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Declining maternal smoking prevalence did not change low birthweight prevalence in Massachusetts from 1989 to 2004

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Background: Maternal smoking is associated with low birthweight (LBW). LBW prevalence is increasing in the US. However, it is unclear whether a fall in maternal smoking has any impact on the LBW prevalence in Massachusetts, a state with a comprehensive tobacco control program since 1993. **Methods:** Temporal patterns in prenatal maternal smoking and in LBW prevalence were quantified between 1989 and 2004, using Massachusetts Community Health Information Profile database. Yearly population-attributable-risk (PAR %) of singleton LBW live-births among pregnant smoking mothers were estimated based on a summary relative risk. The expected number of LBW babies attributable to reductions in maternal smoking in 2004 relative to 1989 was compared to the actual number of LBW babies in 2004. **Results:** Of 88 929 and 74 554 singleton live-births, 4297 and 4004 LBW births occurred in 1989 and 2004, respectively. Between 1989 and 2004, maternal smoking prevalence significantly declined yearly by $\geq$6% (from 19.9% to 6.8%) but overall LBW prevalence increased yearly by <1% (from 4.8% to 5.4%), with a significant yearly increase (<1%) in moderately LBW (1500–2499 g) prevalence. Yearly PAR % declined from 20.3% (n = 872) to 8.0% (n = 320), with an expected total of 3745 [4297 – (872 – 320)] LBW babies in 2004 relative to 1989. However, actual LBW babies numbered 4004 in 2004. The 259 above predicted (4004 – 3745) LBW babies born in 2004 being attributed to factors other than prenatal maternal smoking. **Conclusions:** Massachusetts experienced a decline in prenatal maternal smoking prevalence, but an increase in moderately LBW prevalence has offset the potential gains apparently achieved due to reductions in maternal smoking prevalence.

Keywords: low birthweight, Massachusetts, pregnancy, smoking

Introduction

Smoking during pregnancy has long been recognized as one of the leading preventable causes of low birthweight (LBW), babies weighing <2500 g. A dose-response relationship exists between the number of cigarettes smoked during pregnancy and LBW.[1,2] Studies have also shown that prenatal maternal smoking is associated with almost 2-fold increased risk of LBW birth compared to never-smoking mother.[3,4] In recent years, LBW prevalence is increasing among the industrialized countries.[5,6] A conflicting body of evidence exists regarding the recent increase in LBW prevalence. However, it is unclear whether the recent increase in LBW prevalence is a real increase, and whether a fall in prenatal maternal smoking prevalence has any impact on the LBW prevalence.

Massachusetts experienced a dramatic fall in overall adult smoking prevalence since the introduction of the Massachusetts Tobacco Control Program in January 1993.[7] Currently, there is no quantitative information on the changing temporal patterns in prenatal smoking prevalence, in the overall LBW prevalence, and also within the sub-groups of LBW in Massachusetts. In addition, any falls in prenatal maternal smoking prevalence could in part contribute to fewer LBW births. This study, therefore, examines the following objectives in Massachusetts.

- Describe and quantify temporal patterns in overall LBW prevalence and within sub-groups of LBW [moderately LBW (1500–2499 g) and very LBW (<1500 g)], as well as in prenatal maternal smoking prevalence between 1989 and 2004.
- Estimate the overall reduction in singleton LBW live-births potentially attributable to decreased prenatal maternal smoking prevalence in 2004 relative to 1989 and to compare the expected number of LBW babies to the actual number of LBW babies in 2004.

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Methods

Data sources

The Massachusetts Department of Public Health's electronic database: Massachusetts Community Health Information Profile (Mass CHIP) (http://masschip.state.ma.us/about.htm) is a state-wide comprehensive database for a range of health and disease outcomes. This study uses Mass CHIP database to abstract birth certificate data (natality records) from 1989 to 2004. Mass CHIP receives the birth certificate file and the linked birth-infant death file directly from the Massachusetts Registry of Vital Records and Statistics.

Exposure and outcomes studied

Prenatal maternal smoking is the exposure of interest. Such information is based on self-reported maternal smoking history on birth certificates ('Did you smoke during pregnancy? [Yes/no]'. Although self-reported data is a methodological limitation, there is evidence supporting the validity of such self-reported data.[8] The main outcome studied is LBW birth. All analyses included singleton live-births only. Mothers, with no self-reported smoking information, were excluded from the final analyses, and this includes <0.3% of total live-births.

Estimation of fewer LBW births

Yearly prenatal smoking prevalence was derived from Mass CHIP database among mothers who had singleton live-births. Relative risk (RR) was estimated to quantify the strength of association between LBW and maternal smoking for each calendar year. A summary RR (with 95% CI) was also calculated. Yearly RR estimates were applied to calculate the yearly population-attributable- risk (PAR × 100), which is conventionally calculated as

$$[P \times (RR - 1)]/[(1 + P \times (RR - 1)],$$

where P is the prenatal maternal smoking prevalence.

