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Abortion legislation, maternal healthcare, fertility, female literacy, sanitation, violence against women, and maternal deaths: a natural experiment in 32 Mexican states

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ABSTRACT

Objective: To test whether there is an association between abortion legislation and maternal mortality outcomes after controlling for other factors thought to influence maternal health.

Design: Population-based natural experiment.

Setting and data sources: Official maternal mortality data from 32 federal states of Mexico between 2002 and 2011.

Main outcomes: Maternal mortality ratio (MMR), MMR with any abortive outcome (MMR_{AO}), and induced abortion mortality ratio (iAMR).

Independent variables: Abortion legislation grouped as less (n=18) or more permissive (n=14); constitutional amendment protecting the unborn (n=17); skilled attendance at birth; all-abortion hospitalisation ratio; low birth weight rate; contraceptive use; total fertility rates (TFR); clean water; sanitation; female literacy rate and intimate-partner violence.

Main results: Over the 10-year period, states with less permissive abortion legislation exhibited lower MMR (38.3 vs 49.6; p<0.001), MMR_{AO} (2.7 vs 3.7; p<0.001), and iAMR (0.9 vs 1.7; p<0.001), than more permissive states. Multivariate regression models estimating effect sizes (ß-coefficients) for mortality outcomes showed independent associations (*p-values* between 0.001 and 0.055) with female literacy (ß= -0.061 to -1.100), skilled attendance at birth (ß= -0.032 to -0.427), low birth weight (ß= 0.149 to 2.166), all-abortion hospitalisation ratio (ß= -0.566 to -0.962), clean water (ß= -0.048 to -0.730), sanitation (ß= –0.052 to -0.758), and intimate-partner violence (ß= 0.085 to 0.755). TFR showed inverse association with MMR (ß= -14.329) and MMR_{AO} (ß= -1.750) and a direct association with iAMR (ß=1.383). Altogether, these factors accounted for (R^2) 51% to 88% of the variance among states in overall mortality rates. No statistically independent effect was observed for abortion legislation, constitutional amendment, or other covariates.

Conclusion: Although less permissive states exhibited consistently lower maternal mortality rates, this finding was not explained by abortion legislation itself. Rather, these differences were explained by other independent factors, which appeared to have a more favourable distribution in these states.

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STRENGHTS AND LIMITATIONS

- To the best of our knowledge, this is the first population-based natural experiment analysing the impact of less or more permissive abortion legislation on maternal mortality outcomes in Mexico, simultaneously controlling by 10 variables thought to influence maternal health at the population level.
- In this study, relying on complete official data, Mexican states with less permissive abortion legislation displayed lower maternal and abortion mortality ratios than states with more permissive legislation during a 10-year study period. Nevertheless, observed differences among populations were not attributable to abortion legislation by itself.
- Exhaustive multivariate analyses showed that observed differences in maternal mortality outcomes among states were largely explained by a combination of variables related to maternal healthcare, fertility rate, female literacy, intimate-partner violence against women, and access to clean water and sanitation.
- Although inter-state diversity of abortion legislation in terms of permissiveness provided the opportunity to assess its impact on mortality outcomes, intra-state heterogeneity of criminal exemptions hampered the allocation of population of individuals to groups univocally defined as less or more permissive. Nevertheless, the exemption of criminal prosecution of abortion on the grounds of genetic or congenital foetal malformations was found to provide clear differences in mortality outcomes.
- Because it is based on aggregated data, this study cannot rule out the effect of analysed variables at the individual level, nor its data or results can directly be employed to make assumptions of individual risks.

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INTRODUCTION

Promoting maternal health has been a key concern for public health policy makers worldwide, particularly since the United Nations (UN) put forth the Millennium Development Goals (MDGs).[1] As part of the fifth MDG, which focused on improving maternal health, the UN requested all member states to decrease their maternal mortality ratio (MMR)* by 75% by 2015.[2]

Most causes of maternal mortality are preventable, and improving access to antenatal care,[3-5] maternal health facilities equipped with emergency obstetric units,[3,4,6,7] and skilled attendance at childbirth[3,6,8-10] are acknowledged public health interventions that have led to the decrease in maternal mortality worldwide. However, one year away from the 2015 deadline for the MDGs, the MMR has decreased less than 50% globally,[10-12] suggesting that measures taken to address maternal mortality may have been insufficient.[11,13,14] In this regard, although novel complementary public health or social interventions have been encouraged in support of the post-MDG agenda,[13,14] these ought to be supported by data and evidence, for example, population-based natural experiments.[15-17]

It has been proposed that the legal status of abortion, defined as pregnancy termination by removal or expulsion of the foetus, is a factor that influences maternal health in a region, country, or territory.[18,19] There is a widespread perception that less permissive legislation, i.e. legislation that restricts or prohibits pregnancy termination (note that “abortion” or “pregnancy termination” are terms used interchangeably throughout this study) leads to increased maternal mortality due to complications of clandestine, or illegal, or unsafe abortions.[20-22] Accordingly, it has also been suggested that more permissive abortion legislation would lead to a reduction in maternal deaths.[19-21] However, conflicting results have been recently reported in the literature.[10,12,18,23-29,] For instance, evidence from settings with less permissive abortion legislation[28,26,29-31] suggests that other factors, such as increasing level of women’s education, complimentary nutrition programmes for poor pregnant women, availability of maternal

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healthcare facilities, emergency obstetric units, changes in reproductive behaviour with increased family planning, and access to clean water and sanitation, may facilitate an epidemiologic transition towards low maternal mortality rates in the absence of more permissive abortion legislation.[30] However, this hypothesis remains to be tested or replicated at the population level in different epidemiological scenarios.

The United Mexican States (Mexico) is a federal republic comprising 32 federal territories (31 states and the Federal District, referred to as “states” henceforth), whose population shares a common history and culture. In addition, the Mexican healthcare system reached virtually universal coverage over the past century, assuring equality in access to healthcare to most of their population.[32] Each state has its own political constitution, criminal code, and abortion legislation. Moreover, while the Federal District passed a law allowing pregnancy termination on demand during the first trimester of pregnancy, several states have modified their constitutions in the opposite direction, strengthening the protection of the unborn starting at conception.[22] Thus, Mexico offers a unique epidemiological scenario to test whether more or less permissive abortion legislation affects maternal mortality in a population that shares the same history and culture, and which has a homogeneous healthcare system.

This study presents the results of a population-based natural experiment examining factors associated with maternal mortality in the 32 Mexican states during a period spanning 10 years (2002-2011). It analyses trends in maternal and abortion-related mortality according to differences in abortion legislation, and controlling for a number of factors thought to influence maternal mortality rates.

MATERIALS AND METHODS

Population data

Official records of maternal deaths and observed live births occurring within the United Mexican States were extracted from the General Directorate of Health Information (DGIS)[33] and the

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National Institute of Statistics, Geography, and Informatics (INEGI)[34] respectively, for every state by place of residence (state where the individual used to dwell) and place of occurrence (state where the vital event took place), between 2002 and 2011 (10-year continuous period). Civil registration of vital statistics in Mexico follows international standards, has been regarded as virtually complete by the World Health Organization, and has been included in List A –with good attribution of causes of death– along with 64 other countries.[12] Since 2002, Mexico has strengthened its active epidemiological surveillance system (Intentional Search and Reclassification of Maternal Deaths)[35] to correctly code maternal deaths that were initially not recognised as maternal, and to reclassify maternal deaths with erroneously attributed codes throughout the entire territory. Because this surveillance increased data reliability, 2002 was selected as the initial year for the study.

Classification of maternal deaths

Maternal deaths were identified using the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10)[36] and were classified by place of residence or occurrence. Mortality ratios were directly calculated as the quotient between maternal deaths and observed live births. Three epidemiological indicators were calculated according to the classification proposed by Koch *et al.*[37] The first indicator is maternal mortality ratio (MMR), which considers all maternal death codes (ICD-10 codes O00-O99, A34, B20-B24, and F53) and is often referred to as overall maternal mortality. The second indicator is maternal mortality ratio with any abortive outcome (MMR_{AO}), which considers maternal death classified following ICD-10 codes O00-O08. The third indicator is induced abortion mortality ratio (iAMR), which is used in more specific studies that focus only on deaths likely associated with complications secondary to pregnancy termination (medical abortion [ICD-10 code O04], other abortion [ICD-10 code O05], unspecified abortion [ICD-10 code O06], and failed attempted abortion [ICD-10 code O07]), parsimoniously excluding deaths associated with pathological conditions or complications unrelated to the termination of pregnancy, such as ectopic pregnancy (ICD-10 code O00), hydatidiform mole (ICD-10 code O01), other abnormal products of conception (ICD-10 code

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O02), spontaneous abortion (ICD-10 code O03), and complications following abortion and ectopic and molar pregnancy (ICD-10 code O08).[37]

Abortion legislation

Criminal legislation for each state was reviewed and extracted from the National Office for the Judiciary of the Mexican government.[38] The revision of current criminal codes of each Mexican state is summarized in Table S1 (Supplementary Material). In practical terms, all of the 32 states provide criminal exemptions for abortion by rape, 29 states provide criminal exemptions in imprudent or accidental cases, 28 states provide exemptions when the life or health of the mother is at risk, 10 states in cases of artificial insemination without consent, 1 state for social causes, and 14 states in cases of genetic or congenital foetal conditions resulting in an individual with serious physical or mental deficiencies. In addition, in 2007 the Federal District passed a law allowing legal pregnancy termination on request up to the 12th week of pregnancy.[39] In exploratory analyses, segregating states by the number of exemptions provided in criminal codes did not result in detectable differences in sensitivity analyses, with the exception of abortion allowed by genetic or congenital foetal malformations. The remaining seven exemptions were contemplated in almost every state or very few states, thus offering no discrimination potential. Therefore, to differentiate between states with more or less permissive abortion legislation in subsequent statistical analyses, states allowing pregnancy termination due to serious genetic or congenital conditions were considered more permissive (14 states), while the remaining states were considered less permissive (18 states).

Political constitution amendments

Amendments to the political constitution of each state were extracted from the National Office for the Judiciary of the Mexican government.[38] Specifically, constitutional amendments specifying an explicit protection of the unborn starting at conception were tracked in time and form by examining the political constitution of each state. A number of states amended their constitutions to this effect almost immediately after the legalization of pregnancy termination on request in the

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Federal District, in April of 2007.[39] Thus, progressive changes commanded a dynamic allocation of states according to the date of enactment or derogation of the amendment (Figure S1, Supplementary Material). In addition to the state of Chihuahua, which amended its constitution in 1994, 16 other states had enacted these amendments by the end of 2011. In subsequent statistical analysis, a direct comparison of maternal and abortion-related deaths was carried out between groups of states with amendment (17 states) and without amendment (15 states). In addition, sub-analyses that discriminated maternal and abortion-related mortality in the Federal District were also conducted.

Independent variables

Other independent variables considered were percentage of the population with access to clean water ("clean water"), sanitary sewer coverage ("sanitation"), average total fertility rate between 2002 and 2011 ("TFR"), percentage of contraceptive use by married or in-union female population of fertile age ("contraceptive use"), percentage of skilled attendance at birth ("skilled attendance at birth"), low birth weight rate ("low birth weight"), female literacy rate ("female literacy"), all-abortion hospitalisation ratio, and percentage of intimate-partner violence against married or in-union women over the last year ("intimate-partner violence"). Operational definitions, their significance for epidemiological studies (for subsequent interpretation), measurement scales, and data sources for these variables are detailed in Table S2 (Supplementary Material).

Statistical analyses

Parallel time series were constructed between 2002 and 2011 for maternal deaths and registered live births according to abortion legislation. Trends for MMR, MMR_{AO}, and iAMR per 100,000 live births were directly calculated for every federal state and were evaluated over time by occurrence and residence using an autoregressive integrated moving average (ARIMA) model. The complete time series data used in this study are presented in Tables S3 through S16 (Supplementary Material). Average mortality ratios over the total time period were also computed and directly matched using *Z*-test. The proportion (%) of induced abortion-related deaths (i.e., proportion of

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deaths due to pregnancy termination over the total number of maternal deaths) was also computed and comparatively analysed.

The Kolmogorov-Smirnov test was utilised to assess the normal distribution assumption. Multiple regression was used to estimate the effect size of independent variables on average mortality ratios (MMR, MMR_{AO}, and iAMR) and explain the variance among the 32 states controlling for other factors. Because of a potential problem of collinearity related to the high number of predictors, a Pearson correlation matrix was used to quantify the magnitude of bivariate linear associations among all independent variables. Pearson coefficients (r) ≥0.70 were considered to suggest collinearity. Exploratory models were conducted to assess collinearity using the variance inflation factor (VIF).[40] The covariates selected for inclusion in explanatory regression models were analysed using the backward stepwise elimination method based on *p*-values of 0.05 and 0.059 as criteria of entry and removal, respectively. *β*-coefficients with 95% confidence intervals were computed to assess the effect size of each predictor on the MMR, MMR_{AO}, and iAMR and the change in the adjusted R^2 was used to determine the final models with maximal goodness-of-fit, minimal number of explanatory variables, and minimal collinearity. To examine the stability of *β*-coefficients and obtain unbiased effect sizes, two panels of multivariate explanatory models were considered for each mortality outcome, based on diagnostic regression refinement of residual statistics, by eliminating the presence of outliers (higher than 2 standard deviations of predicted mortality outcome) when presented.

RESULTS

Abortion legislation and maternal mortality

During the 10-year study period there were 11,653 maternal deaths and 25,967,192 live births in Mexico, corresponding to a MMR of 44.9 per 100,000 live births. The MMR in 2002 was 48.7, decreasing to 38 per 100,000 live births in 2011, representing a total reduction of 22%. Regardless of where the vital event took place, figures of MMR, MMR_{AO}, iAMR, and the proportion of induced abortion-related deaths between 2002 and 2011 were lower in the group of

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states with less permissive abortion legislation (Figures 1 and 2, left panels). The group of states with less permissive abortion legislation showed apparently stable trends for MMR (β=-0.563; p=0.202), MMR_{AO} (β=0.030; p=0.615), and iAMR (β=-0.010; p=0.619) during the decade analysed. The group of states with more permissive abortion legislation displayed decreasing trends for MMR (β=-1.766; p=<0.001), MMR_{AO} (β=-0.123; p=0.016), iAMR (β=-0.096, p=0.005), narrowing the gap between the two groups by 2011 but still exhibited statistically significant differences (*e.g.* MMR of 40.9 *vs.* 33.5 per 100,000 live births, Z=3.04, rate ratio=0.82, p=0.002). State-by-state trends and estimated slopes for the time series of MMR, MMR_{AO}, and iAMR are presented by residence (Tables S11 through S13) and by occurrence (Tables S14 through S16) in the Supplementary Material.

Figure 3 illustrates in a blue scale the geographic distribution of average MMR (top panel) and iAMR (bottom panel) for the 10-year period in territories of the whole country. Average MMR for the ten-year period by place of residence and occurrence in the group of states with less permissive legislation was 23% (rate ratio=0.77; p<0.001) and 21% (rate ratio=0.79; p<0.001) lower, respectively, than the value in the group of states with more permissive legislation (Table S17, Supplementary Material). Similarly, the group of states with less permissive abortion legislation showed an average MMR_{AO} by place of residence and occurrence of 27% (rate ratio=0.71; p<0.001) and 24% (rate ratio=0.75; p<0.001) lower, respectively, than states with more permissive legislation. The highest difference between both groups was for the average iAMR, which was 47% lower (rate ratio=0.53; p<0.001) in states with less permissive legislation, for analyses by residence and occurrence. Finally, average proportion of induced abortion-related deaths by place of residence was 2.4% and 3.4% (p=0.002) in the groups of states with less and more permissive abortion legislation, respectively; by place of occurrence, figures were 2.3% and 3.5% (p<0.001), respectively. Excluding the Federal District from the group of states with more permissive abortion legislation did not significantly modify these results.

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Constitutional amendments and maternal mortality

Regardless of where the vital event took place, iAMR and the proportion of induced abortion-related deaths between 2008 and 2011 –but not MMR and MMR_{AO}, for which rates overlapped– were apparently higher in the group of states that did not amend their constitutions (Figures 4 and 5, left panels); however, these differences were not statistically significant for the 4-year period (*p* for trend=0.670). Differences were observed in average iAMR and proportion of induced abortion-related deaths for the total period of 4 years (Table S18, Supplementary Material). Average iAMR either by place of residence or occurrence in states with constitutional amendments was 31% (rate ratio=0.54; *p*=0.042) lower than the value in states without amendments (Table S18, Supplementary Material). The average proportion of induced abortion-related deaths by place of residence was 2.1% in states with amendment and 3.1% in states without amendment (*p*=0.041); by place of occurrence figures were 2.2% in states with amendment and 3.2% in states without amendment (*p*=0.048).

After removing the Federal District from the group of states without constitutional amendments, differences were observed in average MMR and MMR_{AO} between the groups, but only in the analysis of mortality by place of occurrence (Figures 5 and 7, right panels). The Federal District showed higher average MMR and MMR_{AO} by place of occurrence than the group of states with constitutional amendments. In addition, removal of the Federal District from the group of states without constitutional amendments abolished the differences found in average iAMR and proportion of induced abortion-related deaths by place of occurrence (Figures 5 and 7) but not by place of residence (Figures 4 and 6) between the latter group and the group of states with the amendment. Results for each mortality outcome are compared in Table S18 (Supplementary Material).

Explanatory regression models

Table 1 shows data for all covariates for each Mexican state, and includes the results from tests of normal distribution for each variable. Simple regression models illustrating the initial effect size

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(*β*-coefficients) for each covariate, including abortion legislation and constitutional amendment are presented in Table S19 (Supplementary Material).

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Table 1 Independent variables in each Mexican state: frequencies and analyses of normal distribution

State	Abortion legislation	Constitutional amendment	Clean water	Sanitation	TFR	Contraceptive use	Skilled attendance at birth	Low birth weight	Female literacy	All-abortion hospitalisation ratio	Intimate-partner violence
Aguascalientes	1	0	98.0	97.8	2.6	71.7	97.5	6.6	95.9	10.8	12.0
Baja California	1	1	95.3	93.7	2.1	78.8	75.7	6.9	96.0	9.2	11.7
Baja California Sur	0	0	88.1	94.2	2.0	75.9	99.5	6.0	95.8	10.6	16.3
Campeche	1	0	85.0	85.7	2.2	73.9	98.2	7.2	89.7	7.8	10.7
Coahuila	0	0	96.8	95.6	2.3	75.2	89.6	8.0	96.5	8.0	14.3
Colima	0	1	97.3	98.7	2.3	78.3	96.4	5.4	94.2	17.4	11.0
Chiapas	0	1	73.8	80.4	2.8	54.9	90.2	8.6	77.5	5.1	7.0
Chihuahua	1	1	94.9	93.2	2.4	78.9	82.2	7.6	95.3	6.2	12.1
Distrito Federal	0	0	97.5	99.2	1.8	79.6	94.3	14.0	96.3	14.2	20.9
Durango	1	1	92.9	88.3	2.4	73.2	93.3	8.0	95.5	8.2	10.2
Guanajuato	1	1	91.9	89.3	2.4	68.3	90.1	8.9	90.1	7.0	6.4
Guerrero	0	0	62.0	71.7	2.8	61.4	80.8	9.3	79.8	3.2	8.3
Hidalgo	0	0	87.2	83.4	2.4	70.9	89.7	8.5	87.2	6.2	8.6
Jalisco	1	1	94.6	96.9	2.4	71.4	93.5	9.0	94.8	7.4	10.0
México	0	0	92.2	92.0	2.2	76.5	84.7	10.9	93.6	4.4	11.9
Michoacán	1	0	88.1	85.4	2.4	63.2	92.1	8.6	88.4	6.1	9.1
Morelos	0	1	87.6	92.4	2.2	75.4	91.7	10.5	91.8	8.8	9.7
Nayarit	1	1	88.3	93.5	2.3	78.7	81.8	6.8	92.9	7.4	14.8
Nuevo León	1	0	96.9	97.2	2.1	79.2	96.6	8.6	95.8	6.5	13.1
Oaxaca	0	1	69.8	69.6	2.6	63.4	95.0	7.8	79.4	3.7	6.3
Puebla	0	1	83.8	84.9	2.6	69.8	90.8	9.6	86.8	4.0	8.6
Querétaro	1	1	91.9	91.0	2.3	70.3	97.6	9.2	91.7	9.1	11.6
Quintana Roo	0	1	91.7	94.0	2.1	73.4	91.5	8.3	92.4	9,7	10.7
San Luis Potosí	1	1	83.1	80.5	2.5	67.4	91.7	8.1	90.5	6.6	10.5
Sinaloa	1	0	90.3	90.9	2.3	79.8	93.4	6.1	94.7	8.1	15.0
Sonora	1	1	94.4	90.0	2.4	79.9	94.6	6.2	96.3	8.7	15.4
Tabasco	1	0	73.8	91.7	2.3	66.3	82.4	8.4	90.9	7.2	9.6
Tamaulipas	1	1	95.1	88.1	2.3	73.2	99.0	7.4	94.2	10.0	14.9
Tlaxcala	1	0	95.6	92.8	2.4	65.2	98.2	10.1	92.8	7.6	9.3
Veracruz	0	0	76.3	80.2	2.2	73.9	97.8	7.1	86.1	4.8	10.9
Yucatán	0	1	94.4	80.1	2.3	74.9	97.5	10.7	88.6	7.2	11.5
Zacatecas	1	0	91.7	89.0	2.5	70.2	89.1	8.6	93.6	8.3	8.2
p-value[*]	†	†	0.189	0.624	0.311	0.730	0.534	0.666	0.399	0.394	0.505

Abortion Legislation: states classified as less permissive (1) or more permissive (0), according to the presence of an exemption from criminal prosecution of abortion in cases of genetic or congenital malformation. Constitutional amendment: states classified as exhibiting (1) or not (0) an amendment to their political constitution protecting the unborn from conception during 2011. Clean water: Percentage of in-use private dwellings with clean water availability during 2010.

