	26	23	30

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	7	1.4	-2.4	5.3
2	7	12	5.9*	3.4	8.5
3	12	20	-1.9*	-2.9	-0.9
4	20	26	2.2*	0.5	4
5	26	33	-1.1*	-2.1	-0.1

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.160688	-5.0027413	
#2	1 Joinpoint(s)	30	4	26	0.0510979	-5.921716	
#3	2 Joinpoint(s)	30	6	24	0.0346614	-6.0830874	
#4	3 Joinpoint(s)	30	8	22	0.0182291	-6.4989481	
#5	4 Joinpoint(s)	30	10	20	0.0124632	-6.6524435	*
#6	5 Joinpoint(s)	30	12	18	0.0107624	-6.5724118	

* = selected model

Final Selected Model
4 Joinpoint(s)

C: Joinpoint regression trend analysis data for female CHD admissions in Liverpool between January 2004 and March 2012

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	Q4	1090.72	1107.16	
5	2005	Q1	1166.2	1114.92	
6		Q2	1073.24	1122.76	
7		Q3	1164.88	1130.68	Joinpoint 1
8		Q4	1209.24	1255.52	
9	2006	Q1	1438.08	1394.2	
10		Q2	1486.16	1548.16	Joinpoint 2
11		Q3	1551.8	1536.48	
12		Q4	1524.68	1524.88	
13	2007	Q1	1543.2	1513.36	
14		Q2	1516.92	1501.96	
15		Q3	1526.88	1490.64	
16		Q4	1462.04	1479.4	
17	2008	Q1	1470.52	1468.24	
18		Q2	1435.84	1457.16	
19		Q3	1457.08	1446.16	Joinpoint 3
20		Q4	1442.68	1469.44	
21	2009	Q1	1507	1493.12	
22		Q2	1534	1517.16	
23		Q3	1564.04	1541.6	
24		Q4	1520.8	1566.4	
25	2010	Q1	1555.8	1591.64	
26		Q2	1599.76	1617.24	
27		Q3	1674.68	1643.28	Joinpoint 4
28		Q4	1609.48	1574.64	
29	2011	Q1	1509.64	1508.88	
30		Q2	1439.6	1445.84	Joinpoint 5
31		Q3	1450.32	1460.48	
32		Q4	1481.28	1475.28	
33	2012	Q1	1489.68	1490.24	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	7	7	9
2	10	10	13
3	19	13	24
4	27	16	27
5	30	23	30

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	7	0.7	-2.7	4.2
2	7	10	11.0*	3.7	18.9
3	10	19	-0.8*	-1.5	0
4	19	27	1.6*	0.7	2.5
5	27	30	-4.2	-10.5	2.6
6	30	33	1	-2.4	4.5

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.2193499	-4.6915381	
#2	1 Joinpoint(s)	30	4	26	0.0561688	-5.8270977	
#3	2 Joinpoint(s)	30	6	24	0.0423014	-5.883894	
#4	3 Joinpoint(s)	30	8	22	0.0338982	-5.8786038	
#5	4 Joinpoint(s)	30	10	20	0.0202819	-6.1654891	
#6	5 Joinpoint(s)	30	12	18	0.0139677	-6.3117261	*

* = selected model

Final Selected Model
5 Joinpoint(s)

D: Joinpoint regression trend analysis data for all MI admissions in Liverpool between January 2004 and March 2012

