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Accessibility
Teenage smoking behaviour following a high-school smoking ban in Chile: interrupted time-series analysis
Andrea B Feigl, Joshua A Salomon, Goodarz Danaei, Eric L Ding & Esteban Calvo

Objective To evaluate the effect of a smoking ban in high schools on smoking behaviour among Chilean students.

Methods We conducted an interrupted time-series analysis, using repeated cross-sectional data from Chile's school population survey (2000–2011) for high-school students aged 12–18 years and a control group of persons aged 19–24 years. Poisson regression models were used to assess trends in smoking behaviour before and after the policy changes. The outcome measures were self-reported smoking prevalence (any smoking in the past month) and high frequency of smoking (smoking 15 days or more per month).

Findings From 2005 to 2011, the prevalence of smoking declined among high-school students by 6.8% per year compared with 3.6% decline per year in the control group. The decline in the target group was 2.9% (95% confidence interval, CI: 0.18 to 5.00) greater. We estimated that 5–6 years after enforcing the law, smoking prevalence among high-school students was 13.7% lower as a result of the ban. The impact of the smoking ban was primarily driven by declines in smoking prevalence among students in grades 8 to 10. The smoking ban did not significantly alter the frequency of smoking.

Conclusion The 2005 school smoking ban reduced smoking prevalence among younger high-school students in Chile. Further interventions targeting older individuals and frequent smokers may be needed.

Introduction
The detrimental health effects of tobacco smoking and use are widely documented. Every year, first-hand smoking causes five million deaths globally and 80% of smoking-related deaths occur in low- and middle-income countries. To reduce such mortality and morbidity, policy-makers can enforce policies such as public smoking bans, subsidized cessation programmes, tobacco warning labels and tax increases. However, the effect of these legislative changes differ based on context – compliance with smoking bans might be higher in countries with lower smoking prevalence.

There is a high prevalence of tobacco smoking in Chile, with 44% of adult males and 38% of adult females smoking in 2011, which was the highest prevalence in Latin America at that time. In 2009, Chile also had the second highest teenage smoking prevalence on the Global Youth Tobacco Survey, with an annual smoking prevalence of 34.2%. The Chilean government ratified the WHO Framework Convention on Tobacco Control in 2005 and passed tobacco legislation that took effect on 1 January 2006.

One provision in the legislation is a smoking ban, including a cigarette sales ban, within 300 metres of all high schools, which was the only provision that was enforced with 100% reported compliance (further information available from author). Preliminary evidence suggests that between 2005 and 2011, there was a decline in smoking prevalence among high-school students, but not in the general adult population. Here we assess changes in smoking prevalence among high-school students before and after the smoking ban.

Methods

Study design
We used interrupted time-series to evaluate trends in smoking prevalence before and after the smoking ban in the target population (high-school students aged 12–18 years) and compared it to the general population aged 19–24 years, which we assumed to be unaffected by the ban. We assumed a similar institutional environment in both groups, since in Chile, over 40% of individuals aged 19–24 years attended a university or a secondary institution in 2008. To ensure that the control group did not include anyone subjected to the ban, the control population in 2000/2001 to 2006/2007 included individuals aged 19–24 years; in 2008/2009 individuals aged 20–24 years; and in 2010/2011 individuals aged 22–24 years.

Data
For the target population, we used data from the school population survey – a biennial and regionally representative survey on substance abuse and addictive behaviour in the Chilean school population, including the last grade of primary school (8th grade, mean age 13.5 years) and the high-school population (9th to 12th grade, ages 14–18 years). The school surveys were conducted in odd years; data from 2001–2011 were used in the analyses. The school population survey employed a stratified, probabilistic two-stage sampling procedure.

For the control population, we used data from the general population survey, conducted in even years, for 2000–2010. We combined data from the school and the general population surveys for before (2000/2001, 2002/2003 and 2004/2005) and after (2006/2007, 2008/2009 and 2010/2011) the implementation of the law. For each biennium, we analysed an average sample size of 50,000 individuals in the target group and 2300 individuals in the control group (further details available from the author).