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Sanitation: Percentage of in-use private dwellings with availability of sewer drainage during 2010. TFR: Average total fertility rate between 2002 and 2011. Contraceptive use: Percentage of married or in-union women of 15 and above using contraceptive methods during 2009. Skilled attendance at birth: Percentage of observed live births delivered by a physician, nurse or midwife during 2010. Low birth weight: Percentage of observed live births with low birthweight in each state during 2010. Female literacy: Percentage of the female population of ages 15 and above who can understand, read and write a short, simple statement on their everyday life during 2010. All-abortion hospitalisation ratio: Ratio of all-abortion related hospitalisations over observed live births between 2000 and 2008 per 100 live births. Intimate-partner violence: Percentage of married or in-union women of ages 15 and above who have suffered severe intimate partner violence over the past 12 months during 2010.

Abortion legislation and constitutional amendment for each state were reviewed and extracted from the National Office for the Judiciary.[38]
Clean water, Sanitation, TFR, Contraceptive use, Skilled attendance at birth, Low birth weight, Female literacy and Intimate-partner violence series extracted from INEGI.[34]
All-abortion hospitalisation ratio computed using all-abortion hospitalisation series published by Schiavon *et al*.[42] and live births series by INEGI.[34]

*Kolmogorov-Smirnov test for normal distribution.
†Not applicable
INEGI, National Institute of Statistics and Geography; TFR, total fertility rate.

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Exploratory regression analyses showed collinearity between independent variables. A full model introducing all independent variables simultaneously (not shown) showed VIF values between 1.537 and 9.082. In particular, five of the nine independent variables presented VIF values higher than 4.0 (clean water, sanitation, TFR, contraceptive use, and female literacy), suggesting the presence of multicollinearity. A correlation matrix showed a high inverse correlation between TFR and contraceptive use (r=-0.76; p<0.001), suggesting that these variables were interchangeable. Other pairs of variables with high Pearson coefficients were clean water with sanitation (r=0.79; p<0.001), and female literacy with clean water (r=0.85; p<0.001) or with sanitation (r=0.86; p<0.001). Thus, contraceptive use and female literacy were selected for primary explanatory models. When TFR, clean water, and sanitation were excluded, VIF substantially decreased to values between 1.087 and 3.338.

Table 2 shows the multivariate explanatory models for MMR, using the backward stepwise elimination method, before and after regression refinement. Before refinement, three predictors were identified after six steps of backward elimination: female literacy (β=-1.051; p<0.001), low birth weight (β=1.585; p=0.029), and skilled attendance at birth (β=-0.427; p=0.038). These variables accounted for 51% (adjusted R^2=0.512; p<0.001) of the observed differences in MMR among states. After refinement, which excluded two states as outliers (Chihuahua and Nueva León), four predictors were identified after five steps of elimination: female literacy (β=-1.100; p<0.001), low birth weight (β=1.637; p=0.003), all-abortion hospitalisation ratio (β=-0.817; p=0.055), and intimate-partner violence (β=0.755; p=0.051). An increase in β-coefficients for these variables was noted, accounting for 69% (adjusted R^2=0.689; p<0.001) of observed differences in MMR among states. The relative contribution of each variable for explaining the variance (cumulative partial R^2) of MMR among states was 50.9%, 15.1%, 4.4%, and 2.8%, respectively. No independent effect was observed for abortion legislation, constitutional amendment, or other covariates.

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Table 2 Explanatory models for trends on maternal mortality ratio (MMR) in 32 Mexican states, 2002-2011

	Multivariate model before refinement*								Multivariate model after refinement**							
	β	SE	95% CI		*p-value*	VIF	ME	R^2	β	SE	95% CI		*p-value*	VIF	ME	R^2
			Lower	Upper							Lower	Upper				
Female literacy (%)	-1.051	0.235	-1.532	-0.570	<0.001	1.023	None	0.512	-1.100	0.255	-1.625	-0.574	<0.001	2.250	None	0.689
Low birth weight (%)	1.585	0.690	0.171	2.998	0.029	1.018	None		1.637	0.502	0.603	2.671	0.003	1.046	None	
Skilled attendance at birth (%)	-0.427	0.196	-0.827	-0.026	0.038	1.008	None		-0.162	0.157	-0.486	0.162	0.312	1.145	5	
Intimate-partner violence (%)	0.697	0.499	-0.326	1.720	0.173	1.825	6		0.755	0.369	-0.004	1.514	0.051	1.859	None	
All-abortion hospitalisation ratio (per 100 live births)	-0.302	0.557	-1.444	0.840	0.591	1.800	5		-0.817	0.405	-1.652	0.018	0.055	1.882	None	
Constitutional amendment (yes)	1.352	2.385	-3.542	6.246	0.576	1.025	4		0.578	1.827	-3.192	4.348	0.755	1.088	2	
Abortion legislation (less permissive)	-1.960	2.721	-7.543	3.623	0.478	1.328	3		-1.456	2.151	-5.896	2.983	0.505	1.531	4	
Contraceptive use (%)	0.300	0.308	-0.331	0.931	0.337	2.557	2		0.187	0.259	-0.347	0.720	0.477	3.182	3	

*Multivariate model before refinement identified three predictors after six steps of backward elimination (Female literacy, Low birth weight and Skilled attendance at birth), accounting for 51% (R^2) of MMR differences between states. **Multivariate model after one step of refinement excluded two states (Chihuahua and Nueva León) identified as outliers. Four predictors were identified in five steps of backward elimination (Female literacy, Low birth weight, All-abortion hospitalisation ratio and Intimate-partner violence), accounting for 69% (R^2) of MMR differences between states.
R^2 refers to the goodness-of-fit for each model.
CI, confidence interval; ME, model in which the variable was excluded during the backward elimination; MMR, maternal mortality ratio; SE, standard error; VIF, variance inflation factor.

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Table 3 shows the multivariate explanatory models for MMR_{AO}. Before refinement, three predictors were identified after six steps of backward elimination: female literacy (β=-0.061; p=0.039), low birth weight (β=0.299; p=0.001), and skilled attendance at birth (β=-0.072; p=0.004). These variables accounted for 49% (adjusted R^2=0.485; p<0.001) of observed differences on MMR_{AO} among states. After two sequential steps of refinement, which excluded two states as outliers (Aguascalientes and Nayarit), the same three predictors were identified after six steps of elimination: female literacy (β=-0.073; p=0.005), low birth weight (β=0.361; p<0.001), and skilled attendance at birth (β=-0.065; p=0.005). An increase in β-coefficients of these variables was observed accounting for 62% (adjusted R^2=0.624; p<0.001) of observed differences in MMR_{AO} among states. The relative contribution of each factor for explaining the variance (cumulative partial R^2) of MMR_{AO} among states was 11.9%, 40.2%, and 14.2%, respectively. No independent effect was observed for abortion legislation, constitutional amendment, or other covariates.

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Table 3 Explanatory models for trends on maternal mortality ratio with an abortive outcome (MMR_{AO}) in 32 Mexican states, 2002-2011

	Multivariate model before refinement*								Multivariate model after refinement**							
	β	SE	95% CI		*p-value*	VIF	ME	R^2	β	SE	95% CI		*p-value*	VIF	ME	R^2
			Lower	Upper							Lower	Upper				
Female literacy (%)	-0.061	0.028	-0.118	-0.003	0.039	1.023	None	0.485	-0.073	0.024	-0.122	-0.023	0.005	1.014	None	0.624
Low birth weight (%)	0.299	0.082	0.131	0.467	0.001	1.018	None		0.361	0.072	0.213	0.508	<0.001	1.013	None	
Skilled attendance at birth (%)	-0.072	0.023	-0.120	-0.024	0.004	1.008	None		-0.065	0.021	-0.108	-0.022	0.005	1.011	None	
Contraceptive use (%)	0.035	0.037	-0.040	0.110	0.351	2.557	6		0.044	0.032	-0.022	0.111	0.184	2.761	6	
Abortion legislation (less permissive)	0.052	0.327	-0.618	0.723	0.874	1.328	5		-0.062	0.279	-0.636	0.513	0.827	1.276	4	
All-abortion hospitalisation ratio (per 100 live births)	0.046	0.066	-0.089	0.181	0.492	1.800	4		0.036	0.056	-0.080	0.151	0.533	1.742	3	
Constitutional amendment (yes)	0.222	0.282	-0.357	0.802	0.438	1.025	3		0.286	0.243	-0.214	0.787	0.250	1.019	5	
Intimate-partner violence (%)	0.045	0.061	-0.079	0.170	0.462	1.825	2		0.021	0.055	-0.092	0.135	0.702	1.961	2	

*Multivariate model before refinement identified three predictors after six steps of backward elimination (Female literacy, Low birth weight and skilled attendance at birth), accounting for 49% of MMR_{AO} differences between states. **Multivariate model after two sequential steps of refinement excluded two states (Aguascalientes and Nayarit) identified as outliers. Three predictors were identified in six steps of backward elimination (Female literacy, Low birth weight, Skilled attendance at birth), accounting for 62% of MMR_{AO} differences between states.
CI, confidence interval; ME, model in which the variable was excluded during the backward elimination; MMR_{AO}, maternal mortality ratio with abortive outcome ratio; SE, standard error; VIF, variance inflation factor.

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Table 4 shows the multivariate explanatory models for iAMR. Before refinement, two predictors were identified after seven steps of backward elimination: female literacy (β=-0.062; p=0.009) and low birth weight (β=0.149; p=0.031). These variables accounted for 29% (adjusted R^2=0.292; p<0.001) of observed differences in iAMR among states. After three sequential steps of refinement, which excluded four states as outliers (Aguascalientes, Durango, Sonora, and Tlaxcala) four predictors were identified after five steps of elimination: female literacy (β=-0.119; p<0.001), low birth weight (β=0.154; p=0.001), skilled attendance at birth (β=-0.052; p<0.001), and intimate-partner violence (β=0.085; p=0.007). These variables accounted for 78% (adjusted R^2=0.777; p<0.001) of observed differences in iAMR among states. The relative contributions of these variables for explaining the variance of iAMR (cumulative partial R^2) among states were 39.9%, 19.1%, 14.8%, and 7.2%, respectively. No statistically independent effect was observed for abortion legislation, constitutional amendment, or other covariates.

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Table 4 Explanatory models for trends on induced abortion mortality ratio (iAMR) in 32 Mexican states, 2002-2011

	Multivariate model before refinement*								Multivariate model after refinement**							
	β	SE	95% CI		*p-value*	VIF	ME	R^2	β	SE	95% CI		*p-value*	VIF	ME	R^2
			Lower	Upper							Lower	Upper				
Female literacy (%)	-0.062	0.022	-0.108	-0.017	0.009	1.017	None	0.292	-0.119	0.018	-0.155	-0.082	<0.001	1.944	None	0.777
Low birth weight (%)	0.149	0.066	0.014	0.283	0.031	1.017	None		0.154	0.039	0.074	0.234	0.001	1.051	None	
Skilled attendance at birth (%)	-0.023	0.018	-0.061	0.015	0.226	1.008	7		-0.052	0.011	-0.075	-0.030	<0.001	1.061	None	
Intimate-partner violence (%)	0.024	0.048	-0.075	0.123	0.626	1.778	6		0.085	0.029	0.025	0.144	0.007	2.023	None	
Contraceptive use (%)	-0.015	0.030	-0.075	0.046	0.623	2.550	5		0.023	0.020	-0.018	0.064	0.255	3.622	5	
Constitutional amendment (yes)	-0.198	0.224	-0.658	0.261	0.384	1.019	4		-0.034	0.137	-0.318	0.250	0.806	1.081	4	
Abortion legislation (less permissive)	0.144	0.258	-0.385	0.672	0.583	1.312	3		-0.059	0.155	-0.380	0.262	0.705	1.393	3	
All-abortion hospitalisation ratio (per 100 live births)	-0.029	0.050	-0.131	0.073	0.562	1.600	2		-0.004	0.030	-0.067	0.058	0.894	1.854	2	

*Multivariate model before refinement identified two predictors after seven steps of backward elimination (Female literacy, Low birth weight), accounting for 29% of iAMR differences between states. **Multivariate model after three sequential steps of refinement excluded four states (Aguascalientes, Durango, Sonora and Tlaxcala) identified as outliers. Four predictors were identified in five steps of backward elimination (Female literacy, Low birth weight, Skilled attendance at birth and Intimate-partner violence), accounting for 78% of iAMR differences between states.
CI, confidence interval; iAMR, induced abortion mortality ratio; ME, model in which the variable was excluded during the backward elimination; SE, standard error; VIF, variance inflation factor.

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Alternative explanatory regression models

Alternative multivariate regression models were conducted to consider variables excluded by collinearity (Tables S20 through S22, Supplementary Material). Briefly, when clean water was incorporated instead of female literacy, the former showed an independent inverse association with MMR (β=-0.730; p<0.001) and iAMR (β=-0.048; p<0.001) explaining 64.7% and 39.2% (cumulative partial R^2) of the differences among states for these outcomes, respectively. Similarly, when female literacy was exchanged for sanitation, the refined model identified sanitation as inversely associated with MMR (β=-0.758; p<0.001) and iAMR (β=-0.052; p<0.001) explaining 45.6% and 29.8% of the variance among states, respectively. Finally, when TFR was incorporated instead of contraceptive use in multivariate models, an inverse independent association of TFR with MMR (β=-14.329; p=0.002) and MMR_{AO} (β=-1.750; p=0.008), and a direct association with iAMR (β=1.383; p=0.003) was found. In these models, TFR accounted 7.7%, 10% and 17.2% of the variance among states for MMR, MMR_{AO}, and iAMR, respectively. No statistically significant effects were found for abortion legislation, constitutional amendment, or additional covariates other than those already mentioned in either the primary or alternative regression models.

DISCUSSION

Diversity of abortion legislation in different regions, countries, and territories may partially reflect different cultural values and attitudes towards motherhood, childhood, the unborn, and abortion itself.[22,41,43-47] Theoretically, in Mexican states exhibiting less permissive legislation, maternal mortality should have been higher because the practice of unsafe abortion should be more frequent.[19-22] Paradoxically, over a 10-year period, those states almost univocally exhibited lower figures for MMR, MMR_{AO}, and iAMR. Nevertheless, after an exhaustive analysis adjusting for multiple confounders, the initial estimated effects for all mortality outcomes were explained by differences in other independent factors known to influence maternal health rather than by abortion legislation itself. Consequently, making a direct or independent causal link between a less permissive abortion law and a lower incidence of maternal deaths –or conversely by considering a more permissive abortion law– would be a premature or even erroneous

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conclusion. Rather, from an epidemiological perspective, the Mexican natural experiment provides evidence to support three complementary assumptions at the population level: first, abortion legislation *per se* did not appear to have an independent effect on overall maternal mortality rates; second, a less permissive abortion law, in terms of not considering criminal exemptions in cases of genetic or congenital foetal anomalies, did not result associated with increased maternal and abortion-related deaths; and third, differences in maternal mortality incidence in the context of different abortion legislation (more or less permissive), appear mainly explained by the distribution of other major independent factors likely facilitating an epidemiologic transition toward low maternal mortality rates independently from abortion legislation itself.

On the other hand, whether a constitutional amendment protecting the unborn translates into higher or lower maternal mortality rates has not yet been explored. Theoretically, these states might be culturally more reluctant to accept changes in abortion legislation,[22,43,45,46] and therefore, maternal deaths might be higher, particularly if practice of unsafe abortions is frequent.[21,47] At least in the short-term, this natural experiment found no evidence of any detrimental impact on maternal mortality outcomes related to constitutional amendments protecting the unborn. Results showed some differences between groups of states with and without amendment between 2008 and 2011, *i.e.* lower average iAMR and lower average proportion of abortion-related deaths in the former group compared with the latter. Nevertheless, these differences appeared to be explained by other independent factors distributed more favourably in the group of states with less permissive legislation but unrelated to constitutional amendment.

Interestingly, between 2008 and 2011, the Federal District displayed higher MMR and MMR_{AO} than the group of states with the constitutional amendment, when the outcome was measured by place of occurrence, but not by place of residence. Indeed, when mortality ratios by occurrence or residence are compared state-by-state, the Federal District showed the highest difference in maternal mortality outcomes (*e.g.,* 61.9 *vs* 48.7 for MMR per 100,000 live births, respectively).

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From an epidemiological perspective, such disparities often reflect a pattern of temporary mobility among the population.[48] Similarly, the difference in iAMR and the proportion of abortion-related deaths by place of occurrence between states with and without amendment was abolished when the Federal District was removed from the latter group. Thus, inter-state mobility into the Federal District appears to be associated with an increased risk of maternal mortality for pregnant women arriving from other states. Determinants of this phenomenon are largely unknown and warrant further research.

Multivariate regression in both primary and alternative models revealed that a combination of factors related to maternal healthcare, reproductive behaviour, access to clean water, sanitation, female literacy, and intimate-partner violence against women explained 51% to 88% of the variance among states in overall maternal mortality rates.