Finally, the total fewer smoking-attributable LBW births were calculated, as follows.

Let c_i = smoking-attributable LBW live-births in year 'i', $i = 1989, \cdots, 2004$ and $d_i = c_{i-1} - c_i$ for $i = 1990, \cdots, 2004$.

Therefore,

$$\text{total fewer LBW births} = \sum_{i=1990}^{2004} d_i = \sum_{i=1990}^{2004} (c_{i-1} - c_i) = \sum_{i=1989}^{2003} c_i - \sum_{i=1990}^{2004} c_i = c_{1989} - c_{2004}$$

Time-trend analyses in LBW and in prenatal smoking prevalence rates

Log-linear Poisson regression models were employed for trend analysis and to quantify changing temporal patterns by calculating the annual-percent-changes in prenatal maternal smoking prevalence and in LBW prevalence from 1989 to 2004.

Results

Of 4297 and 4004 LBW births in 1989 and in 2004, 872 (20.3%) and 320 (8.0%) were smoking-attributable LBW births, respectively (table 1). Table 1 also details the overall prenatal maternal smoking and the overall LBW prevalence in Massachusetts between 1989 and 2004, and also the yearly smoking-attributable LBW births based on the yearly PAR%. Between 1989 and 2004, a relative decline of 66% (from 19.9% to 6.8%) was observed in prenatal maternal smoking prevalence, but a 13% (from 4.8% to 5.4%) relative increase in LBW prevalence was observed, respectively. PAR% decreased from 20.3% to 8.0% over the same periods, with an expected total of 3745 [4297 − (872 − 320)] LBW babies in 2004 relative to 1989. However, 4004 LBW babies were actually born in 2004. The 259 (4004 − 3745) excess LBW babies born in 2004 being attributed to factors other than prenatal maternal smoking. Yearly RRs remained almost constant between 1989 and 2004. The summary RR used for the calculation of yearly PAR was 2.28 (95% CI: 2.23–2.32), indicating that smoking mothers were more than twice as likely to deliver LBW babies as never-smoking mothers.

Table 2 shows regression analyses quantifying the temporal patterns in both prenatal maternal smoking prevalence and in LBW prevalence rates across specific individual sub-groups. Prenatal maternal smoking prevalence is significantly declining on a yearly basis (≥6%) across all categories of birth-weights, but the yearly decline among mothers with VLBW babies was the greatest (>7%), and among the moderately LBW the lowest (<6%). In contrast, the yearly increase in VLBW prevalence was also the highest (1%) but not statistically significant from zero at $P = 0.05$; only the moderately LBW prevalence showed a significant yearly rise of <1%.

Discussion

This study showed that despite an overall 65% relative decline in prenatal maternal smoking prevalence, a yearly increase in the overall LBW prevalence, and significantly in the moderately LBW prevalence, was observed in Massachusetts. Such an increase in LBW prevalence is consistent with evidence from

Table 2 Regression analyses showing annual-percent-changes in prevalence rates (%) of prenatal maternal smoking and LBW among singleton live-births in Massachusetts, 1989–2004

Categories of births	Annual percent changes (95% CIs)
Prenatal maternal smoking prevalence	
Total live-births	−6.71 (−7.12 to −6.29)*
Normal birthweight births	−6.95 (−7.32 to −6.58)*
LBW births	−5.97 (−6.53 to −5.40)*
Moderately LBW (1500–2499 g) births	−5.82 (−6.37 to −5.28)*
Very LBW (<1500 g) births	−7.33 (−8.38 to −6.27)*
LBW prevalence	
Total LBW (<2500 g) births	0.78 (0.54 to 1.02)
Moderately LBW (1500–2499 g) births	0.72 (0.47 to 0.96)*
Very LBW (<1500 g) births	0.98 (0.43 to 1.52)

*Statistically significant from zero at $P = 0.05$.

Table 1 Prevalence rates of LBW and prenatal maternal smoking in singleton live-births and PAR % of LBW born to smoking mothers in Massachusetts between 1989 and 2004

Year	LBW prevalence	Maternal smoking prevalence (%)	PAR (%)	Total live-births	Total LBW births	Smoking-attributable LBW births
1989	4.8	19.9	20.3	88 929	4297	872
1990	4.7	17.6	18.4	89 809	4208	774
1991	4.7	16.1	17.1	85 615	4027	689
1992	4.7	14.8	15.9	84 529	3946	627
1993	4.8	15.0	16.1	81 887	3911	630
1994	5.0	13.6	14.8	81 030	4006	593
1995	4.9	12.2	13.5	78 743	3846	519
1996	4.8	11.9	13.2	76 652	3648	482
1997	5.1	11.1	12.4	76 908	3904	484
1998	4.9	10.5	11.8	77 786	3809	449
1999	5.0	9.8	11.1	77 215	3861	429
2000	5.0	9.6	10.9	77 700	3867	422
2001	5.1	8.4	9.7	77 208	3914	380
2002	5.2	7.3	8.5	76 507	3960	337
2003	5.3	6.9	8.1	76 194	3993	323
2004	5.4	6.8	8.0	74 554	4004	320