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	251.12	224.72	
5	2005	**Q1**	238	226.64	
6		**Q2**	220.12	228.56	
7		**Q3**	214.12	230.52	
8		**Q4**	210.96	232.48	
9	2006	**Q1**	231.32	234.44	
10		**Q2**	239.76	236.44	
11		**Q3**	240	238.44	
12		**Q4**	245.84	240.48	
13	2007	**Q1**	235.4	242.52	
14		**Q2**	237.6	244.6	
15		**Q3**	241.96	246.68	
16		**Q4**	256.4	248.76	Joinpoint 1
17	2008	**Q1**	251.36	228.16	
18		**Q2**	215.36	209.28	
19		**Q3**	177.28	191.96	
20		**Q4**	167.84	176.04	Joinpoint 2
21	2009	**Q1**	167.28	171.24	
22		**Q2**	174.84	166.56	
23		**Q3**	172.48	162	
24		**Q4**	166.16	157.56	
25	2010	**Q1**	154.76	153.24	
26		**Q2**	144.32	149.04	
27		**Q3**	136.96	144.96	
28		**Q4**	142	140.96	
29	2011	**Q1**	133.64	137.12	
30		**Q2**	141.16	133.36	
31		**Q3**	124.88	129.72	
32		**Q4**	125.16	126.16	
33	2012	**Q1**	124.4	122.68	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	16	15	18
2	20	19	22

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	16	0.9*	0	1.7
2	16	20	-8.3*	-14.4	-1.7
3	20	33	-2.7*	-3.4	-2

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.3447671	-4.239337	
#2	1 Joinpoint(s)	30	4	26	0.1374797	-4.9319834	
#3	2 Joinpoint(s)	30	6	24	0.0733659	-5.3332537	*
#4	3 Joinpoint(s)	30	8	22	0.0647343	-5.2316754	
#5	4 Joinpoint(s)	30	10	20	0.0607942	-5.0677253	
#6	5 Joinpoint(s)	30	12	18	0.0837904	-4.5201547	

* = selected model

Final Selected Model
2 Joinpoint(s)

E: Joinpoint regression trend analysis data for male MI admissions in Liverpool between January 2004 and March 2012

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	341.8	314.84	
5	2005	**Q1**	331.4	317.52	
6		**Q2**	315.24	320.24	
7		**Q3**	312.64	323	
8		**Q4**	300.56	325.76	
9	2006	**Q1**	319.04	328.52	
10		**Q2**	322.24	331.32	
11		**Q3**	328.52	334.16	
12		**Q4**	346.76	337.04	
13	2007	**Q1**	338.56	339.92	
14		**Q2**	342.24	342.8	
15		**Q3**	344.4	345.72	
16		**Q4**	355.8	348.68	Joinpoint 1
17	2008	**Q1**	335.96	314.6	
18		**Q2**	288.68	283.84	
19		**Q3**	237.32	256.08	
20		**Q4**	222.4	231.04	Joinpoint 2
21	2009	**Q1**	215.44	226.24	
22		**Q2**	233.2	221.56	
23		**Q3**	234.76	216.96	
24		**Q4**	221.36	212.48	
25	2010	**Q1**	206.52	208.08	
26		**Q2**	202.56	203.76	
27		**Q3**	193.16	199.56	
28		**Q4**	203.12	195.4	
29	2011	**Q1**	187.08	191.36	
30		**Q2**	197.48	187.4	
31		**Q3**	168.28	183.52	
32		**Q4**	177.6	179.72	
33	2012	**Q1**	180.28	176	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	16	15	17
2	20	19	22

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	16	0.9*	0.1	1.6
2	16	20	-9.8*	-15.5	-3.7
3	20	33	-2.1*	-2.7	-1.4

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.3447511	-4.2393836	
#2	1 Joinpoint(s)	30	4	26	0.1752419	-4.6892922	
#3	2 Joinpoint(s)	30	6	24	0.0584975	-5.5597299	*
#4	3 Joinpoint(s)	30	8	22	0.048604	-5.5182611	
#5	4 Joinpoint(s)	30	10	20	0.0420249	-5.4369586	
#6	5 Joinpoint(s)	30	12	18	0.0668013	-4.746751	

* = selected model

Final Selected Model
2 Joinpoint(s)

F: Joinpoint regression trend analysis data for female MI admissions in Liverpool between January 2004 and March 2012