Regarding maternal healthcare, three factors resulted independently associated to maternal mortality outcomes. First, consistent with the general consensus,[3,6,8-10,49,50,51] skilled attendance at birth showed an inverse relationship with mortality ratios: for each 1% increase in skilled attendance at birth, decreases of 0.2 in MMR, 0.1 in MMR_{AO}, and 0.1 in iAMR per 100,000 live births were estimated. This factor –ranging from 75% to 99% among states (Table 1)– likely reflects important disparities in access to antenatal care and institutional deliveries.[4,5,50,51] Second, all-abortion hospitalisation ratio showed an inverse relationship with MMR in refined explanatory models. For each incremental unit of this variable, a decrease of 0.8 maternal deaths per 100,000 live births was estimated among states. This inverse relationship has been previously identified as an indicator of improved access to emergency obstetric units, specialised obstetric and post-abortion care.[27,30,52,53,54] In contrast, a direct relationship between all-abortion hospitalisation ratio and MMR may indicate high rates of in-hospital deaths secondary to obstetric complications or alternatively, that an important number of unsafe abortions are being conducted (Table 1).[27,30,54-57] Finally, low birth weight rate showed strong direct associations with all mortality ratios in multivariate models: for each 1% increase in low birth weight, increases

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of 1.6 in MMR, 0.4 in MMR_{AO}, and 0.2 in iAMR per 100,000 live births were estimated, explaining from 15.1% to 40.2% of the variance among states. An association between low birth weight and mortality ratios may be explained by the fact that low birth weight and pre-term birth represent *proxies* of pregnancy outcomes related to a series of antecedent individual risk factors and medical conditions, such as advanced maternal age, poor nutrition, infections, preeclampsia, placental abnormalities, cervical incompetence, cardiovascular conditions, pre-existing chronic diseases, drug addiction, alcohol abuse, insufficient prenatal care, and a gynaecological history of previous termination of pregnancy.[58,59,60,61,62] Taking into consideration the wide disparity in low birth weight rates among states (from 5.4% to 14.0%), medical conditions likely make a major contribution to current maternal mortality rates in Mexico. This suggests the need for an expansion of emergency obstetric units, specialised diagnostic centres and prenatal care for high-risk pregnancies, and the incorporation of other medical specialities, which in turn may favourably impact maternal health.[4,7,30,63-65]

Reproductive behaviour is another factor likely influencing maternal health. In this study, two variables were considered as *proxies* of the reproductive behaviour: contraceptive use and the average TFR between 2002 and 2011 for each state (Table 1).[10,30,66,67,68,69] This study provided little evidence that contraceptive use exerts an independent primary influence on maternal mortality differences among Mexican states. Nevertheless, alternative multivariate models considering TFR instead of contraceptive use revealed two opposite effects of TFR on mortality ratios: while displaying an inverse relationship with MMR and MMR_{AO}, TFR showed a direct association with iAMR, explaining 17.2% of the difference in abortion-related mortality among states. The direct association of TFR with iAMR may be related to an increased number of unplanned pregnancies terminated with abortion. In contrast, the inverse association between TFR and MMR or MMR_{AO} is more difficult to interpret. Simple direct correlations between TFR and MMR across multiple countries support the common notion that decreasing fertility reduces maternal mortality by reducing a woman's exposure to pregnancy during her reproductive lifetime.[10,66,67,70] However, results from recent studies show that the relationship between

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TFR and maternal mortality is much more complex and may vary from one country to another.[30,65,71,72] A plausible mechanism to explain an inverse correlation between TFR and maternal mortality has been referred to as “fertility paradox” emerging in advanced stages of demographic transition, when TFR falls under 2.5.[30] While early stages of fertility reduction would be associated with a decreased number of children per woman without a substantial delay of motherhood, later stages of fertility reduction appear to be primarily associated with a delayed motherhood.[30,40,63,65,72,73] The net effect of this change would be an increase in pregnancies among women over 35 years old, consequently increasing the risk of complications and mortality from medical conditions such as gestational hypertension, eclampsia, diabetes, haemorrhage, recurrent miscarriages, caesarean section, non-obstetric pre-existing conditions, and indirect causes.[40,65,71-77] A recent study in Mexico showed that over 75% of maternal deaths are related to these causes.[37] Considering a TFR of 2.3 for this country in 2011, a fertility paradox phenomenon may be underlying the inverse correlations between TFR and MMR or MMR_{AO} observed in this study.

Alternative multivariate models identified clean water and sanitation as variables influencing maternal and abortion-related mortality in Mexican states. These findings are consistent with the association of such environmental risk factors with maternal mortality.[30,78,79] A recent systematic review and meta-analysis proposed plausible mechanisms to explain this association:[79] first, poor hygiene conditions may lead to sepsis during childbirth, one of the main causes of maternal deaths worldwide.[78] Second, exposure to poor water and sanitation increases the likelihood of repeated infections, which may lead to long-term detrimental effects on the female population of fertile age.[79] Considering current disparities among Mexican states in the access to clean water and sanitation (ranging from 62.0% to 99.2%), this study’s findings highlight the potential positive impact of these basic elements of human development to continue improving maternal health in Mexico and other developing countries.

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The present study found that female literacy was a major variable influencing all mortality outcomes studied, explaining between 11.9% and 50.9% of the variance among Mexican states. For each 1% increase in female literacy, decreases of 1.1 in MMR, 0.1 in MMR_{AO}, and 0.1 in iAMR per 100,000 live births were estimated. The gap in female literacy among states, ranging from 77.5% to 96.5%, suggests that public programmes directed to increase women's education level may have a positive impact on maternal health in Mexico. In addition to a direct impact on maternal mortality,[10,30,80,81,82] women's education is correlated with other major predictors of maternal health, such as skilled attendance at birth,[30,83,84] access to antenatal care,[3-5] fertility rate,[10,30,85] family planning,[86] and contraceptive use.[87,88] Since education is likely to indicate early life circumstances and future socioeconomic outcomes,[89-91] women's education level may represent an antecedent variable impacting the reproductive behaviour, use of maternal health facilities and family planning programs, and access to improved sanitation.[30] Furthermore, because women's literacy can explain territorial differences in maternal mortality, predictive models of MMR considering differences in women's education level[10] are likely to be more precise than models neglecting to consider education,[12,68] as a recent comparative analysis suggests.[92]

Finally, intimate-partner violence against women over the last year was identified as an additional factor influencing maternal and induced abortion-related mortality. For each 1% increase in intimate-partner violence, increases of 0.8 in MMR and 0.1 in iAMR per 100,000 live births were estimated, explaining 2.8% and 7.2% of the variance among Mexican states, respectively. An association between intimate-partner violence [93,94] and several detrimental maternal outcomes such as antenatal haemorrhage,[95] vaginal bleeding,[96] antenatal hospitalisation,[96] caesarean section,[96] pre-term birth,[96] miscarriages,[97] pregnancy termination,[97,98] repeated abortion,[99] perinatal death,[95] femicide,[100] and poor mental health outcomes,[101] including suicide attempt,[102] has been previously described. In addition, because sexual coercion[103-106] and abuse[93] have been identified as strong predictors of induced abortion, these factors may influence MMR and iAMR, which warrants further research. Recent reports

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suggest that detection of violence against pregnant women during prenatal visits[107,108] and subsequent interventions by skilled health professionals may improve maternal outcomes.[109,110] Given the current statistics of intimate-partner violence against women observed in Mexican states (ranging from 6.3% in Oaxaca to 20.9% in the Federal District), such interventions may contribute to improve maternal health.

Limitations

Paraphrasing Geoffrey Rose,[111] epidemiological research traditionally distinguishes two kinds of etiological questions. For instance, the question “Why do some pregnant women die from abortion or gestational hypertension and others do not?” is different from “Why do some populations exhibit more deaths of pregnant women because of abortion or gestational hypertension?” While the first question asks for the causes of “cases” at the individual level, the second asks for the causes of “incidence” at the population level; consequently, to answer these questions, different kinds of epidemiological studies are required. In this context, the examination of current abortion laws in 32 Mexican states provided an interesting natural experiment to assess whether more or less permissive legislation were associated to lower or higher incidences of maternal and abortion-related deaths, simultaneously controlling for multiple confounders at the population level. However, this study –based on aggregated data– cannot conclusively rule out the influence of different factors impacting maternal health to an individual level of analysis and therefore, an ecological fallacy,[112,113] should be avoided. In contrast, an individualistic fallacy[113,114] based on the “high-risk”[111] approach should also be avoided in the interpretation of these results.

A major limitation to evaluate the impact of abortion legislation in terms of permissiveness is the intra-state heterogeneity in criminal codes and the inability to randomly allocate population of individuals to univocally defined groups, apparently making the criterion to segregate into each group somewhat arbitrary. However, the exemption due to genetic or congenital foetal malformations in their criminal codes was found to provide clear differences in mortality

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outcomes. In the case of Mexican states, this criminal exemption hinges on the opinion of a physician dictating that there are sufficient reasons to think that such alterations would result in an individual with serious physical or mental deficiencies.[38] Thus, legislation for this exemption would not contemplate criminal prosecution for induced abortion in extreme cases of foetal malformation, such as holoprosencephaly (a failure to develop two cerebral hemispheres, lethal *in utero* or shortly after birth), or less extreme conditions, such as Down syndrome (trisomy of chromosome 21, characterized by survival into adulthood). In addition, it is reasonable to think that the presence or absence of this exemption may reflect different cultural values and attitudes toward abortion itself.

Finally, although most variables, including abortion legislation, exhibited significant correlations with maternal mortality outcomes in Mexico, this study emphasises the importance of multivariate analyses correcting for multicollinearity between covariates and the presence of outliers on mortality outcomes. In addition to seeking unbiased effect sizes for significant predictors, any statistical association requires a plausible mechanism before making causal inferences at the population level.

CONCLUSION

This population-based natural experiment, using official vital statistics of live births and maternal deaths in 32 Mexican states between 2002 and 2011, showed that maternal and abortion-related mortality ratios were lower in states with less permissive abortion legislation compared to states with more permissive legislation. Nevertheless, the observed differences between populations were not attributable to the abortion legislation by itself. In fact, exhaustive multivariate analyses showed that these differences were largely explained by other factors such as women's literacy, maternal healthcare, water, sanitation, fertility rate and violence against women. These findings suggest that favourably addressing disparities on these factors may facilitate an epidemiologic transition toward low maternal mortality rates in developing countries.

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FOOTNOTES

*MMR is the quotient between the number of deaths from conditions related to or aggravated by pregnancy, childbirth or puerperium, and the number of live births during the same period of time. For purposes of comparison, this ratio is usually amplified by 10,000 or 100,000 observed live births.

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CONTRIBUTORS

EK was the leading author. EK and MC conceptualized the study. EK, MC, FP, JS, and SH contributed to the study design. MB, FP, SH, and SG were directly involved in the acquisition of data. SG reviewed abortion legislation for each state with the advice of FP, SH, and PA. EK, MC, PA, and MB had the main responsibility for data analysis and FP, JS, SH, BC, SG, and JT had full access to data, including results of statistical analyses. EK, MC, PA, MB, and SG drafted the manuscript, and FP, JS, SH, BC, and JT reviewed and commented on drafts and approved the final manuscript. EK, MC, BC, and JT are the guarantors of the study, accept full responsibility for the research, had access to the data, and controlled the decision to publish.

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COMPETING INTERESTS

None.

ETHICS APPROVAL, DATA SHARING AND TRANSPARENCY

Ethical approval: The study did not require any ethics committee approval.

Transparency: As guarantors of the study, EK, MC, BC, and JT assure that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Data sharing: All datasets employed are included in the supplementary material. Any additional information can be requested to the corresponding author at ekoch@melisainstitute.com

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FIGURE LEGENDS

Figure 1. Mortality ratios and the proportion of abortion-related deaths by place of residence in states with less and more permissive abortion legislation. Left panels illustrate trends in MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of residence between 2002 and 2011 in Mexican states, grouped as with less permissive (in dark green) or more permissive (in cyan) in terms of abortion legislation in their criminal code (see Material and Methods). For comparison, trends for the whole Mexican country (all states) are depicted as dotted lines. Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively), and the whole Mexican country (hollow bars).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with an abortive outcome.

Figure 2. Mortality ratios and the proportion of abortion-related deaths by place of occurrence in states with less and more permissive abortion legislation. Left panels illustrate trends in MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of occurrence between 2002 and 2011 in Mexican states, grouped as with less permissive (in dark green) or more permissive (in cyan) in terms of abortion legislation in their criminal code (see Material and Methods). For comparison, trends for the whole Mexican country (all states) are depicted as dotted lines. Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively), and the whole Mexican country (hollow bars).

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Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

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Figure 3. Average mortality ratios in states with more or less permissive abortion legislation between 2002 and 2011. Political maps of Mexican states are shown for average MMR (top panel) and average iAMR (bottom panel) for the 2002-2011 period, indicating whether they exhibit less (orange dots) or more (yellow dots) permissive abortion legislation, in terms of abortion legislation in their criminal code (see Material and Methods). Increasing blue colour indicates an increase in MMR or iAMR, on a quintile scale (see legend of each panel).
Abbreviations: Ag., Aguascalientes; Co., Colima; FD., Federal District; iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; Mo., Morelos; Tl., Tlaxcala.

Figure 4. Mortality ratios and the proportion of abortion-related deaths by place of residence in states with or without a constitutional amendment to protect the unborn starting at conception. Left panels illustrate trends for MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of residence between 2008 and 2011 in Mexican states, grouped as with amendment (in dark green) or without amendment (in cyan) in terms of abortion legislation in their criminal code (see Material and Methods). Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively).
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Figure 5. Mortality ratios and the proportion of abortion-related deaths by place of occurrence in states with or without a constitutional amendment to protect the unborn starting at conception. Left panels illustrate trends for MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of occurrence between 2008 and 2011 in Mexican states, grouped as with amendment (in dark green) or without amendment (in cyan) in terms of exhibiting or not a constitutional amendment to protect the unborn starting at conception (Figure S1, Supplementary Material).

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Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

Figure 6. Mortality ratios and the proportion of abortion-related deaths by place of residence in states with or without a constitutional amendment to protect the unborn starting at conception: focus on the Federal District. Left panels illustrate trends for MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of residence between 2008 and 2011 in Mexican states, grouped as with amendment" (in dark green), without amendment (in cyan), and the Federal District (in green) in terms of exhibiting or not an constitutional amendment (the Federal District of Mexico was not included in this group to be illustrated separately) to protect the unborn starting at conception (Figure S1, Supplementary Material) . Right panels show average ratios and proportion of abortion-related deaths for each group (dark green, cyan, and green bars, respectively).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

Figure 7. Mortality ratios and the proportion of abortion-related deaths by place of occurrence in states with or without constitutional amendment to protect the unborn starting at conception: focus on the Federal District. Left panels illustrate trends for MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of occurrence between 2008 and 2011 in Mexican states, grouped as with amendment (in dark green), without amendment (in cyan), and the Federal District (in green) in terms of exhibiting or not a constitutional amendment (the Federal District of

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* $p<0.05$ using *Z*-test.

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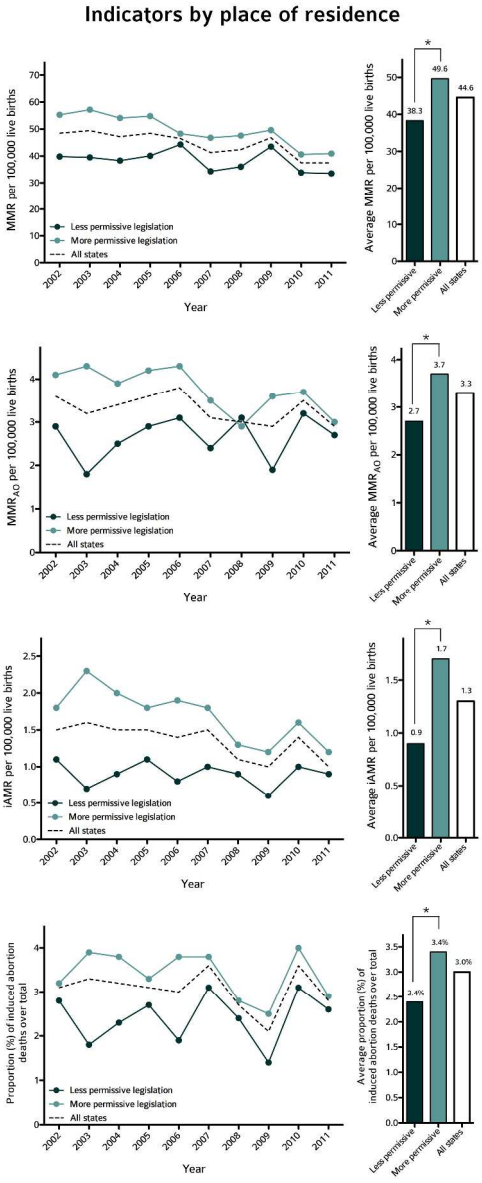

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* p<0.05 using Z-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMRAO, maternal mortality ratio with an abortive outcome.

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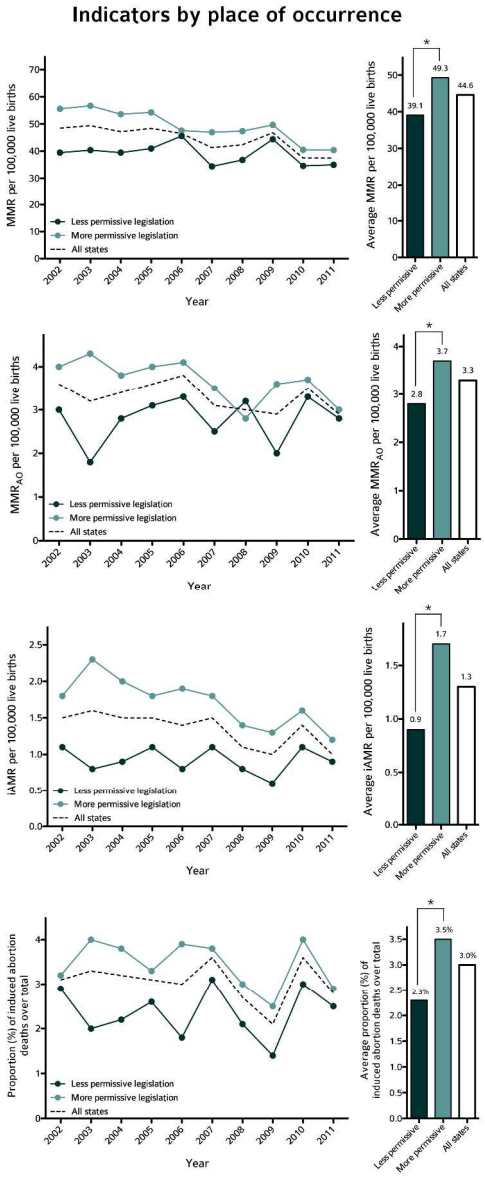

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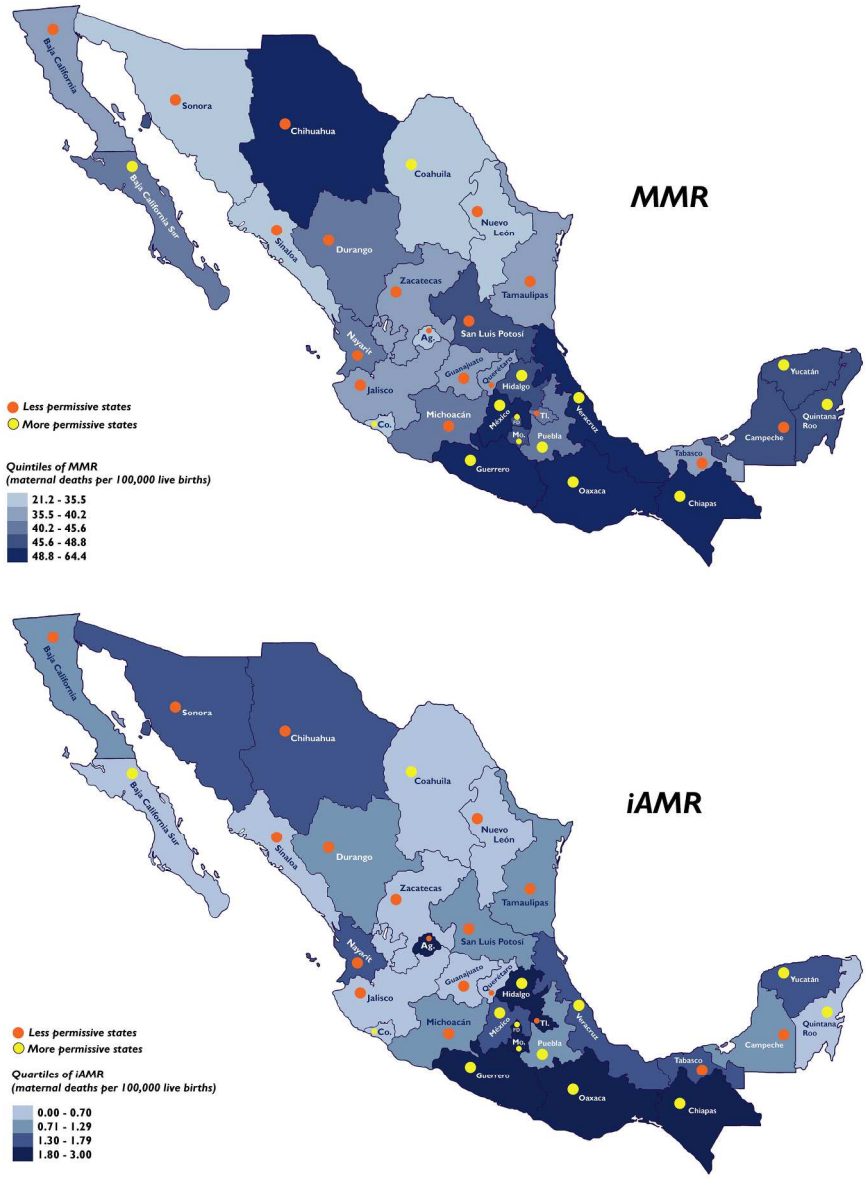

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Abbreviations: Ag., Aguascalientes; Co., Colima; FD., Federal District; iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; Mo., Morelos; Tl., Tlaxcala.