Statistical analyses
To compare trends in smoking prevalence, we used self-reported, past 30-day smoking prevalence (yes/no) as the primary outcome measure. We used Poisson regression models to estimate changes in smoking prevalence over time, using year as the exposure variable. We built the Poisson regression models with an offset term for the log of the sample size and a smooth function of time to account for calendar time trends in smoking prevalence. We estimated the difference between the decline in smoking prevalence among high-school students before and after the ban by comparing the coefficient estimates from models with and without the smoking ban as an additional covariate.
outcome. As a secondary outcome, we created a frequent smoking variable indicating smoking 15 or more days per month during the last month (yes/no).

To model the outcomes, we used Poisson regression models to estimate prevalence ratios. The models were run separately for control and target groups due to different variances arising from different samples and sample frames. In multivariable regression models, we controlled for age, sex and region and included an interaction term for age and sex. For the target group we also controlled for school type, grade-level and grade point average, and in the control group for socioeconomic status and method of survey administration. Absence of data in covariates was generally lower than 2% and the complete case method was chosen for the main analysis. We then conducted a two-sample t-test with unequal variances conducted on the estimated coefficient for post-intervention change in the target group compared to the coefficient in the control group. All analyses were performed using Stata version 12 (StataCorp LP, College Station, United States of America).

We used a 2-stage model with time-dependent spline term for trend before and after 2005 (Table 1). At stage 1, we ran separate robust Poisson regression models for each intervention and control group, specified as follows:

\[ Y_t = \beta_0 + \beta_1 X_t + \beta_2 X_{t-1} + \beta_3 (\text{covariates})_t + \epsilon_t \]

where \( Y \) represents the binary smoking variable of interest, for individual \( i \) at time \( t \); \( \epsilon \) represents standard errors clustered at the municipal level (high schools) and regional level (universities) and \( t \) represents the time period. In the first stage, the models (model a and model b) were run separately for each group.

At stage 2, we were interested in the \( \beta \) coefficients of each model, reflecting the annual rate of change in smoking prevalence during the post-intervention period, relative to the annual rate of change in the pre-intervention period.

### Results

We obtained data on 319,798 individuals surveyed between 2000 and 2011. Characteristics for the target and control groups are presented in Table 2. Unadjusted for covariates, 30-day smoking prevalence among high-school students was highest in 2000/2001, with a prevalence of 41.9% (23,822/56,817) and slightly declining to 40.1% (23,678/59,101) in 2004/2005. After the implementation of the law, the prevalence declined to 25.7% (8,596/33,509) in 2010/2011. Smoking prevalence in the control group was higher overall, with the highest in 2002/2003 (58.2%; 1132/1945). Before the law came into effect the prevalence was 57.3% (1104/1927) which then steadily declined to 44.9% (405/902) by 2010/2011. Immediately after 2005, there was a greater decline in smoking prevalence among high-school students than among the control population (40.1% to 34.9% and 57.3% to 54.8%, respectively).

Smoking frequency was higher in the control group than in the target group. In 2002/2003, high-school individuals smoked an average of 16.5 days per month, which declined to 15.0 days per month in 2006/2007 and further dropped to 13.0 days per month in 2010/2011. The number of days smoked per month in the control group was relatively stable between 2000 and 2011, with a peak of 21.4 days during 2004/2005 and by 2010/2011 this had declined to 19.9 days. In all groups and grades, average smoking frequency was highest in 2002/2003 and lowest in 2010/2011. Smoking prevalence and fre-

### Ethics approval

The study was exempt from ethics approval as it only used secondary data from surveys that had followed conventional ethics guidelines and recorded no personal identifiers.