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	174.44	150.68	
5	2005	**Q1**	158.32	151.04	
6		**Q2**	136	151.4	
7		**Q3**	130.88	151.76	
8		**Q4**	135.56	152.12	
9	2006	**Q1**	159.96	152.52	
10		**Q2**	168.8	152.88	
11		**Q3**	162.96	153.24	
12		**Q4**	156.68	153.6	
13	2007	**Q1**	146.04	153.96	
14		**Q2**	147.6	154.32	
15		**Q3**	152.8	154.72	
16		**Q4**	168.24	155.08	Joinpoint 1
17	2008	**Q1**	174.44	148.56	
18		**Q2**	148.28	142.28	
19		**Q3**	122.12	136.28	
20		**Q4**	116.8	130.52	
21	2009	**Q1**	121.16	125.04	
22		**Q2**	120.04	119.76	
23		**Q3**	114.48	114.72	
24		**Q4**	116.2	109.88	
25	2010	**Q1**	108.28	105.24	
26		**Q2**	93.84	100.8	
27		**Q3**	87.84	96.56	
28		**Q4**	88.12	92.48	
29	2011	**Q1**	87.48	88.6	
30		**Q2**	92.56	84.84	
31		**Q3**	87.6	81.28	
32		**Q4**	78.92	77.84	
33	2012	**Q1**	74.32	74.56	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	16	13	19

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	16	0.2	-1.2	1.7
2	16	33	-4.2*	-5	-3.4

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.4528029	-3.9667492	
#2	1 Joinpoint(s)	30	4	26	0.1851368	-4.6343646	*
#3	2 Joinpoint(s)	30	6	24	0.1662321	-4.5153284	
#4	3 Joinpoint(s)	30	8	22	0.1626941	-4.3100946	
#5	4 Joinpoint(s)	30	10	20	0.1609003	-4.0944354	
#6	5 Joinpoint(s)	30	12	18	0.1824625	-3.7419288	

* = selected model

Final Selected Model
1 Joinpoint(s)

G: Joinpoint regression trend analysis data for MI admissions in Liverpool between January 2004 and March 2012 in the 10 most deprived wards of Liverpool

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	323.97	309.68	
5	2005	**Q1**	295.57	296.13	
6		**Q2**	269.28	283.16	
7		**Q3**	251.39	270.76	
8		**Q4**	252.45	258.91	Joinpoint 1
9	2006	**Q1**	277.69	266.09	
10		**Q2**	286.1	273.47	
11		**Q3**	288.21	281.05	
12		**Q4**	300.83	288.85	
13	2007	**Q1**	303.99	296.86	
14		**Q2**	301.88	305.09	
15		**Q3**	296.62	313.56	
16		**Q4**	311.35	322.25	Joinpoint 2
17	2008	**Q1**	299.78	285.24	
18		**Q2**	262.96	252.47	
19		**Q3**	199.85	223.47	
20		**Q4**	195.65	197.8	Joinpoint 3
21	2009	**Q1**	199.85	199.11	
22		**Q2**	215.63	200.44	
23		**Q3**	220.89	201.77	
24		**Q4**	209.32	203.11	Joinpoint 4
25	2010	**Q1**	187.23	193.4	
26		**Q2**	169.35	184.15	
27		**Q3**	155.67	175.35	
28		**Q4**	170.4	166.96	
29	2011	**Q1**	156.73	158.98	
30		**Q2**	167.25	151.38	
31		**Q3**	143.05	144.14	
32		**Q4**	138.85	137.25	
33	2012	**Q1**	129.38	130.69	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	8	8	17
2	16	12	21
3	20	16	25
4	24	20	29

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	8	-4.4*	-8.2	-0.4
2	8	16	2.8*	1	4.6
3	16	20	-11.5*	-17	-5.6
4	20	24	0.7	-5.6	7.4
5	24	33	-4.8*	-5.9	-3.7

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.4752184	-3.9184316	
#2	1 Joinpoint(s)	30	4	26	0.2078359	-4.5187106	
#3	2 Joinpoint(s)	30	6	24	0.1587246	-4.5615428	
#4	3 Joinpoint(s)	30	8	22	0.1214503	-4.6024615	
#5	4 Joinpoint(s)	30	10	20	0.0860639	-4.7201297	*
#6	5 Joinpoint(s)	30	12	18	0.0791676	-4.5769064	

* = selected model

Final Selected Model
4 Joinpoint(s)