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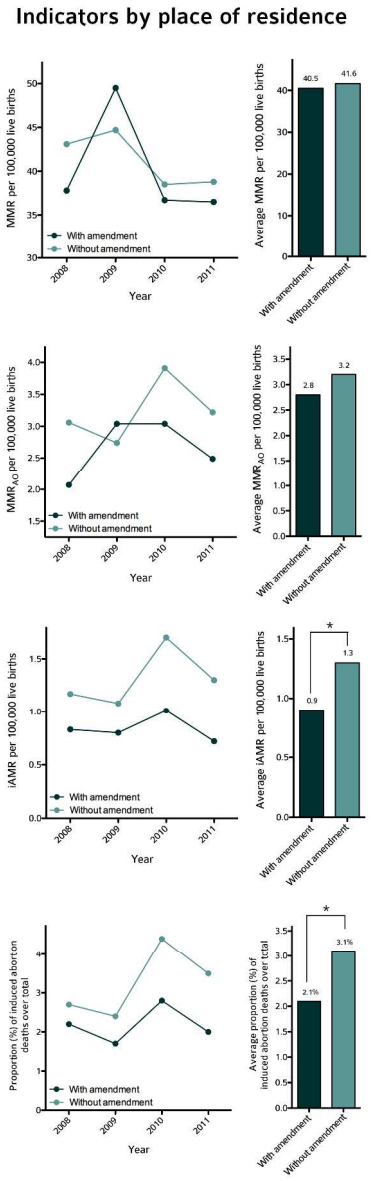

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* p<0.05 using Z-test.
Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMRAO, maternal mortality ratio with abortive outcome.
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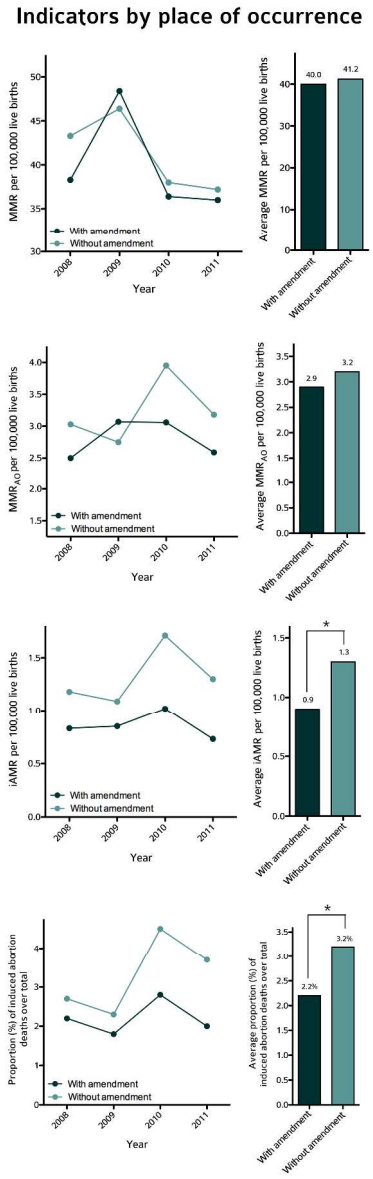

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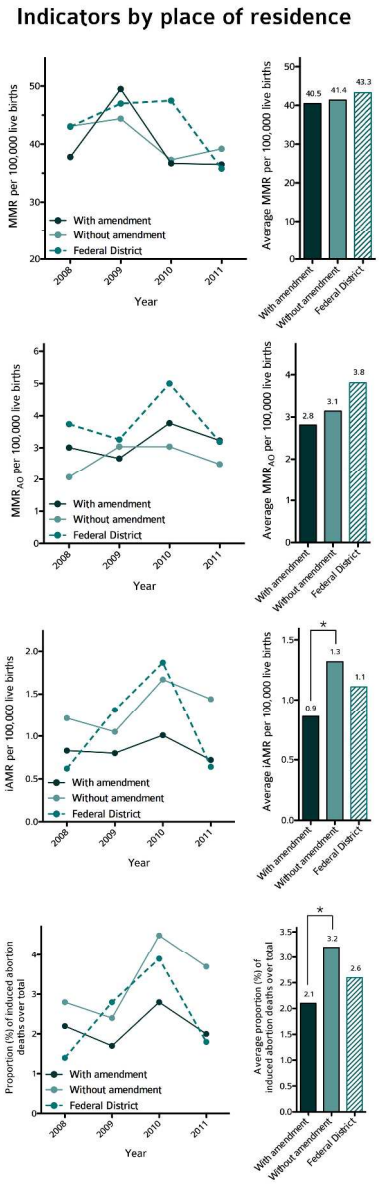

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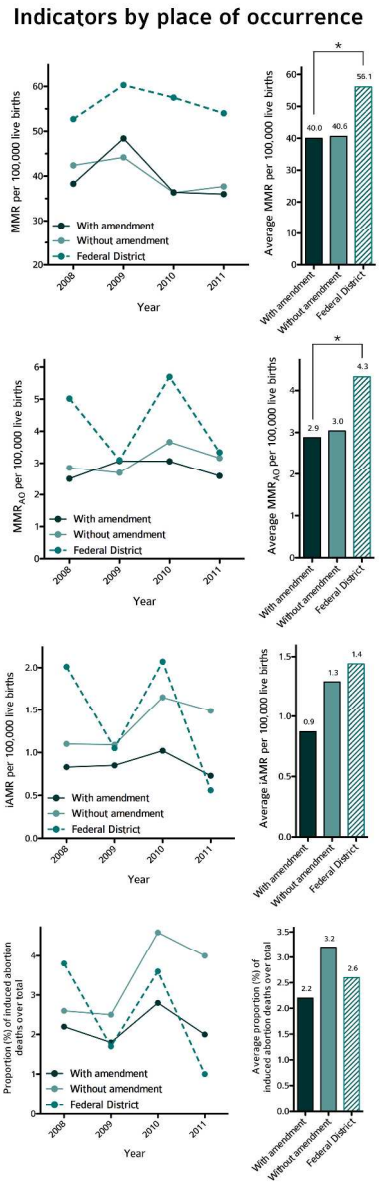

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Abortion legislation, maternal healthcare, fertility, female literacy, sanitation, violence against women, and maternal deaths: a natural experiment in 32 Mexican states

Elard Koch, Monique Chireau, Fernando Pliego, Joseph Stanford, Sebastián Haddad, Byron Calhoun, Paula Aracena, Miguel Bravo, Sebastián Gatica, and John Thorp

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Supplementary Material

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Figure S1 Mexican states with and without constitutional amendment to protect the unborn starting at conception between 2008 and 2011

Political maps of Mexican states are shown for 2008 (top panel), 2009 (middle panel), and 2010 (bottom panel), indicating whether they exhibit a constitutional amendment to protect the unborn starting at conception[1] in dark geen (with amendment) and cyan (without amendment). The state of Chihuahua enacted its political constitution in 1994; Baja California, Morelos, and Sonora in 2008; Campeche, Chiapas, Colima, Durango, Guanajuato, Jalisco, Nayarit, Oaxaca, Puebla, Querétaro, Quintana Roo, San Luis Potosí, and Yucatán in 2009; and Tamaulipas in 2010. Campeche revoked the amendment in 2010.

Ag, Aguascalientes; Co, Colima; FD, Federal District; Mo, Morelos; Tl, Tlaxcala.

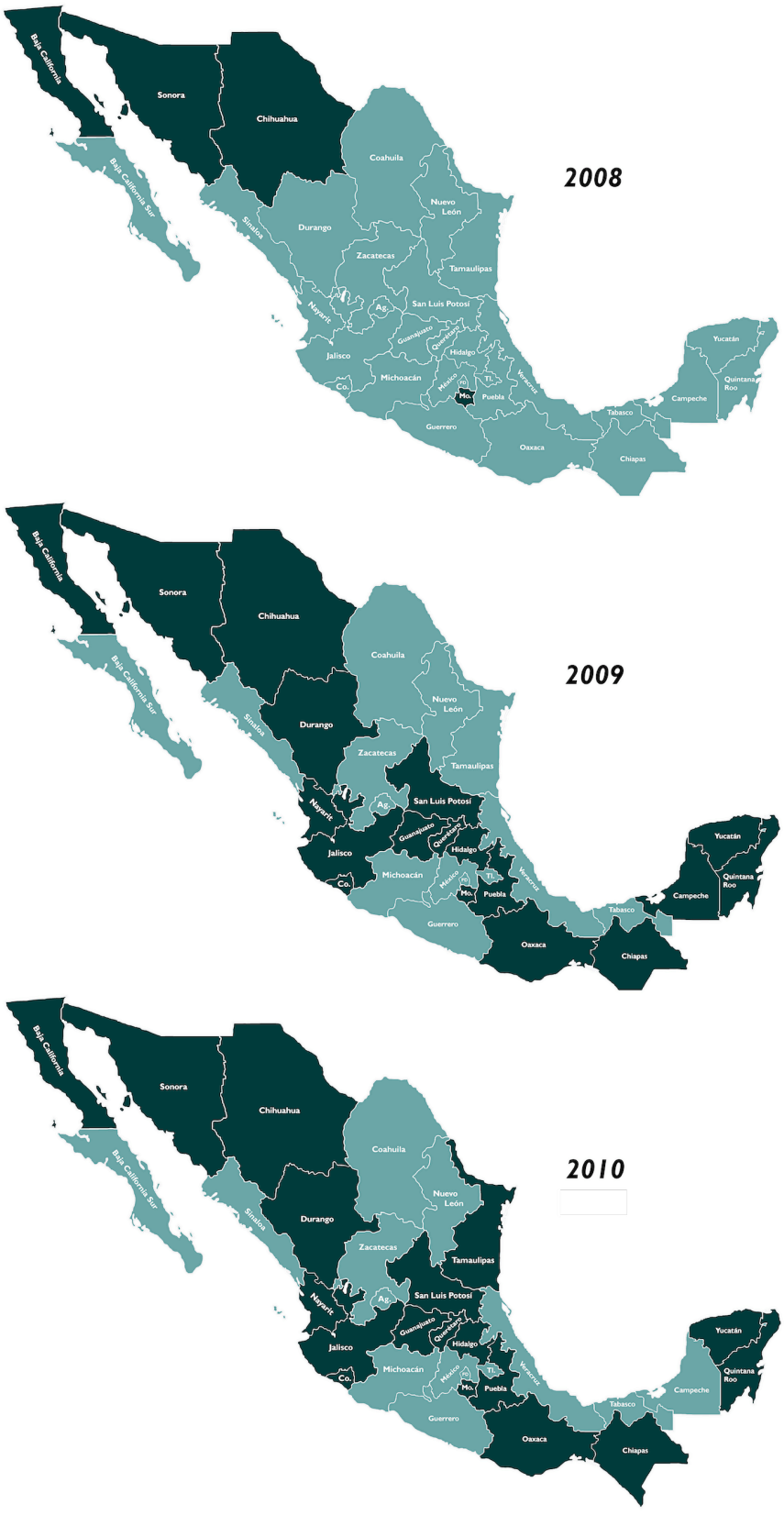

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Table S1 Current abortion legislations based on criminal exemptions from prosecution of abortion in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation

	Rape	Imprudential conduct	Risk to the life of the mother	Genetic or congenital malformation	Serious risk to the health of the mother	Artificial insemination without consent	Economic or social reasons	On demand
Aguascalientes (l)	✓	✓	✓					
Baja California (l)	✓	✓	✓			✓		
Baja California Sur (m)	✓	✓	✓	✓	✓	✓		
Campeche (l)	✓	✓			✓			
Coahuila (m)	✓	✓	✓	✓				
Colima (m)	✓	✓	✓	✓		✓		
Chiapas (m)	✓		✓	✓				
Chihuahua (l)	✓	✓			✓	✓		
Distrito Federal (m)	✓	✓		✓	✓	✓		✓
Durango (l)	✓	✓	✓					
Guanajuato (l)	✓	✓						
Guerrero (m)	✓	✓		✓		✓		
Hidalgo (m)	✓	✓		✓	✓			
Jalisco (l)	✓	✓	✓		✓			
México (m)	✓	✓	✓	✓				
Michoacán (l)	✓	✓	✓		✓			
Morelos (m)	✓	✓	✓	✓		✓		
Nayarit (l)	✓	✓	✓		✓			
Nuevo León (l)	✓		✓		✓			
Oaxaca (m)	✓	✓	✓	✓				
Puebla (m)	✓	✓	✓	✓				
Querétaro (l)	✓	✓						
Quintana Roo (m)	✓	✓	✓	✓				
San Luis Potosí (l)	✓	✓	✓			✓		
Sinaloa (l)	✓	✓	✓					
Sonora (l)	✓	✓	✓					
Tabasco (l)	✓		✓			✓		
Tamaulipas (l)	✓	✓	✓		✓			
Tlaxcala (l)	✓	✓	✓		✓			
Veracruz (m)	✓	✓	✓	✓		✓		
Yucatán (m)	✓	✓	✓	✓			✓	
Zacatecas (l)	✓	✓	✓		✓			
Total	**32**	**29**	**25**	**14**	**12**	**10**	**1**	**1**

Official criminal legislation for each state were reviewed and extracted from the National Office for the Judiciary.[1]
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.

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Table S2 Detailed description of independent variables considered in the natural experiment of 32 Mexican states on maternal mortality outcomes

Independent variable (abbreviated name)	International Definition	Significance for epidemiological studies	Scale of measure	Source of data
Criminal code exemption from prosecution of abortion in cases of serious foetal genetic or congenital malformation.. **(Abortion legislation)**	Exemption from prosecution of abortion when performed with the consent of the mother and when a physician's opinion dictates there are sufficient reasons to suppose that the foetus suffers from genetic or congenital conditions yielding serious physical or mental deficiencies.	It has been proposed that restriction of induced abortion is detrimental to maternal mortality.[2-4] Among the eight exemptions for criminal prosecution of abortion in Mexico, serious genetic and congenital foetal malformation was selected as suggestive of more permissive abortion legislation. It is reasonable to think that states excluding this exemption may be culturally less willing to accept pregnancy termination as a legal practice.[5-8]	Dichotomous data: states with less permissive (1) and more permissive (0) abortion legislations.	National Office for the Judiciary of the Mexican government.[1]
Constitutional amendment to protect the unborn starting at conception. **(Constitutional amendment)**	Enactment of an amendment to the constitution that explicitly protects the unborn starting at conception.	It is plausible that states including such amendment may be culturally less willing to accept the legal practice of pregnancy termination.[5-8]	Dichotomous data: states with (1) and without (0) constitutional amendment.	National Office for the Judiciary of the Mexican government.[1]
Percentage of access to clean water. **(Clean water)**	Proportion of people with access to a source of clean drinking water less than 1 kilometre away from its place of use, and that it is possible to reliably obtain at least 20 litres per member of a household per day.[9]	Pregnant women may be particularly vulnerable to water-related diseases such as vitamin deficiency, trachoma and hepatitis. In addition, access to clean water is an integral part of preventing infections in pregnant women, especially in medical facilities. Puerperal sepsis introduced at the time of delivery through unhygienic environment or practices may be a plausible mechanism.[10] Increased water access has been associated with decreased maternal mortality ratio.[9-11]	Percentage of occupied private dwellings with clean water availability in each state during 2010.	INEGI: 2010 Census of Population and Housing.[12]
Sanitary sewer coverage. **(Sanitation)**	Proportion of people using improved sanitation facilities (*e.g.*, public sewer connection, septic system connection, pour-flush latrine, simple pit latrine, ventilated improved pit latrine).[9]	Increased access to sanitary sewer has been associated with decreased maternal mortality ratio.[9-11] Puerperal sepsis introduced at the time of delivery through unhygienic environment or practices, or repeated exposure to infections during pregnancy may be a plausible mechanism.[10]	Percentage of occupied private dwellings with availability of sewer drainage in each state during 2010.	INEGI: 2010 Census of Population and Housing.[12]
Average total fertility rate between 2002 and 2011. **(TFR)**	Average number of children that would be born per woman if all women lived to the end of their childbearing years and bore children according to a given fertility rate at each age.[13]	TFR is considered to be a result of the overall factors influencing the reproductive behaviour of the entire female population over time. It has been proposed that fertility is an important determinant of reduced maternal mortality.[11,14-16] However, it has been reported that the effect of TFR on maternal mortality trends disappears when controlling for the education level of women.[11,17,18]	Average total fertility rate of each state between 2002 and 2011.	INEGI: Populations, Homes, and Housing.[19]
Percentage of contraceptive use by married or in-union female population of fertile age. **(Contraceptive use)**	Percentage of women who are currently using, or whose sexual partner is currently using, at least one method of contraception, regardless of the method used.[20]	Contraceptive use is considered a major component of family planning, and it is thought to decrease unplanned pregnancies, unsafe abortion, and fertility rates, leading to a decrease in maternal mortality.[16,21,22]	Percentage of married or in-union women 15 years and older who were using contraceptive methods in each state during 2009.	INEGI: National Survey of Demographics Dynamics 2009.[23]

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Table S2 Detailed description of independent variables considered in the natural experiment of 32 Mexican states on maternal mortality outcomes (Continued)