### Table 1. Values for time period variable in first stage Poisson regressions to estimate trends in tobacco smoking, Chile, 2000–2011

| Time period | Survey period |
|-------------|---------------|
| 2000/2001   | 1             |
| 2002/2003   | 3             |
| 2004/2005   | 5             |
| 2006/2007   | 7             |
| 2008/2009   | 9             |
| 2010/2011   | 11            |

The first null hypothesis (H_0) was tested in the analyses was:

\[ \beta_a = \beta_b \]

the second null hypothesis (H_1) was:

\[ \beta_a = 0 \]

the third null hypothesis (H_2) was:

\[ \beta_b = 0 \]

H_1 was tested via a two-sample t-test with unequal variances, and H_2 and H_3 were tested via the significance test of the coefficient in each model.

We conducted several sensitivity analyses: (i) including all aged 19–24 years in the control population; (ii) running analogous analyses using past 30-day cannabis use as the main outcome (to test for the specificity of the school smoking ban on smoking behaviour versus addictive behaviour in general); (iii) including only those municipalities measured in every survey; (iv) excluding individuals with less than high-school education in the control group; (v) including additional control variables (alcohol consumption and religion); (vi) including additional control variables (alcohol consumption, religion, and paternal education); (vii) adjusting for survey weights; (viii) adjusting for complex survey design; (ix) using the general population survey for individuals aged 19–64 years as the control population; and (x) using the missing indicator method to account for missing data. For smoking frequency, we conducted the two sensitivity analyses – adjusting for complex survey design and stratifying the analysis by grade level in the target group – to investigate the robustness of the result.

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Smoking frequency increased with increasing school grade (data available from author).

**Smoking prevalence**

Adjusting for covariates in the multivariable regression model, smoking prevalence significantly increased among high-school students over the period 2000–2005, from an adjusted smoking prevalence of 37.4% in 2000/2001, to an adjusted smoking prevalence of 38.6% in 2004/05 ($P = 0.014$); there was no significant trend observed in the control group. After 2005, there was a significant decline in smoking prevalence in the target group ($P < 0.001$), resulting in an adjusted smoking prevalence of 24.9% in 2010/11 in the high-school population. The prevalence ratio of the smoking prevalence change before versus after the law in the control versus the target group was 0.971 annually (95% confidence interval, CI: 0.950 to 0.992), or 0.863 (95% CI: 0.774 to 0.961) over the course of the intervention (Table 3). Thus, smoking prevalence after 2005 declined significantly faster in the target group than in the control group.

Since the descriptive analysis revealed a difference in smoking prevalence among different high-school grades (data available from author), a grade-based stratified analysis was done to determine the grades in which the law had the greatest effect. The smoking ban was most effective among students in the lowest grade, leading to a 7.2% (95% CI: 4.3 to 10.1) annual improvement in smoking trend in this population versus the control group. The ban was least effective among students in the two highest grades, where no significant effect on smoking prevalence was detected (Table 4).

**Smoking frequency**

Before the ban, frequent smoking in the target group declined by 2.5% annually from 2000 to 2005 (95% CI: -4.1 to -0.8); while in the control group no significant trend was observed. After 2005, the difference in smoking frequency between the target and control group was not significant ($P = 0.58$; Table 5).

**Sensitivity analyses**

When examining the changes in cannabis use before and after the implementation of the law, after 2005 cannabis use increased significantly in the target group, but declined in the control population. Hence, after 2005, past 30-day...
Table 3. Changes in smoking prevalence before and after the implementation of a high-school smoking ban in Chile, 2000–2011

| Policy period               | Target group | Control group | Intervention effect |
|-----------------------------|--------------|---------------|---------------------|
| Pre-policy (2000–2005)      | 1.006 (1.001 to 1.012) | 1.010 (0.999 to 1.02) | 0.971 (0.950 to 0.992) |
| Post-policy (2006–2011)     | 0.932 (0.927 to 0.937) | 0.964 (0.953 to 0.974) | 0.863 (0.774 to 0.961) |
| Difference between pre-     | 0.926 (0.917 to 0.934) | 0.953 (0.935 to 0.973) |                     |
| policy and post-policy      |               |               |                     |
| Per year                    |               |               |                     |
| Five years                  |               |               |                     |

CI: confidence interval; PR: prevalence rate ratio.

a PRs represent the annual decrease in smoking prevalence.

b High-school population aged 12–18 years. Adjusted for age, sex, region, school-type, course, and sex * age.

c Aged 19–24 years. Adjusted for age, sex, region, socioeconomic status, survey method, and sex * age.

d Difference in changes of smoking prevalence between target and control group.