both Europe and the US.[5,6] Assuming an independent causal relation with no interactions between other potential risk factors, 3745 LBW babies were expected to be born in 2004 relative to the 1989 LBW estimates ($n = 4297$), and those fewer LBW babies were entirely attributed to reductions in prenatal maternal smoking since 1989. However, we actually observed 4004 LBW babies born in 2004. Therefore, the 259 excess LBW babies born in 2004 are entirely or in part attributed to factors other than prenatal maternal smoking. Such observations highlight that the potential gains achieved due to substantial declines in maternal smoking prevalence were apparently offset due to some underlying factors contributing to the increasing LBW prevalence observed in Massachusetts.

Recent increase in multiple births from factors such as assisted reproductive technology might contribute to increased LBW prevalence.[5,6] However, our study included only singleton births. Better monitoring and modern diagnostic facilities in recent years might contribute to increased intra-uterine survival rates of fetuses, thereby reducing peri-natal and fetal death rates.[5,9] Consequently, an increase in preterm births could contribute to increased LBW prevalence.[5,9] An increased trend in preterm births in recent years has also been reported.[5] Evidence also suggests that the increased use of Caesarean section deliveries might contribute to increased LBW babies.[6,10] Caesarean section deliveries have increased dramatically over the past decade both in the United States and elsewhere.[5,6] Other factors, such as ethnicity, the lack of adequate prenatal care or limited access to health insurance schemes might indirectly contribute to increased LBW babies.[11,12] In short, it is worth considering in future studies to look at the potential factors contributing to increased LBW prevalence both in Massachusetts and elsewhere.

Furthermore, significant yearly increase of almost 1% in LBW babies (particularly in the moderately LBW category) strongly suggests that there is a real increase in LBW prevalence and such an increase points towards a secular trend. A significant yearly increase in the moderately LBW prevalence is also consistent with the recent nationwide report.[5] However, the reasons for such an increase are not clear. In contrast, the current overall maternal smoking prevalence of 6.8% in 2004 is well below the 2010 US Healthy People Objective of 11%.[13] Such a positive health gain could perhaps in part be attributed to the comprehensive Massachusetts Tobacco Control Program (MTCP) introduced in 1993.[7] It would be worth considering whether the MTCP had any impacts on the maternal smoking prevalence rates *per se*.

Strengths and limitations

Strength of this study is that we used a comprehensive statewide database and excluded only <0.3% of the target population, and therefore the findings are generalizable. Although the smoking status of pregnant women is self-reported, there is evidence supporting the validity of such self-reported data.[8] Nonetheless, the extent to which under-reporting of smoking during pregnancy may or may not occur is unknown, thereby introducing some exposure misclassification bias and also recall bias. In addition to residual confounding, we did not look at other potential confounders that might have influenced the study findings. It was also not apparent from our study analyses that how many mothers initiated and stopped smoking during different stages of their gestational periods. The visibility of the comprehensive MTCP might have increased the awareness of the link between smoking and adverse birth outcomes among pregnant women and thus made it less likely that they would accurately report smoking behavior on the birth certificate. Although prenatal smoking may be underreported on the birth certificate, the trends and variations in smoking based on birth certificate data are reliable.[14]

Conclusions

In conclusion, Massachusetts experienced a significant yearly decline of ≥6% in maternal smoking prevalence during pregnancy between 1989 and 2004, but a significant yearly increase of <1% in the moderately LBW prevalence was also observed. This study estimated 259 excess LBW babies in 2004 relative to 1989 that are potentially attributable to worsening trends in LBW risk factors other than prenatal maternal smoking, thereby, apparently reversing the potential gains achieved due to reductions in maternal smoking prevalence since 1989. Therefore, it is essential to identify the underlying factors contributing to such increased LBW prevalence seen in Massachusetts and elsewhere in the United States and in Europe.

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Conflicts of interest: None declared.

Key points

- A significant yearly decline of ≥6% in maternal smoking prevalence over a 15-year period did not improve the overall LBW prevalence in Massachusetts, a state with a comprehensive tobacco control program since 1993.
- Only the moderately LBW (1500–2499 g) prevalence showed a significant yearly increase of <1%.
- An excess of 259 LBW babies were actually born in 2004 relative to 1989 that might be attributed to factors other than prenatal maternal smoking.
- Health gains achieved due to substantial reductions in maternal smoking were apparently offset due to risk factors other than prenatal maternal smoking that potentially contributed to the increased LBW prevalence.
- The need for identifying underlying factors contributing to the increased LBW prevalence both in the United States and in Europe.

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