Independent variable (abbreviated name)	International Definition	Significance for epidemiological studies	Scale of measure	Source of data
Percentage of skilled attendance at birth. **(Skilled attendance at birth)**	Childbirth attended by a health professional.[24]	This is an indicator of women's use of maternal healthcare care services and a measure of the health system's functioning and potential to provide adequate coverage for deliveries.[25-28] In addition, this factor is positively correlated to access to antenatal care and institutional delivery.[11,29,30]	Percentage of observed live births delivered by a physician, nurse or midwife in each state during 2010.	INEGI: Live births registry.[31]
Low birth weight rate. **(Low birth weight)**	Birth weight of a live born infant of less than 2,500g (5.5 pounds), regardless of the gestational age.[32]	Risk factors in the mother that likely contribute to low birth weight and pre-term birth include extreme ages, multiple pregnancies, previous infants with low birth weight, poor nutrition, heart disease or hypertension, substance and alcohol abuse, and insufficient prenatal care. Environmental risk factors include smoking, lead exposure, and other types of air pollutions. In addition, induced abortion by itself has been identified as major individual risk factor for preterm birth and low birth weight en subsequent pregnancies.[33-37]	Percentage of observed live births with low birth weight in each state during 2010.	INEGI: Society and Government.[38]
Literacy rate of the adult female population **(Female literacy)**	Percentage of the female population of ages 15 and above who can understand, read and write a short, simple statement on their everyday life. Generally, 'literacy' also encompasses 'numeracy', the ability to make simple arithmetic calculations. This indicator is calculated by dividing the number of literates aged 15 years and over by the corresponding age group population and multiplying the result by 100.[39]	The relationship between literacy on maternal morality is both direct and indirect. Literate women are more likely to maintain adequate care during and after pregnancy, make better decisions regarding their health and well-being, better access and use information, and are better able to control their own fertility.[11,14,28,40-42] Recently, education of women has been shown to be a major determinant in the improvement of maternal health.[11]	Percentage of the female population of ages 15 and above who can understand, read and write a short, simple statement on their everyday life in each state during 2010.	INEGI: 2010 Census of Population and Housing.[12]
All-abortion hospitalisation ratio	Ratio of all abortion-related hospitalisations per women of fertile age over 100 live births.	Recent studies in low maternal mortality settings, show that this indicator is a measure of access to opportune or immediate emergency care for women experiencing complications due to any kind of abortion.[11,43-46] However, the relationship between all-abortion hospitalisation ratio and MMR may be bidirectional. A direct correlation may be an indicator of high rates of in-hospital deaths secondary to complications of pregnancy termination[47] or alternatively that an important number of unsafe abortions are being conducted.[48,49]	Ratio of all-abortion related hospitalisations in each state between 2000 and 2008 per 100 live births	Schiavon *et al.*: Series of all-abortion hospitalizations.[43] INEGI: Live births registry.[31]
Percentage of intimate partner violence against married or in-union women over the last year **(Intimate-partner violence)**	Any act of gender-based violence that results in, or is likely to result in, physical, sexual or mental harm or suffering to women, including threats of such acts, coercion or arbitrary deprivation of liberty, whether occurring in public or in private life.[50]	Violence against pregnant women increases the risk of death, which makes this variable a potential factor influencing maternal mortality of a territory.[51,52] In addition, factors such as coercion, sexual or intimate partner violence have been consistently identified in the literature as strong predictors of abortion.[51,53-55]	Percentage of married or in-union women of ages 15 and above who have suffered severe intimate partner violence during the past 12 months in each state during 2010.	INEGI: Overview of Violence Against Women in the United Mexican States.[56]

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Table S3 Observed live births by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (*l*)	27524	26165	26527	25619	25434	25822	26509	25800	26583	27427	263410
Baja California (*l*)	58347	57938	60925	61844	64909	66114	65060	63709	63559	65631	628036
Baja California Sur (*m*)	11714	12030	12461	11509	12256	13110	13993	13343	13988	13412	127816
Campeche (*l*)	15138	15808	17144	18246	16629	16962	18105	17307	20380	22138	177857
Coahuila (*m*)	60052	56410	57393	55962	56458	58898	58575	58132	56972	58882	577734
Colima (*m*)	13012	12477	13272	12276	11762	12765	12723	13447	13796	14054	129584
Chiapas (*m*)	187312	144410	133979	137488	132205	155885	153738	145085	175382	168256	1533740
Chihuahua (*l*)	84086	78192	75468	77840	72731	76154	82263	76300	74063	69376	766473
Distrito Federal (*m*)	170405	159844	167285	163212	155703	160735	160377	153237	160057	156549	1607404
Durango (*l*)	45135	44437	39519	39519	38424	40284	39292	39736	42514	41922	410782
Guanajuato (*l*)	123313	130183	123312	127290	118270	127270	125187	125272	126741	124003	1250841
Guerrero (*m*)	103732	137277	116293	101699	101972	116033	101554	98945	119780	113692	1110977
Hidalgo (*m*)	65715	62757	68906	61410	62985	67543	64237	61431	62185	63380	640549
Jalisco (*l*)	160145	157618	158748	155082	153636	157334	156782	154738	161543	163123	1578749
México (*m*)	334352	332666	343150	335257	330108	346720	342830	355392	335898	327165	3383538
Michoacán (*l*)	114588	121624	112451	104243	99531	104550	107123	107287	116260	111362	1099019
Morelos (*m*)	38714	36373	35648	35810	34072	40061	38295	36760	40210	40230	376173
Nayarit (*l*)	23667	24240	24517	22338	24213	24548	24972	24598	24639	24949	242681
Nuevo León (*l*)	91424	88195	90440	87645	87634	91855	91247	91490	94119	93747	907796
Oaxaca (*m*)	120286	119465	122467	112991	106831	122579	118307	108978	109624	98888	1140416
Puebla (*m*)	172667	169725	158391	165560	156914	158165	164257	155738	160571	146865	1608853
Querétaro (*l*)	36928	38113	40075	41902	39504	43459	42460	41260	40863	41714	406278
Quintana Roo (*m*)	24370	23754	23711	24363	27235	29110	29311	29539	28999	28848	269240
San Luis Potosí (*l*)	60240	59917	61214	59005	58021	60223	59365	58300	58583	57549	592417
Sinaloa (*l*)	68625	63456	65065	61615	59947	60668	61559	59942	61233	60208	622318
Sonora (*l*)	57435	54811	53631	53609	53347	55481	55372	53930	54110	54756	546482
Tabasco (*l*)	52202	51146	55720	52744	52545	54978	51979	55402	49844	49575	526135
Tamaulipas (*l*)	70513	66497	72847	74080	71556	76472	74492	72381	69211	66892	714941
Tlaxcala (*l*)	28347	27896	29225	26754	27507	29011	27522	27276	27076	27867	278481
Veracruz (*m*)	195458	199471	190790	189414	179690	184287	187560	173101	174086	171417	1845274

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Table S3 Observed live births by place of residence in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Yucatán (m)	38006	38251	33855	35655	36576	37872	38562	38147	37703	36860	371487
Zacatecas (l)	36937	35198	35099	34131	33746	35722	35277	35304	35974	36629	354017
Less permissive states	**1154594**	**1141434**	**1141927**	**1123506**	**1097584**	**1146907**	**1144566**	**1130032**	**1147295**	**1138868**	**11366713**
More permissive states	**1535795**	**1504910**	**1477601**	**1442606**	**1404767**	**1503763**	**1484319**	**1441275**	**1489251**	**1438498**	**14722785**
United Mexican States	**2690389**	**2646344**	**2619528**	**2566112**	**2502351**	**2650670**	**2628885**	**2571307**	**2636546**	**2577366**	**26089498**

Official records of observed live births by place of residence were extracted from the National Institute of Statistics and Geography (INEGI),[31] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of observed live births by place of residence between 2002 and 2011.

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Table S4 Observed live births by place of occurrence in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (l)	29805	28378	28395	28002	27714	27888	28375	27509	28154	28282	282502
Baja California (l)	59327	58040	59776	60739	61643	62491	63053	61566	61071	61988	609694
Baja California Sur (m)	11355	11512	11877	11196	11816	12733	13639	14041	13673	13303	125145
Campeche (l)	14462	15027	16095	17045	15657	16103	17345	16585	18664	18844	165767
Coahuila (m)	60724	56967	57588	56463	57082	59170	58766	58343	57057	59060	581230
Colima (m)	13102	12742	13194	12716	12672	13786	13505	14075	14565	14990	135287
Chiapas (m)	188933	146005	135507	138955	133619	159278	157916	144841	175324	168480	1548858
Chihuahua (l)	83124	78214	74479	78215	73640	76752	82939	76888	74620	69785	768656
Distrito Federal (m)	222105	212947	222547	216405	201419	203892	199060	190625	193089	179731	2041830
Durango (l)	43980	43297	38845	38677	37564	39225	38531	38677	40960	39929	399625
Guanajuato (l)	123622	130878	130786	130367	121672	130727	128647	123935	125246	122593	1268473
Guerrero (m)	102376	135613	114506	100139	100033	113906	99358	96411	117110	111205	1090657
Hidalgo (m)	67275	64988	71342	64326	64373	68911	65372	62939	63052	63531	656109
Jalisco (l)	159163	156651	157292	154817	153363	157254	156862	155387	161748	163808	1576345
México (m)	283436	280954	287806	282571	285229	304542	304096	317021	300447	304178	2950280
Michoacán (l)	114859	120825	109175	100663	96497	100507	101936	101990	110477	104895	1061824
Morelos (m)	38860	36151	35763	36338	34955	40431	38923	37595	40690	40126	379832
Nayarit (l)	22171	22451	22560	20520	22231	22183	22278	22642	22879	22566	222411
Nuevo León (l)	91343	88209	90564	88382	88849	93185	92571	92973	95372	94857	916305
Oaxaca (m)	121148	119893	122401	112168	105733	120642	115788	106971	108721	98685	1132155
Puebla (m)	171432	168018	157109	163621	155048	155559	160850	150847	155177	142171	1579832
Querétaro (l)	39387	40634	42002	43149	41062	44894	43704	42704	42768	43548	423852
Quintana Roo (m)	24190	23498	23590	24291	26920	28610	28453	29310	28801	28819	266482
San Luis Potosí (l)	59804	59554	60102	58300	57005	59039	57808	55865	57068	57101	581661
Sinaloa (l)	68197	63287	64588	61592	59939	60684	61359	59350	61034	60445	620475
Sonora (l)	57453	54683	53751	53789	53586	55534	55199	53815	54147	54724	546675
Tabasco (l)	52715	51371	56024	53081	52951	55256	52593	56625	51958	52358	534933
Tamaulipas (l)	71498	67620	73925	74932	72248	76469	74640	73076	70312	68526	723306
Tlaxcala (l)	26924	26673	27663	25328	26007	27086	26241	26430	26543	27350	266245
Veracruz (m)	189144	193812	184046	183161	173955	178486	180907	167664	169126	165522	1785823

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Table S4 Observed live births by place of occurrence in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Yucatán (m)	38777	39015	34834	36673	37763	38923	39574	39065	38490	37605	380719
Zacatecas (l)	35920	34298	34064	33095	32630	34592	34294	34565	35423	35323	344204
Less permissive states	**1153754**	**1140090**	**1140086**	**1120693**	**1094258**	**1139869**	**1138375**	**1120582**	**1138324**	**1126922**	**11312953**
More permissive states	**1532857**	**1502115**	**1472110**	**1439023**	**1400617**	**1498869**	**1476207**	**1429748**	**1475287**	**1427406**	**14654239**
United Mexican States	**2686611**	**2642205**	**2612196**	**2559716**	**2494875**	**2638738**	**2614582**	**2550330**	**2613611**	**2554328**	**25967192**

Official records of observed live births by place of occurrence were extracted from the National Institute of Statistics and Geography (INEGI),[31] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of observed live births by place of occurrence between 2002 and 2011.

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Table S5 Total maternal deaths by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total †
Aguascalientes (*l*)	6	12	5	7	12	4	9	13	10	5	83
Baja California (*l*)	17	22	33	28	23	22	24	30	24	21	244
Baja California Sur (*m*)	6	9	4	3	4	8	5	5	4	4	52
Campeche (*l*)	11	9	7	11	10	3	7	8	8	10	84
Coahuila (*m*)	23	21	15	24	14	13	19	15	24	22	190
Colima (*m*)	2	3	4	1	6	2	4	3	‡	5	30
Chiapas (*m*)	94	106	96	82	82	78	92	71	69	60	830
Chihuahua (*l*)	50	33	34	57	43	46	38	55	39	46	441
Distrito Federal (*m*)	77	99	87	80	78	89	69	72	76	56	783
Durango (*l*)	14	19	24	14	26	14	23	13	15	13	175
Guanajuato (*l*)	58	62	53	42	43	40	39	60	42	42	481
Guerrero (*m*)	77	85	69	85	84	64	62	68	53	69	716
Hidalgo (*m*)	31	32	34	37	26	30	28	30	29	16	293
Jalisco (*l*)	50	56	66	52	77	46	52	81	48	36	564
México (*m*)	192	210	198	197	149	144	154	166	119	127	1656
Michoacán (*l*)	39	47	39	46	53	39	44	41	49	53	450
Morelos (*m*)	25	28	14	23	17	15	15	23	10	13	183
Nayarit (*l*)	16	15	10	18	7	5	9	12	8	10	110
Nuevo León (*l*)	22	10	12	20	24	17	23	25	14	25	192
Oaxaca (*m*)	80	50	64	70	54	70	67	66	59	50	630
Puebla (*m*)	88	89	87	74	63	58	62	78	58	59	716
Querétaro (*l*)	19	17	18	15	20	17	16	12	13	16	163
Quintana Roo (*m*)	12	14	11	13	13	14	17	10	13	13	130
San Luis Potosí (*l*)	42	38	32	25	19	30	17	28	22	24	277
Sinaloa (*l*)	19	11	18	23	20	25	18	18	18	9	179
Sonora (*l*)	23	18	18	19	25	20	14	21	12	22	192
Tabasco (*l*)	15	22	21	21	21	23	28	23	14	21	209
Tamaulipas (*l*)	23	22	26	31	35	25	33	24	26	10	255
Tlaxcala (*l*)	19	16	12	14	14	7	6	11	14	7	120
Veracruz (*m*)	113	94	100	82	79	99	98	93	78	81	917
Yucatán (*m*)	29	21	17	19	10	20	15	15	12	14	172
Zacatecas (*l*)	16	22	9	8	14	10	12	17	12	12	132
Less permissive states	**459**	**451**	**437**	**451**	**486**	**393**	**412**	**492**	**388**	**382**	**4351**
More permissive states	**849**	**861**	**800**	**790**	**679**	**704**	**707**	**715**	**604**	**589**	**7298**
United Mexican States	**1308**	**1312**	**1237**	**1241**	**1165**	**1097**	**1119**	**1207**	**992**	**971**	**11649**

Official records of maternal deaths (ICD-10 codes O00-O99, A34, B20-B24, and F53) by place of residence were extracted from the General Directorate of Health Information (DGIS),[57] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of maternal deaths by place of residence between 2002 and 2011.
‡ Not available.

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Table S6 Maternal deaths with abortive outcome by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (*l*)	0	1	0	0	3	2	2	0	1	0	9
Baja California (*l*)	3	1	7	1	2	1	0	2	4	3	24
Baja California Sur (*m*)	0	0	0	0	0	0	0	0	0	0	0
Campeche (*l*)	1	0	0	0	0	0	1	0	2	0	4
Coahuila (*m*)	1	2	0	0	2	1	0	0	2	1	9
Colima (*m*)	1	0	0	0	0	1	0	0	0	0	2
Chiapas (*m*)	9	11	9	5	10	5	6	2	4	4	65
Chihuahua (*l*)	2	3	1	5	2	0	3	2	6	3	27
Distrito Federal (*m*)	9	9	7	8	8	13	6	5	8	5	78
Durango (*l*)	1	0	0	0	1	0	7	0	1	1	11
Guanajuato (*l*)	5	0	3	5	4	2	2	4	2	2	29
Guerrero (*m*)	9	7	8	4	5	1	2	4	3	3	46
Hidalgo (*m*)	3	2	3	1	3	5	2	3	1	0	23
Jalisco (*l*)	3	2	3	4	6	5	5	6	6	2	42
México (*m*)	8	14	14	15	21	8	13	15	18	15	141
Michoacán (*l*)	3	2	5	5	5	4	2	1	3	6	36
Morelos (*m*)	2	2	3	2	0	0	1	2	2	0	14
Nayarit (*l*)	3	2	0	2	1	1	0	0	1	1	11
Nuevo León (*l*)	2	2	1	3	2	4	2	0	1	3	20
Oaxaca (*m*)	4	3	3	3	5	6	1	7	3	4	39
Puebla (*m*)	8	5	4	6	2	5	2	5	3	4	44
Querétaro (*l*)	0	0	0	2	2	1	0	0	1	2	8
Quintana Roo (*m*)	0	2	1	2	0	2	1	2	0	0	10
San Luis Potosí (*l*)	4	3	2	0	0	0	3	2	3	2	19
Sinaloa (*l*)	1	1	1	1	0	0	0	0	1	0	5
Sonora (*l*)	2	1	0	0	3	2	1	0	1	1	11
Tabasco (*l*)	0	0	4	1	2	3	2	0	0	3	15
Tamaulipas (*l*)	1	0	2	2	1	1	2	4	1	1	15
Tlaxcala (*l*)	1	2	0	2	0	1	2	0	1	0	9
Veracruz (*m*)	8	6	6	10	4	6	7	5	10	6	68
Yucatán (*m*)	1	2	0	4	0	0	2	2	1	1	13
Zacatecas (*l*)	2	0	0	0	0	1	1	1	2	1	8
Less permissive states	**34**	**20**	**29**	**33**	**34**	**28**	**35**	**22**	**37**	**31**	**303**
More permissive states	**63**	**65**	**58**	**60**	**60**	**53**	**43**	**52**	**55**	**43**	**552**
United Mexican States	**97**	**85**	**87**	**93**	**94**	**81**	**78**	**74**	**92**	**74**	**855**

Official records of maternal deaths with abortive outcome (ICD-10 codes O00-O08) by place of residence were extracted from the General Directorate of Health Information (DGIS),[57] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of maternal deaths with abortive outcome by place of residence between 2002 and 2011.

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Table S7 Induced abortion-related deaths by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (*l*)	0	1	0	0	2	2	1	0	0	0	6
Baja California (*l*)	0	1	3	0	0	0	0	0	1	0	5
Baja California Sur (*m*)	0	0	0	0	0	0	0	0	0	0	0
Campeche (*l*)	1	0	0	0	0	0	0	0	1	0	2
Coahuila (*m*)	1	1	0	0	0	1	0	0	1	0	4
Colima (*m*)	0	0	0	0	0	0	0	0	0	0	0
Chiapas (*m*)	7	7	3	1	5	2	3	2	1	0	31
Chihuahua (*l*)	2	2	0	2	0	0	1	1	2	1	11
Distrito Federal (*m*)	3	3	2	6	2	7	1	2	3	1	30
Durango (*l*)	1	0	0	0	0	0	3	0	1	0	5
Guanajuato (*l*)	1	0	1	2	0	0	0	0	1	1	6
Guerrero (*m*)	5	6	6	3	4	1	2	1	2	3	33
Hidalgo (*m*)	1	0	3	0	2	3	1	1	1	0	12
Jalisco (*l*)	0	0	0	1	2	3	1	1	1	0	9
México (*m*)	0	9	6	6	9	3	8	4	7	7	59
Michoacán (*l*)	2	1	1	3	0	1	0	0	1	3	12
Morelos (*m*)	0	2	2	0	0	0	0	2	1	0	7
Nayarit (*l*)	1	1	0	0	1	1	0	0	0	0	4
Nuevo León (*l*)	1	0	0	0	0	0	1	0	0	0	2
Oaxaca (*m*)	4	2	2	1	3	4	1	2	2	1	22
Puebla (*m*)	4	1	2	3	0	4	1	2	1	1	19
Querétaro (*l*)	0	0	0	1	0	1	0	0	0	1	3
Quintana Roo (*m*)	0	1	1	0	0	0	0	0	0	0	2
San Luis Potosí (*l*)	1	0	0	0	0	0	1	0	1	2	5
Sinaloa (*l*)	0	0	0	0	0	0	0	0	0	0	0
Sonora (*l*)	1	1	0	0	2	1	1	0	1	1	8
Tabasco (*l*)	0	0	4	0	2	2	0	0	0	1	9
Tamaulipas (*l*)	1	0	1	1	0	0	0	4	0	0	7
Tlaxcala (*l*)	1	1	0	2	0	1	1	0	1	0	7
Veracruz (*m*)	2	2	3	4	1	2	1	2	5	3	25
Yucatán (*m*)	0	0	0	2	0	0	2	0	0	1	5
Zacatecas (*l*)	0	0	0	0	0	0	0	1	1	0	2
Less permissive states	**13**	**8**	**10**	**12**	**9**	**12**	**10**	**7**	**12**	**10**	**103**
More permissive states	**27**	**34**	**30**	**26**	**26**	**27**	**20**	**18**	**24**	**17**	**249**
United Mexican States	**40**	**42**	**40**	**38**	**35**	**39**	**30**	**25**	**36**	**27**	**352**

Official records of induced abortion related deaths (ICD-10 codes O04-O07) by place of residence were extracted from the General Directorate of Health Information (DGIS),[57] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of induced abortion related deaths by place of residence between 2002 and 2011.