The similar decline in frequent smoking in both groups suggests that the ban did not affect how often people smoke and therefore better-targeted programmes and policies are needed for frequent smokers. Examples of effective programmes include smoking-cessation counselling in high schools and free prescription of nicotine patches. Legislation featuring such programmes has been proposed, but not yet passed or funded in Chile.

Several sensitivity analyses supported the robustness of our results. When we included all individuals aged 19–24 years in the control group, we found that the effect estimate was lower since the control group in 2008 and 2010 also included people previously targeted by the law. In contrast, when including only those with a high-school diploma in the control group, the effect size increased. A possible explanation is that those with at least a high-school diploma continued, rather than altered, their smoking behaviour between 19 and 24 years of age. Applying cannabis use as the main outcome suggested that relative to the control group, cannabis use in high-school students increased after the implementation of the law. This is further evidence that the decline in smoking prevalence among high-school students is attributable to the smoking ban. Our findings confirm results from previous studies that increased difficulty of obtaining cigarettes was associated with less positive views about smoking among adolescents and lower smoking prevalence among Chilean teenagers.

In addition to the immediate effect of the law, the long-term effect on disease burden should also be considered. Emerging evidence suggests that adolescence is the most critical period in life for development of long-term addictive behaviours. In the USA, it has been shown that laws on youth access to tobacco might have long-term effects on smoking prevalence, however, these effects might be limited to women only. To estimate whether the smoking ban would have a long-term effect on morbidity, one can use a life table approach such as the 1960–1972 American cohort. In this cohort, the mortality rate in men aged 35–39 years, who have never smoked regularly, was 1.34 per 1000 person-years, versus 2.55 in those who smoked one or more packs of cigarettes per day. In the age group 40–44 years, mortality in men who never smoked was 1.93 per 1000 person-years, versus 4.59 in frequent smokers (smoking more than 20 cigarettes per day). Overall mortality rates in women were lower in both smokers and non-smokers, but still substantially higher in frequent smokers than non-smokers. Assuming that the mortality rates from this American cohort apply to the current Chilean high-school population and that the effect of the ban on prevalence persists long-term, the Chilean high-school smoking ban could potentially reduce mortality by more than twofold 20 years from now. This reduction would result in better health outcomes for a large number of people as well as reducing health expenditure on smoking-related diseases like lung cancer or chronic obstructive pulmonary disease. However, there is uncertainty as to how long this effect on smoking behaviour will last, and long-term assessments are needed.

This study has limitations. First, individuals were not randomly assigned to the target group and control group. However, all provisions of the 2005 law uniformly affected Chile’s general population (data available from author).
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Thus, even if the law affected the control group, the same section of the law also affected the target group. Second, the average age of smoking initiation was 13.2 years in Chile and older individuals are less likely to start or quit smoking. Hence, individuals in the control group (19–24 years) – both smokers and non-smokers – may have a lower propensity to change their behaviour in response to a similar ban. This could have led to an upward bias in the effect size estimates. However, in a sensitivity analysis using the general population aged 25–64 years as a control group, the effect sizes were not significantly higher. Third, the cross-sectional design of our study means that we cannot identify specific outcomes of the ban at an individual level. We can not distinguish, for example, whether the ban prevented people from starting smoking or encouraged current smokers to stop. Neither can we estimate the effect of the ban on overall levels of tobacco consumption per capita. Fourth, there were no data on how schools enforced the ban. Additional data on compliance with the smoking ban at Chilean high schools – similar to a study conducted in India – could have further strengthened our conclusions.