H: Joinpoint regression trend analysis data for MI admissions in Liverpool between January 2004 and March 2012 in the 10 middle socioeconomically-ranked wards of Liverpool

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	293.84	286.64	
5	2005	**Q1**	292.76	284.16	
6		**Q2**	274.48	281.72	
7		**Q3**	268	279.28	
8		**Q4**	265.84	276.88	
9	2006	**Q1**	276.64	274.48	
10		**Q2**	294.92	272.12	
11		**Q3**	269.08	269.76	
12		**Q4**	269.08	267.44	
13	2007	**Q1**	242.16	265.16	
14		**Q2**	258.32	262.84	
15		**Q3**	284.16	260.6	
16		**Q4**	291.68	258.36	Joinpoint 1
17	2008	**Q1**	275.56	248.84	
18		**Q2**	215.28	239.68	
19		**Q3**	201.28	230.84	
20		**Q4**	209.88	222.36	
21	2009	**Q1**	213.12	214.16	
22		**Q2**	205.6	206.28	
23		**Q3**	195.88	198.68	
24		**Q4**	199.12	191.36	
25	2010	**Q1**	191.6	184.32	
26		**Q2**	179.76	177.52	
27		**Q3**	166.84	171	
28		**Q4**	166.84	164.72	
29	2011	**Q1**	159.32	158.64	
30		**Q2**	156.08	152.8	
31		**Q3**	133.48	147.16	
32		**Q4**	137.76	141.76	
33	2012	**Q1**	151.76	136.52	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	16	12	18

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	16	-0.9	-1.9	0.2
2	16	33	-3.7*	-4.3	-3.1

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.220956	-4.6842427	
#2	1 Joinpoint(s)	30	4	26	0.1131469	-5.1267723	*
#3	2 Joinpoint(s)	30	6	24	0.1005679	-5.0178798	
#4	3 Joinpoint(s)	30	8	22	0.0900131	-4.9020117	
#5	4 Joinpoint(s)	30	10	20	0.0813158	-4.7768801	
#6	5 Joinpoint(s)	30	12	18	0.0764994	-4.6111912	

* = selected model

Final Selected Model
1 Joinpoint(s)

I: Joinpoint regression trend analysis data for MI admissions in Liverpool between January 2004 and March 2012 in the 10 most affluent wards of Liverpool

Period	Time (Quarters)		Observed Rate	Joinpoint Modelled Trend	
4	2004	**Q4**	227.52	201.08	
5	2005	**Q1**	214.12	202.6	
6		**Q2**	180.68	204.12	
7		**Q3**	180.68	205.64	
8		**Q4**	176.2	207.16	
9	2006	**Q1**	223.08	208.72	
10		**Q2**	226.4	210.28	
11		**Q3**	233.12	211.84	
12		**Q4**	228.64	213.44	
13	2007	**Q1**	216.36	215.04	
14		**Q2**	214.12	216.64	
15		**Q3**	203	218.24	
16		**Q4**	221.96	219.88	
17	2008	**Q1**	233.12	221.52	Joinpoint 1
18		**Q2**	224.16	207.96	
19		**Q3**	185.16	195.2	
20		**Q4**	163.96	183.24	
21	2009	**Q1**	155.04	172.04	
22		**Q2**	171.76	161.48	
23		**Q3**	160.6	151.6	
24		**Q4**	148.32	142.32	
25	2010	**Q1**	130.48	133.6	
26		**Q2**	123.8	125.4	Joinpoint 2
27		**Q3**	124.92	125.96	
28		**Q4**	126.04	126.52	
29	2011	**Q1**	121.56	127.08	
30		**Q2**	137.2	127.64	
31		**Q3**	134.96	128.2	
32		**Q4**	133.84	128.76	
33	2012	**Q1**	118.24	129.32	

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	17	13	19
2	26	20	29

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI
1	4	17	0.7	-0.6	2.1
2	17	26	-6.1*	-8.7	-3.5
3	26	33	0.4	-2.9	3.9