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Table S8 Total maternal deaths by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (*l*)	7	14	5	8	12	5	9	19	10	5	94
Baja California (*l*)	17	20	34	27	24	23	24	33	26	22	250
Baja California Sur (*m*)	6	9	4	4	4	8	5	5	3	3	51
Campeche (*l*)	10	8	8	9	10	3	7	8	8	10	81
Coahuila (*m*)	25	17	16	22	17	14	19	18	20	20	188
Colima (*m*)	2	4	2	1	4	3	5	3	1	3	28
Chiapas (*m*)	92	104	93	79	77	75	86	63	65	55	789
Chihuahua (*l*)	49	33	35	56	43	43	39	56	39	47	440
Distrito Federal (*m*)	134	159	152	140	129	122	105	115	111	97	1264
Durango (*l*)	11	19	20	15	20	13	22	11	14	9	154
Guanajuato (*l*)	58	61	51	38	45	35	40	62	39	41	470
Guerrero (*m*)	78	85	67	79	80	61	58	67	51	62	688
Hidalgo (*m*)	28	32	29	34	24	29	26	29	26	13	270
Jalisco (*l*)	52	58	67	51	76	48	51	74	51	40	568
México (*m*)	145	159	142	145	109	119	128	129	91	99	1266
Michoacán (*l*)	36	43	37	45	49	33	42	40	46	52	423
Morelos (*m*)	24	25	12	23	14	16	15	25	9	13	176
Nayarit (*l*)	14	14	11	16	7	4	10	11	6	11	104
Nuevo León (*l*)	26	17	14	25	26	22	24	27	23	33	237
Oaxaca (*m*)	76	48	60	71	53	66	66	63	59	50	612
Puebla (*m*)	89	87	89	71	58	60	61	79	59	58	711
Querétaro (*l*)	19	18	22	23	22	21	16	11	14	15	181
Quintana Roo (*m*)	9	15	9	9	10	12	15	9	11	12	111
San Luis Potosí (*l*)	43	38	29	23	20	29	16	27	23	22	270
Sinaloa (*l*)	19	13	17	24	23	27	17	18	18	10	186
Sonora (*l*)	23	18	18	19	23	21	14	17	11	22	186
Tabasco (*l*)	17	27	24	26	23	26	32	30	19	23	247
Tamaulipas (*l*)	24	26	36	35	47	22	38	29	23	11	291
Tlaxcala (*l*)	17	13	11	13	13	6	4	8	12	8	105
Veracruz (*m*)	111	87	95	80	75	98	94	90	78	78	886
Yucatán (*m*)	33	21	19	24	13	22	17	15	13	14	191
Zacatecas (*l*)	14	21	11	7	16	11	14	16	12	13	135
Less permissive states	**456**	**461**	**450**	**460**	**499**	**392**	**419**	**497**	**394**	**394**	**4422**
More permissive states	**852**	**852**	**789**	**782**	**667**	**705**	**700**	**710**	**597**	**577**	**7231**
United Mexican States	**1308**	**1313**	**1239**	**1242**	**1166**	**1097**	**1119**	**1207**	**991**	**971**	**11653**

Official records of maternal deaths (ICD-10 codes O00-O99, A34, B20-B24, and F53) by place of occurrence were extracted from the General Directorate of Health Information (DGIS),[57] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of maternal deaths by place of occurrence between 2002 and 2011.

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Table S9 Maternal deaths with abortive outcome by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (*l*)	0	1	0	0	2	2	2	0	1	0	8
Baja California (*l*)	3	1	7	1	2	1	0	2	5	3	25
Baja California Sur (*m*)	0	0	0	0	0	0	0	0	0	0	0
Campeche (*l*)	1	0	0	0	0	0	1	0	3	0	5
Coahuila (*m*)	1	1	0	0	2	1	0	0	2	1	8
Colima (*m*)	1	0	0	0	0	1	0	0	0	0	2
Chiapas (*m*)	8	12	9	4	9	5	6	2	4	4	63
Chihuahua (*l*)	2	3	1	5	2	0	4	2	5	3	27
Distrito Federal (*m*)	13	14	10	12	14	13	10	6	11	6	109
Durango (*l*)	1	0	0	0	1	0	6	0	1	1	10
Guanajuato (*l*)	6	0	3	5	4	2	2	4	2	2	30
Guerrero (*m*)	8	7	7	4	3	2	2	3	3	3	42
Hidalgo (*m*)	3	2	2	0	3	5	2	3	1	1	22
Jalisco (*l*)	3	2	4	4	6	7	5	6	7	2	46
México (*m*)	5	9	11	11	13	7	9	15	15	14	109
Michoacán (*l*)	2	2	6	5	5	3	2	1	4	6	36
Morelos (*m*)	3	2	2	2	1	0	1	2	2	0	15
Nayarit (*l*)	3	2	1	2	1	0	0	0	0	1	10
Nuevo León (*l*)	3	3	1	3	2	4	2	0	1	3	22
Oaxaca (*m*)	3	3	3	3	6	5	1	7	3	4	38
Puebla (*m*)	7	5	4	5	3	5	2	5	3	5	44
Querétaro (*l*)	0	0	0	3	4	1	0	0	1	2	11
Quintana Roo (*m*)	0	2	0	2	0	2	1	2	0	0	9
San Luis Potosí (*l*)	4	3	1	0	0	0	3	2	3	2	18
Sinaloa (*l*)	1	1	0	1	0	0	0	0	1	0	4
Sonora (*l*)	2	1	0	0	3	2	1	0	1	1	11
Tabasco (*l*)	1	0	4	2	3	3	2	0	0	3	18
Tamaulipas (*l*)	0	0	3	2	1	1	4	4	1	1	17
Tlaxcala (*l*)	1	2	0	2	0	1	1	0	1	0	8
Veracruz (*m*)	9	6	7	11	4	7	6	5	9	4	68
Yucatán (*m*)	1	2	1	4	0	0	2	2	1	1	14
Zacatecas (*l*)	2	0	1	0	0	1	1	1	1	1	8
Less permissive states	**35**	**21**	**32**	**35**	**36**	**28**	**36**	**22**	**38**	**31**	**314**
More permissive states	**62**	**65**	**56**	**58**	**58**	**53**	**42**	**52**	**54**	**43**	**543**
United Mexican States	**97**	**86**	**88**	**93**	**94**	**81**	**78**	**74**	**92**	**74**	**857**

Official records of maternal deaths with abortive outcome (ICD-10 codes O00-O08) by place of occurrence were extracted from the General Directorate of Health Information (DGIS),[57] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of maternal deaths with abortive outcome by place of occurrence between 2002 and 2011.

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Table S10 Induced abortion-related deaths by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (*l*)	0	1	0	0	1	2	1	0	0	0	5
Baja California (*l*)	0	1	3	0	0	0	0	0	1	0	5
Baja California Sur (*m*)	0	0	0	0	0	0	0	0	0	0	0
Campeche (*l*)	1	0	0	0	0	0	0	0	1	0	2
Coahuila (*m*)	1	0	0	0	0	1	0	0	1	0	3
Colima (*m*)	0	0	0	0	0	0	0	0	0	0	0
Chiapas (*m*)	7	8	3	1	4	2	3	2	1	0	31
Chihuahua (*l*)	2	2	0	2	0	0	1	1	2	1	11
Distrito Federal (*m*)	3	6	5	8	5	7	4	2	4	1	45
Durango (*l*)	1	0	0	0	0	0	3	0	1	0	5
Guanajuato (*l*)	1	0	1	2	0	0	0	1	1	1	7
Guerrero (*m*)	4	6	6	3	3	2	2	1	2	3	32
Hidalgo (*m*)	1	0	2	0	2	2	2	1	1	1	12
Jalisco (*l*)	1	0	0	1	2	4	1	0	1	0	10
México (*m*)	0	5	4	4	7	3	5	4	6	7	45
Michoacán (*l*)	1	1	1	3	0	1	0	0	2	3	12
Morelos (*m*)	1	2	1	0	0	0	0	2	1	0	7
Nayarit (*l*)	1	1	0	0	1	0	0	0	0	0	3
Nuevo León (*l*)	2	1	0	0	0	0	1	0	0	0	4
Oaxaca (*m*)	3	2	2	2	3	3	1	2	2	1	21
Puebla (*m*)	4	2	2	2	1	4	1	2	1	1	20
Querétaro (*l*)	0	0	0	1	0	1	0	0	0	1	3
Quintana Roo (*m*)	0	1	0	0	0	0	0	0	0	0	1
San Luis Potosí (*l*)	1	0	0	0	0	0	1	0	1	2	5
Sinaloa (*l*)	0	0	0	0	0	0	0	0	0	0	0
Sonora (*l*)	1	1	0	0	2	1	1	0	1	1	8
Tabasco (*l*)	0	0	4	0	3	2	0	0	0	1	10
Tamaulipas (*l*)	0	0	1	1	0	0	0	4	0	0	6
Tlaxcala (*l*)	1	1	0	2	0	1	0	0	1	0	6
Veracruz (*m*)	3	2	4	4	1	3	1	2	5	2	27
Yucatán (*m*)	0	0	1	2	0	0	2	0	0	1	6
Zacatecas (*l*)	0	0	0	0	0	0	0	1	0	0	1
Less permissive states	**13**	**9**	**10**	**12**	**9**	**12**	**9**	**7**	**12**	**10**	**103**
More permissive states	**27**	**34**	**30**	**26**	**26**	**27**	**21**	**18**	**24**	**17**	**250**
United Mexican States	**40**	**43**	**40**	**38**	**35**	**39**	**30**	**25**	**36**	**27**	**353**

Official records of induced abortion related deaths (ICD-10 codes O04-O07) by place of occurrence were extracted from the General Directorate of Health Information (DGIS),[57] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of induced abortion related deaths by place of occurrence between 2002 and 2011.

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Table S11 Maternal mortality ratio (MMR) by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total †	Trend‡	P for trend§
Aguascalientes (*l*)	21.80	45.86	18.85	27.32	47.18	15.49	33.95	50.39	37.62	18.23	31.51	0.340	0.830
Baja California (*l*)	29.14	37.97	54.16	45.28	35.43	33.28	36.89	47.09	37.76	32.00	38.85	-0.233	0.801
Baja California Sur (*m*)	51.22	74.81	32.10	26.07	32.64	61.02	35.73	37.47	28.60	29.82	40.68	-2.617	0.149
Campeche (*l*)	72.66	56.93	40.83	60.29	60.14	17.69	38.66	46.22	39.25	45.17	47.23	-2.737	0.108
Coahuila (*m*)	38.30	37.23	26.14	42.89	24.80	22.07	32.44	25.80	42.13	37.36	32.89	-0.060	0.948
Colima (*m*)	15.37	24.04	30.14	8.15	51.01	15.67	31.44	22.31	¶	35.58	23.15	1.385	0.407
Chiapas (*m*)	50.18	73.40	71.65	59.64	62.02	50.04	59.84	48.94	39.34	35.66	54.12	-2.994	0.018
Chihuahua (*l*)	59.46	42.20	45.05	73.23	59.12	60.40	46.19	72.08	52.66	66.31	57.54	1.153	0.373
Distrito Federal (*m*)	45.19	61.94	52.01	49.02	50.10	55.37	43.02	46.99	47.48	35.77	48.71	-1.357	0.078
Durango (*l*)	31.02	42.76	60.73	35.43	67.67	34.75	58.54	32.72	35.28	31.01	42.60	-0.946	0.568
Guanajuato (*l*)	47.03	47.63	42.98	33.00	36.36	31.43	31.15	47.90	33.14	33.87	38.45	-1.247	0.114
Guerrero (*m*)	74.23	61.92	59.33	83.58	82.38	55.16	61.05	68.73	44.25	60.69	64.45	-1.778	0.204
Hidalgo (*m*)	47.17	50.99	49.34	60.25	41.28	44.42	43.59	48.84	46.64	25.24	45.74	-1.680	0.084
Jalisco (*l*)	31.22	35.53	41.58	33.53	50.12	29.24	33.17	52.35	29.71	22.07	35.72	-0.553	0.627
México (*m*)	57.42	63.13	57.70	58.76	45.14	41.53	44.92	46.71	35.43	38.82	48.94	-2.796	0.001
Michoacán (*l*)	34.03	38.64	34.68	44.13	53.25	37.30	41.07	38.22	42.15	47.59	40.95	0.844	0.217
Morelos (*m*)	64.58	76.98	39.27	64.23	49.89	37.44	39.17	62.57	24.87	32.31	48.65	-3.796	0.033
Nayarit (*l*)	67.60	61.88	40.79	80.58	28.91	20.37	36.04	48.78	32.47	40.08	45.33	-3.368	0.107
Nuevo León (*l*)	24.06	11.34	13.27	22.82	27.39	18.51	25.21	27.33	14.87	26.67	21.15	0.708	0.324
Oaxaca (*m*)	66.51	41.85	52.26	61.95	50.55	57.11	56.63	60.56	53.82	50.56	55.24	-0.168	0.842
Puebla (*m*)	50.97	52.44	54.93	44.70	40.15	36.67	37.75	50.08	36.12	40.17	44.50	-1.576	0.035
Querétaro (*l*)	51.45	44.60	44.92	35.80	50.63	39.12	37.68	29.08	31.81	38.36	40.12	-1.772	0.019
Quintana Roo (*m*)	49.24	58.94	46.39	53.36	47.73	48.09	58.00	33.85	44.83	45.06	48.28	-1.120	0.170
San Luis Potosí (*l*)	69.72	63.42	52.28	42.37	32.75	49.81	28.64	48.03	37.55	41.70	46.76	-2.901	0.030
Sinaloa (*l*)	27.69	17.33	27.66	37.33	33.36	41.21	29.24	30.03	29.40	14.95	28.76	-0.211	0.827
Sonora (*l*)	40.05	32.84	33.56	35.44	46.86	36.05	25.28	38.94	22.18	40.18	35.13	-0.532	0.538
Tabasco (*l*)	28.73	43.01	37.69	39.81	39.97	41.83	53.87	41.51	28.09	42.36	39.72	0.493	0.573
Tamaulipas (*l*)	32.62	33.08	35.69	41.85	48.91	32.69	44.30	33.16	37.57	14.95	35.67	-0.904	0.401
Tlaxcala (*l*)	67.03	57.36	41.06	52.33	50.90	24.13	21.80	40.33	51.71	25.12	43.09	-3.265	0.046

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Table S11 Maternal mortality ratio (MMR) by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total †	Trend‡	P for trend§
Veracruz (*m*)	57.81	47.12	52.41	43.29	43.96	53.72	52.25	53.73	44.81	47.25	49.69	-0.412	0.485
Yucatán (*m*)	76.30	54.90	50.21	53.29	27.34	52.81	38.90	39.32	31.83	37.98	46.30	-3.506	0.013
Zacatecas (*l*)	43.32	62.50	25.64	23.44	41.49	27.99	34.02	48.15	33.36	32.76	37.29	-1.020	0.468
Less permissive states	**39.75**	**39.51**	**38.27**	**40.14**	**44.28**	**34.27**	**36.00**	**43.54**	**33.82**	**33.54**	**38.28**	**-0.563**	**0.202**
More permissive states	**55.28**	**57.21**	**54.14**	**54.76**	**48.34**	**46.82**	**47.63**	**49.61**	**40.56**	**40.95**	**49.57**	**-1.766**	**<0.001**
United Mexican States	**48.62**	**49.58**	**47.22**	**48.36**	**46.56**	**41.39**	**42.57**	**46.94**	**37.62**	**37.67**	**44.65**	**-1.258**	**0.002**

Maternal mortality ratio per 100,000 live births directly calculated from data in tables S3 and S5.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Average MMR between 2002 and 2011.
‡β-coefficient representing the average change per year for MMR trend between 2002 and 2011 computed by autoregressive integrated moving average (ARIMA) model.
§P for trend between 2002 and 2011 calculated with ARIMA.
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Table S12 Maternal mortality ratio with abortive outcome (MMR_{AO}) by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	P for trend§
Aguascalientes (*l*)	0.00	3.82	0.00	0.00	11.80	7.75	7.54	0.00	3.76	0.00	3.42	-0.110	0.831
Baja California (*l*)	5.14	1.73	11.49	1.62	3.08	1.51	0.00	3.14	6.29	4.57	3.82	-0.130	0.743
Baja California Sur (*m*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	¶	¶
Campeche (*l*)	6.61	0.00	0.00	0.00	0.00	0.00	5.52	0.00	9.81	0.00	2.25	-0.156	0.724
Coahuila (*m*)	1.67	3.55	0.00	0.00	3.54	1.70	0.00	0.00	3.51	1.70	1.56	-0.011	0.952
Colima (*m*)	7.69	0.00	0.00	0.00	0.00	7.83	0.00	0.00	0.00	0.00	1.54	-0.372	0.330
Chiapas (*m*)	4.80	7.62	6.72	3.64	7.56	3.21	3.90	1.38	2.28	2.38	4.24	-0.542	0.017
Chihuahua (*l*)	2.38	3.84	1.33	6.42	2.75	0.00	3.65	2.62	8.10	4.32	3.52	-0.259	0.349
Distrito Federal (*m*)	5.28	5.63	4.18	4.90	5.14	8.09	3.74	3.26	5.00	3.19	4.85	-0.172	0.301
Durango (*l*)	2.22	0.00	0.00	0.00	2.60	0.00	17.82	0.00	2.35	2.39	2.68	-0.417	0.518
Guanajuato (*l*)	4.05	0.00	2.43	3.93	3.38	1.57	1.60	3.19	1.58	1.61	2.32	-0.096	0.530
Guerrero (*m*)	8.68	5.10	6.88	3.93	4.90	0.86	1.97	4.04	2.50	2.64	4.14	-0.586	0.012
Hidalgo (*m*)	4.57	3.19	4.35	1.63	4.76	7.40	3.11	4.88	1.61	0.00	3.59	-0.257	0.294
Jalisco (*l*)	1.87	1.27	1.89	2.58	3.91	3.18	3.19	3.88	3.71	1.23	2.66	-0.136	0.263
México (*m*)	2.39	4.21	4.08	4.47	6.36	2.31	3.79	4.22	5.36	4.58	4.17	-0.136	0.339
Michoacán (*l*)	2.62	1.64	4.45	4.80	5.02	3.83	1.87	0.93	2.58	5.39	3.28	-0.024	0.901
Morelos (*m*)	5.17	5.50	8.42	5.59	0.00	0.00	2.61	5.44	4.97	0.00	3.72	-0.449	0.179
Nayarit (*l*)	12.68	8.25	0.00	8.95	4.13	4.07	0.00	0.00	4.06	4.01	4.53	-0.814	0.079
Nuevo León (*l*)	2.19	2.27	1.11	3.42	2.28	4.35	2.19	0.00	1.06	3.20	2.20	-0.040	0.794
Oaxaca (*m*)	3.33	2.51	2.45	2.66	4.68	4.89	0.85	6.42	2.74	4.04	3.42	-0.137	0.464
Puebla (*m*)	4.63	2.95	2.53	3.62	1.27	3.16	1.22	3.21	1.87	2.72	2.73	-0.162	0.178
Querétaro (*l*)	0.00	0.00	0.00	4.77	5.06	2.30	0.00	0.00	2.45	4.79	1.97	-0.262	0.315
Quintana Roo (*m*)	0.00	8.42	4.22	8.21	0.00	6.87	3.41	6.77	0.00	0.00	3.71	-0.326	0.445
San Luis Potosí (*l*)	6.64	5.01	3.27	0.00	0.00	0.00	5.05	3.43	5.12	3.48	3.21	-0.071	0.808
Sinaloa (*l*)	1.46	1.58	1.54	1.62	0.00	0.00	0.00	0.00	1.63	0.00	0.80	-0.154	0.090
Sonora (*l*)	3.48	1.82	0.00	0.00	5.62	3.60	1.81	0.00	1.85	1.83	2.01	-0.068	0.756
Tabasco (*l*)	0.00	0.00	7.18	1.90	3.81	5.46	3.85	0.00	0.00	6.05	2.85	-0.158	0.639
Tamaulipas (*l*)	1.42	0.00	2.75	2.70	1.40	1.31	2.68	5.53	1.44	1.49	2.10	-0.148	0.394
Tlaxcala (*l*)	3.53	7.17	0.00	7.48	0.00	3.45	7.27	0.00	3.69	0.00	3.23	-0.323	0.390