Smoking prevalence is often highly correlated with socioeconomic status. In our study, socioeconomic status variables in both target and control groups were highly collinear with neighbourhood. For this reason, socioeconomic status variables were omitted from the main analyses. Future studies could explore equity concerns relating to the high-school smoking ban.

In conclusion, smoking bans in schools can be effective in reducing the number of teenagers smoking. However, they may help to further decrease smoking prevalence. In addition, interventions that target school-age youth may also help to reduce smoking initiation and increase the age at which the first cigarette is smoked. These are important findings for public health professionals who work with youth. The results of this study provide evidence that smoking bans in schools can be effective in reducing smoking among teenagers. However, further research is needed to determine the long-term effects of these interventions.

### Table 4. Changes in smoking prevalence before and after the implementation of a high-school smoking ban in Chile, 2000–2011 by school grade

| Policy period | Annual prevalence change, PR (95% CI) | Control group<sup>c</sup> |
|---------------|--------------------------------------|-------------------------|
|               |                                      | 8th                     | 9th                     | 10th                    | 11th                    | 12th                    |
| Pre-policy (2000–2005) | 1.02 (1.001 to 1.03) | 1.01 (0.999 to 1.02) | 1.01 (0.999 to 1.02) | 0.998 (0.990 to 1.01) | 0.995 (0.941 to 1.00) | 1.010 (0.999 to 1.02) |
| Post-policy (2006–2011) | 0.898 (0.886 to 0.910) | 0.930 (0.923 to 0.938) | 0.930 (0.923 to 0.937) | 0.940 (0.934 to 0.947) | 0.948 (0.941 to 0.956) | 0.964 (0.953 to 0.974) |
| Difference between pre-policy and post-policy | 0.928 (0.899 to 0.957) | 0.967 (0.943 to 0.992) | 0.968 (0.945 to 0.992) | 0.988 (0.965 to 1.01) | 1.00 (0.975 to 1.02) |
| Intervention effect<sup>d</sup> | 0.928 (0.899 to 0.957) | 0.967 (0.943 to 0.992) | 0.968 (0.945 to 0.992) | 0.988 (0.965 to 1.01) | 1.00 (0.975 to 1.02) | NA |

CI: confidence interval; NA: not applicable; PR: prevalence rate ratio.
<sup>a</sup> PRs represent the annual decrease in smoking prevalence.
<sup>b</sup> High-school population aged 12–18 years. Adjusted for age, sex, region, school-type, course, and sex * age.
<sup>c</sup> Aged 19–24 years. Adjusted for age, sex, region, socioeconomic status, survey method, and sex * age.

### Table 5. Change in prevalence of high frequency smoking<sup>a</sup> before and after the implementation of a high-school smoking ban in Chile, 2000–2011

| Policy period | Annual prevalence change, PR (95% CI) |
|---------------|--------------------------------------|
|               | Target group<sup>c</sup> | Control group<sup>d</sup> |
| Pre-policy (2000–2005) | 0.975 (0.959 to 0.992) | 0.992 (0.959 to 1.03) |
| Post-policy (2006–2011) | 0.924 (0.916 to 0.932) | 0.953 (0.938 to 0.969) |
| Difference between pre-policy and post-policy | 0.947 (0.926 to 0.969) | 0.961 (0.919 to 1.00) |
| Intervention effect<sup>e</sup> | 0.986 (0.938 to 1.036) |

CI: confidence interval; PR: prevalence rate ratio.
<sup>a</sup> Smoking more than 15 days per month.
<sup>b</sup> PRs represent the annual decrease in smoking prevalence.
<sup>c</sup> High-school population aged 12–18 years. Adjusted for age, sex, region, school-type, course, and sex * age.
<sup>d</sup> Aged 19–24 years. Adjusted for age, sex, region, socioeconomic status, survey method, and sex * age.
<sup>e</sup> Difference in changes of smoking prevalence between target and control group.
the reduction in smoking among students during these years. The intervention targeted individuals aged 19–24 years and the intervention was conducted as educational programs in secondary schools.