* = significantly different from 0% rate of change

Test For Number of Joinpoints

Model	Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Bayesian Information Criterion	
#1	0 Joinpoint(s)	30	2	28	0.5123481	-3.843202	
#2	1 Joinpoint(s)	30	4	26	0.2820797	-4.21327	
#3	2 Joinpoint(s)	30	6	24	0.1686568	-4.5008475	*
#4	3 Joinpoint(s)	30	8	22	0.1608549	-4.321464	
#5	4 Joinpoint(s)	30	10	20	0.1280593	-4.3227271	
#6	5 Joinpoint(s)	30	12	18	0.1257466	-4.1142046	

* = selected model

Final Selected Model
2 Joinpoint(s)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract ***Reduction in Myocardial Infarction Admissions in Liverpool after the Smoking Ban: Potential Socio-Economic Implications for Policymaking***
		√ (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	√ Explain the scientific background and rationale for the investigation being reported
Objectives	3	√ State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	√ Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection. ***Setting and dates described, the other items not applicable.***
Participants	6	(*a*) e.g. *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up ***Time trend study used. Eligibility criteria: Hospital admission for CHD for residents with a Liverpool (city) UK address between 2004 and 2012, aged 16 and over.***
		(*b*) e.g. *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed ***Section not applicable***
Variables	7	√ Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable. ***Available within the HES data were sex and age, as well as diagnosis codes for MI and non-MI CHD. Socio-economic status was estimated at ward-level using Liverpool City Council socio-economic rankings.***
Data sources/ measurement	8*	√**.** For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. ***As 7 above.***
Bias	9	Describe any efforts to address potential sources of bias. ***Explicitly addressed in the discussion section.***
Study size	10	Explain how the study size was arrived at. ***Largest possible size aimed for. All eligible admissions considered as opposed to using a sample.***
Quantitative variables	11	√ Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why

Statistical methods	12	√ (*a*) Describe all statistical methods, including those used to control for confounding ***Basic statistical methods such as direct standardisation to a European population, and calculation of 95% confidence intervals were used. Specific more complex techniques, such as Joinpoint and ARIMA were also used which are discussed in the manuscript in their respective sections.***
		√ (*b*) Describe any methods used to examine subgroups and interactions ***Differences in sex, and differences in socioeconomic status were considered in the analysis. Socio-economic status was estimated at ward-level using Liverpool City Council socio-economic rankings.***
		(*c*) Explain how missing data were addressed ***The Hospital Episodes Statistics data set is a mandatory, routinely collected data set. Like any source of data, there is always the possibility of systematic, missed data that we are unaware of, however as a national, routine record it is assumed to be the most complete reasonably available data source.***
		(*d*) e.g. *Cohort study*—If applicable, explain how loss to follow-up was addressed ***Study was retrospective in nature***
		(*e*) Describe any sensitivity analyses. ***Entire population of interest was used via routinely collected HES data.***

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. ***All 56,995 admissions for CHD in Liverpool between 2004 and 2012 for patients aged 16 and over were included.***
		(b) Give reasons for non-participation at each stage ***Not applicable***
		(c) Consider use of a flow diagram ***Not applicable***
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. ***See Table 1 and Table 2 for descriptive data for HES admissions used.***
		(b) Indicate number of participants with missing data for each variable of interest ***HES (cleansed and quality checked database) data was complete at time of reaching researcher.***
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) ***Not applicable***
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time ***56,995 admissions for CHD overall, of which 6,356 admission with a diagnosis of MI were recorded.***
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	√ (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included.
		√ (*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period. ***Not applicable***
Other analyses	17	√ Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses. ***Analyses by gender, diagnosis, and socioeconomic stratum are included in the study.***

Discussion		
Key results	18	√ Summarise key results with reference to study objectives
Limitations	19	√ Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	√ Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results. ***Results assumed to be representative of the specific Liverpool population in question (complete HES data used). Some cautious interpretation has been used to discuss the generalisability to populations of***

		similar poor health, behavioural and socioeconomic characteristics. The evidence base for smoking legislation on any (generic) populations is also considered in the discussion.
Other information		
Funding	22	√Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based. ***Study not externally funded.***

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.