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Table S12 Maternal mortality ratio with abortive outcome (MMR_{AO}) by place of residence in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	P for trend§
Veracruz (m)	4.09	3.01	3.14	5.28	2.23	3.26	3.73	2.89	5.74	3.50	3.69	0.054	0.678
Yucatán (m)	2.63	5.23	0.00	11.22	0.00	0.00	5.19	5.24	2.65	2.71	3.50	-0.056	0.893
Zacatecas (l)	5.41	0.00	0.00	0.00	0.00	2.80	2.83	2.83	5.56	2.73	2.26	0.244	0.336
Less permissive states	**2.94**	**1.75**	**2.54**	**2.94**	**3.10**	**2.44**	**3.06**	**1.95**	**3.22**	**2.72**	**2.67**	**0.030**	**0.615**
More permissive states	**4.10**	**4.32**	**3.93**	**4.16**	**4.27**	**3.52**	**2.90**	**3.61**	**3.69**	**2.99**	**3.75**	**-0.123**	**0.016**
United Mexican States	**3.61**	**3.21**	**3.32**	**3.62**	**3.76**	**3.06**	**2.97**	**2.88**	**3.49**	**2.87**	**3.28**	**-0.056**	**0.121**

Maternal mortality ratio with abortive outcome per 100,000 live births directly calculated from data in tables S3 and S6.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Average MMR_{AO} between 2002 and 2011.
‡β-coefficient representing the average change per year for MMR_{AO} trend between 2002 and 2011 computed by autoregressive integrated moving average (ARIMA) model.
§P for trend between 2002 and 2011 calculated with ARIMA.
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Table S13 Induced abortion mortality ratio (iAMR) by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Toral†	Trend‡	P for trend§
Aguascalientes (*l*)	0.00	3.82	0.00	0.00	7.86	7.75	3.77	0.00	0.00	0.00	2.28	0.094	0.811
Baja California (*l*)	0.00	1.73	4.92	0.00	0.00	0.00	0.00	0.00	1.57	0.00	0.80	0.156	0.407
Baja California Sur (*m*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	¶	¶
Campeche (*l*)	6.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.91	0.00	1.12	0.152	0.604
Coahuila (*m*)	1.67	1.77	0.00	0.00	0.00	1.70	0.00	0.00	1.76	0.00	0.69	0.081	0.440
Colima (*m*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	¶	¶
Chiapas (*m*)	3.74	4.85	2.24	0.73	3.78	1.28	1.95	1.38	0.57	0.00	2.02	0.405	0.010
Chihuahua (*l*)	2.38	2.56	0.00	2.57	0.00	0.00	1.22	1.31	2.70	1.44	1.44	0.030	0.823
Distrito Federal (*m*)	1.76	1.88	1.20	3.68	1.28	4.35	0.62	1.31	1.87	0.64	1.87	0.095	0.515
Durango (*l*)	2.22	0.00	0.00	0.00	0.00	0.00	7.64	0.00	2.35	0.00	1.22	0.118	0.689
Guanajuato (*l*)	0.81	0.00	0.81	1.57	0.00	0.00	0.00	0.00	0.79	0.81	0.48	0.020	0.769
Guerrero (*m*)	4.82	4.37	5.16	2.95	3.92	0.86	1.97	1.01	1.67	2.64	2.97	0.396	0.010
Hidalgo (*m*)	1.52	0.00	4.35	0.00	3.18	4.44	1.56	1.63	1.61	0.00	1.87	0.061	0.762
Jalisco (*l*)	0.00	0.00	0.00	0.64	1.30	1.91	0.64	0.65	0.62	0.00	0.57	0.050	0.511
México (*m*)	0.00	2.71	1.75	1.79	2.73	0.87	2.33	1.13	2.08	2.14	1.74	0.070	0.496
Michoacán (*l*)	1.75	0.82	0.89	2.88	0.00	0.96	0.00	0.00	0.86	2.69	1.09	0.021	0.871
Morelos (*m*)	0.00	5.50	5.61	0.00	0.00	0.00	0.00	5.44	2.49	0.00	1.86	0.133	0.671
Nayarit (*l*)	4.23	4.13	0.00	0.00	4.13	4.07	0.00	0.00	0.00	0.00	1.65	0.406	0.082
Nuevo León (*l*)	1.09	0.00	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.22	0.039	0.470
Oaxaca (*m*)	3.33	1.67	1.63	0.89	2.81	3.26	0.85	1.84	1.82	1.01	1.93	0.112	0.301
Puebla (*m*)	2.32	0.59	1.26	1.81	0.00	2.53	0.61	1.28	0.62	0.68	1.18	0.094	0.330
Querétaro (*l*)	0.00	0.00	0.00	2.39	0.00	2.30	0.00	0.00	0.00	2.40	0.74	0.101	0.453
Quintana Roo (*m*)	0.00	4.21	4.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.306	0.122
San Luis Potosí (*l*)	1.66	0.00	0.00	0.00	0.00	0.00	1.68	0.00	1.71	3.48	0.84	0.202	0.138
Sinaloa (*l*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	¶	¶
Sonora (*l*)	1.74	1.82	0.00	0.00	3.75	1.80	1.81	0.00	1.85	1.83	1.46	0.027	0.847
Tabasco (*l*)	0.00	0.00	7.18	0.00	3.81	3.64	0.00	0.00	0.00	2.02	1.71	0.108	0.716
Tamaulipas (*l*)	1.42	0.00	1.37	1.35	0.00	0.00	0.00	5.53	0.00	0.00	0.98	0.024	0.908
Tlaxcala (*l*)	3.53	3.58	0.00	7.48	0.00	3.45	3.63	0.00	3.69	0.00	2.51	0.237	0.419

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Table S13 Induced abortion mortality ratio (iAMR) by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	P for trend§
Veracruz (*m*)	1.02	1.00	1.57	2.11	0.56	1.09	0.53	1.16	2.87	1.75	1.35	0.081	0.337
Yucatán (*m*)	0.00	0.00	0.00	5.61	0.00	0.00	5.19	0.00	0.00	2.71	1.35	0.140	0.609
Zacatecas (*l*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.83	2.78	0.00	0.56	0.204	0.122
Less permissive states	**1.13**	**0.70**	**0.88**	**1.07**	**0.82**	**1.05**	**0.87**	**0.62**	**1.05**	**0.88**	**0.91**	**-0.010**	**0.619**
More permissive states	**1.76**	**2.26**	**2.03**	**1.80**	**1.85**	**1.80**	**1.35**	**1.25**	**1.61**	**1.18**	**1.69**	**-0.096**	**0.005**
United Mexican States	**1.49**	**1.59**	**1.53**	**1.48**	**1.40**	**1.47**	**1.14**	**0.97**	**1.37**	**1.05**	**1.35**	**-0.058**	**0.010**

Induced abortion mortality ratio per 100,000 live births directly calculated from data in tables S3 and S7.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Average iAMR between 2002 and 2011.
‡β-coefficient representing the average change per year for iAMR trend between 2002 and 2011 computed by autoregressive integrated moving average (ARIMA) model.
§P for trend between 2002 and 2011 calculated with ARIMA.
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Table S14 Maternal mortality ratio (MMR) by place of occurrence in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	P for trend§
Aguascalientes (l)	23.49	49.33	17.61	28.57	43.30	17.93	31.72	69.07	35.52	17.68	33.27	0.560	0.779
Baja California (l)	28.65	34.46	56.88	44.45	38.93	36.81	38.06	53.60	42.57	35.49	41.00	0.489	0.639
Baja California Sur (m)	52.84	78.18	33.68	35.73	33.85	62.83	36.66	35.61	21.94	22.55	40.75	3.787	0.046
Campeche (l)	69.15	53.24	49.70	52.80	63.87	18.63	40.36	48.24	43.00	53.07	48.86	1.856	0.242
Coahuila (m)	41.17	29.84	27.78	38.96	29.78	23.66	32.33	30.85	35.05	33.86	32.35	0.242	0.697
Colima (m)	15.26	31.39	15.16	7.86	31.57	21.76	37.02	21.31	6.89	20.01	20.70	0.123	0.919
Chiapas (m)	48.69	71.23	68.63	56.85	57.63	47.09	54.46	43.50	37.07	32.64	50.94	3.194	0.009
Chihuahua (l)	58.95	42.19	46.99	71.60	58.39	56.02	47.02	72.83	52.26	67.35	57.24	1.207	0.331
Distrito Federal (m)	60.33	74.67	68.30	64.69	64.05	59.84	52.75	60.33	57.48	53.97	61.91	1.560	0.020
Durango (l)	25.01	43.88	51.49	38.78	53.24	33.14	57.10	28.44	34.23	22.54	38.54	1.031	0.476
Guanajuato (l)	46.92	46.61	38.99	29.15	36.98	26.77	31.09	50.03	31.14	33.44	37.05	1.084	0.255
Guerrero (m)	76.19	62.68	58.51	78.89	79.97	53.55	58.37	69.49	43.55	55.75	63.08	2.127	0.113
Hidalgo (m)	41.62	49.24	40.65	52.86	37.28	42.08	39.77	46.08	41.24	20.46	41.15	1.538	0.108
Jalisco (l)	32.67	37.02	42.60	32.94	49.56	30.52	32.51	47.62	31.53	24.42	36.03	0.654	0.492
México (m)	51.16	56.59	49.34	51.31	38.21	39.08	42.09	40.69	30.29	32.55	42.91	2.555	0.001
Michoacán (l)	31.34	35.59	33.89	44.70	50.78	32.83	41.20	39.22	41.64	49.57	39.84	1.240	0.099
Morelos (m)	61.76	69.15	33.55	63.29	40.05	39.57	38.54	66.50	22.12	32.40	46.34	3.051	0.100
Nayarit (l)	63.15	62.36	48.76	77.97	31.49	18.03	44.89	48.58	26.31	48.75	46.76	3.003	0.141
Nuevo León (l)	28.46	19.27	15.46	28.29	29.26	23.61	25.93	29.04	24.12	34.79	25.86	0.885	0.154
Oaxaca (m)	62.73	40.04	49.02	63.30	50.13	54.71	57.00	58.89	54.26	50.67	54.06	0.158	0.852
Puebla (m)	51.92	51.78	56.65	43.39	37.41	38.57	37.92	52.37	38.02	40.80	45.00	1.412	0.084
Querétaro (l)	48.24	44.30	52.38	53.30	53.58	46.78	36.61	25.76	32.73	34.44	42.70	2.395	0.015
Quintana Roo (m)	37.21	63.84	38.15	37.05	37.15	41.94	52.72	30.71	38.19	41.64	41.65	0.758	0.503
San Luis Potosí (l)	71.90	63.81	48.25	39.45	35.08	49.12	27.68	48.33	40.29	38.53	46.42	2.944	0.034
Sinaloa (l)	27.86	20.54	26.32	38.97	38.37	44.49	27.71	30.33	29.49	16.54	29.98	0.284	0.782
Sonora (l)	40.03	32.92	33.49	35.32	42.92	37.81	25.36	31.59	20.32	40.20	34.02	0.795	0.330
Tabasco (l)	32.25	52.56	42.84	48.98	43.44	47.05	60.84	52.98	36.57	43.93	46.17	0.504	0.612
Tamaulipas (l)	33.57	38.45	48.70	46.71	65.05	28.77	50.91	39.68	32.68	16.05	40.23	1.617	0.307
Tlaxcala (l)	63.14	48.74	39.76	51.33	49.99	22.15	15.24	30.27	45.21	29.25	39.44	3.111	0.051

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Table S14 Maternal mortality ratio (MMR) by place of occurrence in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	P for trend§
Veracruz (m)	58.69	44.89	51.62	43.68	43.11	54.91	51.96	53.68	46.12	47.12	49.61	-0.294	0.644
Yucatán (m)	85.10	53.83	54.54	65.44	34.43	56.52	42.96	38.40	33.78	37.23	50.17	-4.226	0.007
Zacatecas (l)	38.98	61.23	32.29	21.15	49.03	31.80	40.82	46.29	33.88	36.80	39.22	-0.602	0.649
Less permissive states	**39.52**	**40.44**	**39.47**	**41.05**	**45.60**	**34.39**	**36.81**	**44.35**	**34.61**	**34.96**	**39.09**	**-0.487**	**0.288**
More permissive states	**55.58**	**56.72**	**53.60**	**54.34**	**47.62**	**47.04**	**47.42**	**49.66**	**40.47**	**40.42**	**49.34**	**-1.764**	**<0.001**
United Mexican States	**48.69**	**49.69**	**47.43**	**48.52**	**46.74**	**41.57**	**42.80**	**47.33**	**37.92**	**38.01**	**44.88**	**-1.258**	**0.002**

Maternal mortality ratio per 100,000 live births directly calculated from data in tables S4 and S8.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Average MMR between 2002 and 2011.
‡β-coefficient representing the average change per year for MMR trend between 2002 and 2011 computed by autoregressive integrated moving average (ARIMA) model.
§P for trend between 2002 and 2011 calculated with ARIMA.

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Table S15 Maternal mortality ratio with abortive outcome (MMR_{AO}) by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	P for trend§
Aguascalientes (*l*)	0.00	3.52	0.00	0.00	7.22	7.17	7.05	0.00	3.55	0.00	2.83	0.129	0.743
Baja California (*l*)	5.06	1.72	11.71	1.65	3.24	1.60	0.00	3.25	8.19	4.84	4.10	0.034	0.937
Baja California Sur (*m*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	¶	¶
Campeche (*l*)	6.91	0.00	0.00	0.00	0.00	0.00	5.77	0.00	16.13	0.00	3.02	0.412	0.517
Coahuila (*m*)	1.65	1.76	0.00	0.00	3.50	1.69	0.00	0.00	3.50	1.69	1.38	0.065	0.693
Colima (*m*)	7.63	0.00	0.00	0.00	0.00	7.25	0.00	0.00	0.00	0.00	1.48	0.372	0.308
Chiapas (*m*)	4.23	8.22	6.64	2.88	6.74	3.14	3.80	1.38	2.28	2.37	4.07	0.518	0.027
Chihuahua (*l*)	2.41	3.84	1.34	6.39	2.72	0.00	4.82	2.60	6.70	4.30	3.51	0.218	0.383
Distrito Federal (*m*)	5.85	6.57	4.49	5.55	6.95	6.38	5.02	3.15	5.70	3.34	5.34	0.228	0.115
Durango (*l*)	2.27	0.00	0.00	0.00	2.66	0.00	15.57	0.00	2.44	2.50	2.50	0.383	0.496
Guanajuato (*l*)	4.85	0.00	2.29	3.84	3.29	1.53	1.55	3.23	1.60	1.63	2.37	0.132	0.431
Guerrero (*m*)	7.81	5.16	6.11	3.99	3.00	1.76	2.01	3.11	2.56	2.70	3.85	0.523	0.005
Hidalgo (*m*)	4.46	3.08	2.80	0.00	4.66	7.26	3.06	4.77	1.59	1.57	3.35	0.090	0.716
Jalisco (*l*)	1.88	1.28	2.54	2.58	3.91	4.45	3.19	3.86	4.33	1.22	2.92	0.148	0.293
México (*m*)	1.76	3.20	3.82	3.89	4.56	2.30	2.96	4.73	4.99	4.60	3.69	0.228	0.052
Michoacán (*l*)	1.74	1.66	5.50	4.97	5.18	2.98	1.96	0.98	3.62	5.72	3.39	0.095	0.660
Morelos (*m*)	7.72	5.53	5.59	5.50	2.86	0.00	2.57	5.32	4.92	0.00	3.95	0.526	0.055
Nayarit (*l*)	13.53	8.91	4.43	9.75	4.50	0.00	0.00	0.00	0.00	4.43	4.50	1.213	0.011
Nuevo León (*l*)	3.28	3.40	1.10	3.39	2.25	4.29	2.16	0.00	1.05	3.16	2.40	0.150	0.341
Oaxaca (*m*)	2.48	2.50	2.45	2.67	5.67	4.14	0.86	6.54	2.76	4.05	3.36	0.178	0.370
Puebla (*m*)	4.08	2.98	2.55	3.06	1.93	3.21	1.24	3.31	1.93	3.52	2.79	0.077	0.448
Querétaro (*l*)	0.00	0.00	0.00	6.95	9.74	2.23	0.00	0.00	2.34	4.59	2.60	0.178	0.668
Quintana Roo (*m*)	0.00	8.51	0.00	8.23	0.00	6.99	3.51	6.82	0.00	0.00	3.38	0.198	0.666
San Luis Potosí (*l*)	6.69	5.04	1.66	0.00	0.00	0.00	5.19	3.58	5.26	3.50	3.09	0.012	0.968
Sinaloa (*l*)	1.47	1.58	0.00	1.62	0.00	0.00	0.00	0.00	1.64	0.00	0.64	0.107	0.255
Sonora (*l*)	3.48	1.83	0.00	0.00	5.60	3.60	1.81	0.00	1.85	1.83	2.01	0.068	0.754
Tabasco (*l*)	1.90	0.00	7.14	3.77	5.67	5.43	3.80	0.00	0.00	5.73	3.36	0.008	0.980
Tamaulipas (*l*)	0.00	0.00	4.06	2.67	1.38	1.31	5.36	5.47	1.42	1.46	2.35	0.231	0.326
Tlaxcala (*l*)	3.71	7.50	0.00	7.90	0.00	3.69	3.81	0.00	3.77	0.00	3.00	0.413	0.236

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Table S15 Maternal mortality ratio with abortive outcome (MMR_{AO}) by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	P for trend§
Veracruz (*m*)	4.76	3.10	3.80	6.01	2.30	3.92	3.32	2.98	5.32	2.42	3.81	-0.097	0.506
Yucatán (*m*)	2.58	5.13	2.87	10.91	0.00	0.00	5.05	5.12	2.60	2.66	3.68	-0.141	0.709
Zacatecas (*l*)	5.57	0.00	2.94	0.00	0.00	2.89	2.92	2.89	2.82	2.83	2.32	0.039	0.855
Less permissive states	**3.03**	**1.84**	**2.81**	**3.12**	**3.29**	**2.46**	**3.16**	**1.96**	**3.34**	**2.75**	**2.78**	**0.025**	**0.688**
More permissive states	**4.04**	**4.33**	**3.80**	**4.03**	**4.14**	**3.54**	**2.85**	**3.64**	**3.66**	**3.01**	**3.71**	**-0.112**	**0.022**
United Mexican States	**3.61**	**3.25**	**3.37**	**3.63**	**3.77**	**3.07**	**2.98**	**2.90**	**3.52**	**2.90**	**3.30**	**-0.056**	**0.121**

Maternal mortality ratio with abortive outcome per 100,000 live births directly calculated from data in tables S4 and S9.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Average MMR_{AO} between 2002 and 2011.
‡β-coefficient representing the average change per year for MMR_{AO} trend between 2002 and 2011 computed by autoregressive integrated moving average (ARIMA) model.
§P for trend between 2002 and 2011 calculated with ARIMA.
¶Not applicable.