Results

The intervention resulted in a decrease of 3.6% per year in the secondary school population. In comparison, the reduction rate was much lower in the control group (0.18% per year, 95% CI: 0.18–5.00).

Discussion

The results of the present study indicate that the high-school smoking ban in Chile was effective in reducing smoking prevalence among students aged 19–24 years. The reduction rate was significantly higher in the intervention group compared to the control group. The intervention was conducted as educational programs in secondary schools and included the implementation of comprehensive smoking cessation programs.

Conclusion

The results of this study suggest that high-school smoking bans can be effective in reducing smoking prevalence among adolescents. The implementation of comprehensive smoking cessation programs in secondary schools is recommended as a strategy to reduce smoking among adolescents.

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Competing interests: None declared.

Research

High-school smoking ban in Chile

Comportement tabagique des adolescents à la suite d’une interdiction de fumer dans les établissements d‘enseignement secondaire du Chili: analyse de séries chronologiques interrompues

Objectif

Evaluer les conséquences d’une interdiction de fumer dans les établissements d‘enseignement secondaire sur le comportement tabagique des élèves chiens.

Méthodes

Nous avons effectué une analyse de séries chronologiques interrompues à l’aide de données transversales répétées provenant d’une enquête sur la population scolaire du Chili (2000-2011) menée auprès d’élèves du secondaire âgés de 12 à 18 ans et d’un groupe de contrôle constitué d’individus âgés de 19 à 24 ans. Des modèles de régression Poisson ont été utilisés pour évaluer l’évolution du comportement tabagique avant et après les changements d’orientation. Les mesures de résultat reposaient sur les auto-déclarations de prévalence du tabagisme (toute consommation de tabac au cours du mois passé) et de fréquence élevée de consommation de tabac (consommation de tabac 15 jours ou plus par mois).

Résultats

De 2005 à 2011, la prévalence du tabagisme a diminué de 6.8 % par an chez les élèves du secondaire; en comparaison, elle a diminué de 3.6 % par an dans le groupe de contrôle. La diminution observée dans le groupe cible était supérieure de 2.9 % (intervalles de confiance, IC, à 95 %: 0.18 à 5.00). Nous avons estimé que 5-6 ans après l’entrée en vigueur de la loi, la prévalence du tabagisme chez les élèves du secondaire avait diminué de 13.7 % grâce à l’interdiction. L’impact de l’interdiction de fumer s’est principalement traduit par une diminution de la prévalence du tabagisme chez les élèves des 8e, 9e et 10e années. L’interdiction de fumer n’a pas considérablement changé la fréquence de consommation de tabac.
El consumo de tabaco entre adolescentes tras la prohibición de fumar en los institutos de Chile: análisis de series temporales interrumpidas

**Objetivo** Evaluar el efecto de la prohibición de fumar en los institutos sobre el consumo de tabaco entre los alumnos chilenos.

**Métodos** Se llevó a cabo un análisis de series temporales interrumpidas utilizando datos transversales repetidos obtenidos de la encuesta de la población escolar de Chile (2000-2011) en alumnos de instituto de entre 12 y 18 años y con un grupo de control de personas de entre 19 y 24 años. Se utilizaron modelos de regresión de Poisson para evaluar las tendencias en el consumo de tabaco antes y después de los cambios en la política. Los indicadores de resultados eran la prevalencia autodeclarada del consumo de tabaco (12–18 años) y con un grupo de control de personas de entre 19 y 24 años. Para más de 18–24 años, y de las intervenciones ciblant des individus plus âgés et des fumeurs fréquents pourraient être nécessaires.

**Resultados** Durante 2005 hasta 2011, la prevalencia del consumo de tabaco entre los alumnos de instituto era un 13,7% menor como consecuencia de la prohibición. El impacto de la prohibición de fumar se notó principalmente en la disminución del consumo de tabaco entre los alumnos de instituto de más edad y a fumadores frecuentes. Para más de 18–24 años, y de las intervenciones dirigidas a individuos de más edad y a fumadores frecuentes.