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Table S16 Induced abortion mortality ratio (iAMR) by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	P for trend§
Aguascalientes (*l*)	0.00	3.52	0.00	0.00	3.61	7.17	3.52	0.00	0.00	0.00	1.77	0.064	0.834
Baja California (*l*)	0.00	1.72	5.02	0.00	0.00	0.00	0.00	0.00	1.64	0.00	0.82	0.156	0.417
Baja California Sur (*m*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	¶	¶
Campeche (*l*)	6.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.38	0.00	1.21	0.149	0.635
Coahuila (*m*)	1.65	0.00	0.00	0.00	0.00	1.69	0.00	0.00	1.75	0.00	0.52	0.006	0.955
Colima (*m*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	¶	¶
Chiapas (*m*)	3.71	5.48	2.21	0.72	2.99	1.26	1.90	1.38	0.57	0.00	2.00	0.425	0.008
Chihuahua (*l*)	2.41	2.56	0.00	2.56	0.00	0.00	1.21	1.30	2.68	1.43	1.43	0.034	0.803
Distrito Federal (*m*)	1.35	2.82	2.25	3.70	2.48	3.43	2.01	1.05	2.07	0.56	2.20	0.136	0.236
Durango (*l*)	2.27	0.00	0.00	0.00	0.00	0.00	7.79	0.00	2.44	0.00	1.25	0.121	0.685
Guanajuato (*l*)	0.81	0.00	0.76	1.53	0.00	0.00	0.00	0.81	0.80	0.82	0.55	0.008	0.897
Guerrero (*m*)	3.91	4.42	5.24	3.00	3.00	1.76	2.01	1.04	1.71	2.70	2.93	0.334	0.010
Hidalgo (*m*)	1.49	0.00	2.80	0.00	3.11	2.90	3.06	1.59	1.59	1.57	1.83	0.090	0.518
Jalisco (*l*)	0.63	0.00	0.00	0.65	1.30	2.54	0.64	0.00	0.62	0.00	0.63	0.001	0.994
México (*m*)	0.00	1.78	1.39	1.42	2.45	0.99	1.64	1.26	2.00	2.30	1.53	0.126	0.106
Michoacán (*l*)	0.87	0.83	0.92	2.98	0.00	0.99	0.00	0.00	1.81	2.86	1.13	0.074	0.573
Morelos (*m*)	2.57	5.53	2.80	0.00	0.00	0.00	0.00	5.32	2.46	0.00	1.84	0.194	0.461
Nayarit (*l*)	4.51	4.45	0.00	0.00	4.50	0.00	0.00	0.00	0.00	0.00	1.35	0.462	0.044
Nuevo León (*l*)	2.19	1.13	0.00	0.00	0.00	0.00	1.08	0.00	0.00	0.00	0.44	0.148	0.077
Oaxaca (*m*)	2.48	1.67	1.63	1.78	2.84	2.49	0.86	1.87	1.84	1.01	1.85	0.085	0.243
Puebla (*m*)	2.33	1.19	1.27	1.22	0.64	2.57	0.62	1.33	0.64	0.70	1.27	0.110	0.164
Querétaro (*l*)	0.00	0.00	0.00	2.32	0.00	2.23	0.00	0.00	0.00	2.30	0.71	0.097	0.458
Quintana Roo (*m*)	0.00	4.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.181	0.244
San Luis Potosí (*l*)	1.67	0.00	0.00	0.00	0.00	0.00	1.73	0.00	1.75	3.50	0.86	0.206	0.136
Sinaloa (*l*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	¶	¶
Sonora (*l*)	1.74	1.83	0.00	0.00	3.73	1.80	1.81	0.00	1.85	1.83	1.46	0.027	0.848
Tabasco (*l*)	0.00	0.00	7.14	0.00	5.67	3.62	0.00	0.00	0.00	1.91	1.87	0.125	0.702
Tamaulipas (*l*)	0.00	0.00	1.35	1.33	0.00	0.00	0.00	5.47	0.00	0.00	0.83	0.101	0.626
Tlaxcala (*l*)	3.71	3.75	0.00	7.90	0.00	3.69	0.00	0.00	3.77	0.00	2.25	0.323	0.306

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Table S16 Induced abortion mortality ratio (iAMR) by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	P for trend§
Veracruz (*m*)	1.59	1.03	2.17	2.18	0.57	1.68	0.55	1.19	2.96	1.21	1.51	0.009	0.926
Yucatán (*m*)	0.00	0.00	2.87	5.45	0.00	0.00	5.05	0.00	0.00	2.66	1.58	0.051	0.850
Zacatecas (*l*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.89	0.00	0.00	0.29	0.088	0.416
Less permissive states	**1.13**	**0.79**	**0.88**	**1.07**	**0.82**	**1.05**	**0.79**	**0.62**	**1.05**	**0.89**	**0.91**	**-0.011**	**0.602**
More permissive states	**1.76**	**2.26**	**2.04**	**1.81**	**1.86**	**1.80**	**1.42**	**1.26**	**1.63**	**1.19**	**1.71**	**-0.092**	**0.004**
United Mexican States	**1.49**	**1.63**	**1.53**	**1.48**	**1.40**	**1.48**	**1.15**	**0.98**	**1.38**	**1.06**	**1.36**	**-0.058**	**0.010**

Induced abortion mortality ratio per 100,000 live births directly calculated from data in tables S4 and S10.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Average iAMR between 2002 and 2011.
‡β-coefficient representing the average change per year for iAMR trend between 2002 and 2011 computed by autoregressive integrated moving average (ARIMA) model.
§P for trend between 2002 and 2011 calculated with ARIMA.
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Table S17 Comparative analysis of cumulative maternal mortality ratios by residence and occurrence for 32 Mexican states exhibiting a more or less permissive abortion legislation, 2002-2011

Indicator		Less permissive	More permissive	Rate ratio†	P value‡
MMR	By residence	38.3	49.6	0.7722	< 0.001
	By occurrence	39.1	49.3	0.7922	< 0.001
MMR_{AO}	By residence	2.7	3.7	0.7110	< 0.001
	By occurrence	2.8	3.7	0.7491	< 0.001
iAMR	By residence	0.9	1.7	0.5358	< 0.001
	By occurrence	0.9	1.7	0.5337	< 0.001
Proportion of induced abortion-related deaths	By residence	2.4%	3.4%	§	< 0.001
	By occurrence	2.3%	3.5%	§	< 0.001

Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.[1]
Less permissive states: Aguascalientes, Baja California, Campeche, Chihuahua, Durango, Guanajuato, Jalisco, Michoacán, Nayarit, Nuevo León, Querétaro, San Luis Potosí, Sinaloa, Sonora, Tabasco, Tamaulipas, Tlaxcala, Zacatecas.
More permissive states: Baja California Sur, Coahuila, Colima, Chiapas, Distrito Federal, Guerrero, Hidalgo, México, Morelos, Oaxaca, Puebla, Quintana Roo, Veracruz, Yucatán.
†*Z*-test rate ratio.
‡*Z*-test P value.
§Not applicable.
iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

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Table S18 Comparative analysis of cumulative maternal mortality ratios by residence and occurrence for 32 Mexican states with or without constitutional amendment protecting the unborn from conception, 2008-2011

Indicator		With amendment	Without amendment	Rate ratio†	P value‡	Without amendment excluding the FD	Rate ratio§	P value¶	FD	Rate ratio††	P value‡‡
MMR	By residence	40.5	41.6	0.9413	0.347	41.4	0.9792	0.514	43.3	0.9357	0.310
	By occurrence	40.0	41.2	0.9031	0.114	40.6	0.9856	0.657	56.1	0.7124	<0.001
MMR_{AO}	By residence	2.8	3.2	0.7728	0.273	3.1	0.8959	0.361	3.8	0.7379	0.175
	By occurrence	2.9	3.2	0.8134	0.378	3.0	0.9475	0.656	4.3	0.6663	0.039
iAMR	By residence	0.9	1.3	0.5360	0.042	1.3	0.6522	0.037	1.1	0.7750	0.538
	By occurrence	0.9	1.3	0.5338	0.043	1.3	0.6717	0.054	1.4	0.6014	0.138
Proportion of induced abortion-related deaths	By residence	2.1%	3.1%	§§	0.041	3.2%	§§	0.030	2.6%	§§	0.649
	By occurrence	2.2%	3.2%	§§	0.048	3.2%	§§	0.063	2.6%	§§	0.625

Constitutional amendments until 2011 were considered.[1]
States with amendment: Baja California, Chiapas, Chihuahua, Colima, Durango, Guanajuato, Jalisco, Morelos, Nayarit, Oaxaca, Puebla, Querétaro, Quintana Roo, San Luis Potosi, Sonora, Tamaulipas, Yucatán.
States without amendment: Aguascalientes, Baja California Sur, Campeche, Coahuila, Distrito Federal, Guerrero, Hidalgo, México, Michoacán, Nuevo León, Sinaloa, Tabasco, Tlaxcala, Veracruz, Zacatecas
†Z-test rate ratio between states with and without amendment.
‡Z-test P value between states with and without amendment.
§Z-test rate ratio between states with and without amendment, excluding the Federal District.
¶Z-test P value between states with and without amendment, excluding the Federal District.
††Z-test rate ratio between states with amendment and the Federal District.
‡‡Z-test P value between states with amendment and the Federal District.
§§Not applicable.
FD, Federal District (Distrito Federal); iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

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Table S19 Univariate association between independent variables and maternal mortality outcomes for 32 Mexican states, 2002-2011

Variable	MMR						MMR_{AO}						iAMR					
	β	SE	95% CI		R^2	P value	β	SE	95% CI		R^2	P value	β	SE	95% CI		R^2	P value
			Lower	Upper					Lower	Upper					Lower	Upper		
Female literacy (%)	-1.16	0.26	-1.700	-0.627	0.38	<0.001	-0.08	0.03	-0.155	-0.007	0.11	0.033	-0.07	0.02	-0.117	-0.021	0.20	0.007
Low birth weight (%)	2.05	0.92	0.173	3.937	0.11	0.033	0.33	0.09	0.134	0.534	0.26	0.002	0.17	0.07	0.025	0.319	0.13	0.023
Skilled attendance at birth (%)	-0.52	0.27	-1.067	0.023	0.08	0.060	-0.08	0.03	-0.140	-0.020	0.17	0.010	-0.03	0.02	0.073	0.015	0.02	0.192
Intimate-partner violence (%)	-0.86	0.52	-1.931	0.205	0.05	0.109	-0.06	0.06	-0.189	0.066	0.00	0.332	-0.05	0.04	0.138	0.034	0.02	0.230
All-abortion hospitalization ratio (per 100 live births)	-1.71	0.51	-2.750	-0.678	0.25	0.002	-0.11	0.06	-0.247	0.022	0.05	0.099	-0.10	0.04	0.187	-0.009	0.11	0.033
Constitutional amendment (yes)	1.93	3.36	-4.946	8.809	0.01	0.571	0.22	0.39	-0.575	1.019	-0.02	0.574	-0.20	0.26	0.742	0.340	-0.01	0.454
Abortion legislation (less permissive)	-7.31	3.13	-13.710	-0.911	0.12	0.027	-0.47	0.38	-1.263	0.310	0.01	0.226	-0.31	0.26	0.843	0.232	0.01	0.255
Contraceptive use (%)	-0.64	0.25	-1.165	-0.130	0.15	0.016	-0.04	0.03	-0.106	0.023	0.02	0.195	-0.05	0.02	0.093	-0.012	0.16	0.013
TFR	9.51	6.56	-3.899	22.927	0.03	0.158	0.46	0.78	-1.134	2.063	-0.02	0.557	1.21	0.48	0.221	2.216	0.14	0.018
Clean water (%)	-0.66	0.15	-0.970	-0.355	0.37	<0.001	-0.03	0.02	-0.076	0.012	0.03	0.152	-0.03	0.01	0.065	-0.009	0.16	0.012
Sanitation (%)	-0.79	0.18	-1.174	-0.425	0.36	<0.001	-0.03	0.02	-0.090	0.017	0.02	0.177	-0.04	0.01	0.075	-0.005	0.12	0.026

Univariate associations considering each independent variable as explaining differences in MMR, MMR_{AO} and iAMR.
CI, confidence interval; iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome; SE, standard error; TFR, average total fertility rate between 2002-2011.

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Alternative explanatory models

Alternative multivariate regression models considering the variables excluded by collinearity were conducted (Tables S20 to S22, Supplementary Material). First, female literacy was interchanged with clean water. After regression refinement (adjusted R^2=0.886, P for model<0.001), four factors were identified as independent explanatory variables for the MMR: clean water (β=-0.730, P<0.001, VIF=1.928), low birth weight (β=1.938, P<0.001, VIF=1.086), all-abortion hospitalization ratio (β=-0.566, P=0.049, VIF=2.288), and intimate-partner violence (β=0.554, P=0.015, VIF=1.570). These variables explained (cumulative multivariate R^2) 64.7%, 22.0%, 1.9%, and 1.7% of the differences observed on the MMR among states, respectively. Second, female literacy was interchanged with sanitation (adjusted R^2=0.640, P for model<0.001). Variables showing significant effects were the latter (β=-0.758, P<0.001, VIF=1.001) and low birth weight (β=2.166, P<0.001, VIF=1.001), explaining 45.6% and 20.9% of the variance on MMR, respectively. Finally, cumulative TFR between 2002 and 2011 was interchanged with contraceptive use. Four explanatory factors were identified in the final model (adjusted R^2=0.714, P for model<0.001): female literacy (β=-1.013, P<0.001, VIF=1.876), low birth weight (β=1.260, P=0.009; VIF=1.127), all-abortion hospitalization ratio (β=-0.962, P=0.012, VIF=1.779) and TFR (β=-14.329, P=0.002, VIF=1.728). These variables accounted for 41.3%, 18.8%, 7.6%, and 7.7% of the variance of observed MMR among states, respectively. No statistically significant effect was present for abortion legislation, constitutional amendment, or additional covariates other than those already mentioned.

Table S20 Alternative explanatory regression models for maternal mortality ratio

MMR	β	SE	95% CI		P value	VIF	R^2
			Lower	Upper			
Clean water instead of female literacy†							
Clean water (%)	-0.730	0.085	-0.908	-0.553	<0.001	1.928	0.886
Low birth weight (%)	1.938	0.318	1.279	2.596	<0.001	1.086	
All-abortion hospitalization ratio (per 100 live births)	-0.566	0.271	-1.129	-0.003	0.049	2.288	
Intimate-partner violence (%)	0.554	0.210	0.118	0.990	0.015	1.570	
Sanitation instead of female literacy‡							
Sanitation (%)	-0.758	0.127	-1.019	-0.497	<0.001	1.001	0.640
Low birth weight (%)	2.166	0.528	1.082	3.249	<0.001	1.001	
TFR instead of contraceptive use§							
Female literacy (%)	-1.013	0.218	-1.463	-0.563	<0.001	1.876	0.714
Low birth weight (%)	1.260	0.446	0.339	2.180	0.009	1.127	
All-abortion hospitalization ratio (per 100 live births)	-0.962	0.352	-1.689	-0.236	0.012	1.779	
TFR	-14.329	4.158	-22.911	-5.747	0.002	1.728	

Alternative multivariate regression models for MMR after refinement considering independent variables excluded from the explanatory models (Tables 2-4) due to collinearity.
†Initial model considered the following variables: clean water, low birth weight, skilled attendance at birth, intimate-partner violence, all-abortion hospitalization ratio, contraceptive use, abortion legislation and constitutional amendment.
‡Initial model considered the following variables: sanitation, low birth weight, skilled attendance at birth, intimate-partner violence, all-abortion hospitalization ratio, contraceptive use, abortion legislation and constitutional amendment.
§Initial model considered the following variables: female literacy, low birth weight, skilled attendance at birth, intimate-partner violence, all-abortion hospitalization ratio, TFR, abortion legislation and constitutional amendment.
R^2 refers to the goodness-of-fit for each model.
CI, confidence interval; MMR, maternal mortality ratio; TFR, average total fertility rate from 2002 to 2011; SE, standard error; VIF, variance inflation factor.

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For MMR_{AO}, when female literacy was replaced by clean water in multivariate regression models (adjusted R^2=0.420, P for model<0.001), only two variables appeared independently associated to this mortality outcome: skilled attendance at birth (β=-0.076, P=0.004, VIF=1.002) and low birth weight (β=0.321, P=0.001, VIF=1.002). These variables explained 17.8% and 27.9% of the variance on the MMR_{AO} among states, respectively. In the refined model when female literacy rate was replaced by sanitation (adjusted R^2=0.420, P for model<0.001), variables exhibiting significant effect sizes were low birth weight (β=0.321, P=0.001, VIF=1.002) and skilled attendance at birth (β=-0.076, P=0.004, VIF=1.002) explaining 27.9% and 17.8% of the variance on MMR_{AO}, respectively. Finally, when contraceptive use was replaced by TFR in the refined explanatory modeling (adjusted R^2=0.666, P for model<0.001), female literacy (β=-0.125, P<0.001, VIF=2.043), low birth weight (β=0.271, P<0.001, VIF=1.096), skilled attendance at birth (β=-0.064, P=0.002, VIF=1.031), and TFR (β=-1.750, P=0.008, VIF=2.143) were identified as explanatory factors. These variables accounted for 14.0%, 35.9%, 11.5%, and 10.0% of the variance of observed MMR_{AO} among states, respectively. No statistically significant effects were obtained for abortion legislation, constitutional amendment, or additional covariates other than those mentioned.

Table S21 Alternative explanatory regression models for maternal mortality ratio with abortive outcome

MMR_{AO}	β	SE	95% CI		P value	VIF	R^2
			Lower	Upper			
Clean water instead of female literacy†							
Low birth weight (%)	0.321	0.087	0.144	0.498	0.001	1.002	0.420
Skilled attendance at birth (%)	-0.076	0.025	-0.126	-0.026	0.004	1.002	
Sanitation instead of female literacy‡							
Low birth weight (%)	0.321	0.087	0.144	0.498	0.001	1.002	0.420
Skilled attendance at birth (%)	-0.076	0.025	-0.126	-0.026	0.004	1.002	
TFR instead of contraceptive use§							
Female literacy (%)	-0.125	0.029	-0.184	-0.066	<0.001	2.043	0.666
Low birth weight (%)	0.271	0.064	0.138	0.404	<0.001	1.096	
Skilled attendance at birth (%)	-0.064	0.018	-0.102	-0.027	0.002	1.031	
TFR	-1.750	0.606	-3.001	-0.500	0.008	2.143	

Alternative multivariate regression models for MMR_{AO} after refinement considering independent variables excluded from the explanatory models (Tables 2-4) due to collinearity.
†Initial model considered the following variables: clean water, low birth weight, skilled attendance at birth, intimate-partner violence, all-abortion hospitalization ratio, contraceptive use, abortion legislation and constitutional amendment.
‡Initial model considered the following variables: sanitation, low birth weight, skilled attendance at birth, intimate-partner violence, all-abortion hospitalization ratio, contraceptive use, abortion legislation and constitutional amendment.
§Initial model considered the following variables: female literacy, low birth weight, skilled attendance at birth, intimate-partner violence, all-abortion hospitalization ratio, TFR, abortion legislation and constitutional amendment.
R^2 refers to the goodness-of-fit for each model.
CI, confidence interval; MMR_{AO}, maternal mortality ratio with abortive outcome; TFR, average total fertility rate from 2002 to 2011; SE, standard error; VIF, variance inflation factor.

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Lastly, in the case of iAMR, when clean water replaced female literacy in regression modeling, three factors (adjusted R^2=0.700, P for model<0.001) were identified as independent explanatory variables: clean water (β=-0.048, P<0.001, VIF=1.041), low birth weight (β=0.210, P<0.001, VIF=1.006), and skilled attendance at birth (β=-0.032, P=0.014, VIF=1.039). These variables explained 39.2%, 26.6%, and 7.4% of the differences observed in iAMR among states, respectively. When female literacy rate was replaced by sanitation, the model (adjusted R^2=0.593, P for model<0.001) identified sanitation (β=-0.052, P<0.001, VIF=1.000), low birth weight (β=0.169, P=0.002, VIF=1.003), and skilled attendance at birth (β=-0.044, P=0.004, VIF=1.003) explaining 29.8%, 19.2%, and 14.5% of the variance on iAMR, respectively. Finally, when contraceptive use was replaced by TFR, the model (adjusted R^2=0.335, P for model<0.001) identified low birth weight (β=0.197, P=0.004, VIF=1.015) and TFR (β=1.383, P=0.003, VIF=1.015) as explanatory factors. These variables accounted for 20.6% and 17.2% of the variance observed on iAMR among states, respectively. No statistically significant effects were obtained for abortion legislation, constitutional amendment, or additional covariates other than those mentioned.

Table S22 Alternative explanatory regression models for induced abortion mortality ratio

iAMR	β	SE	95% CI		P value	VIF	R^2
			Lower	Upper			
Clean water instead of female literacy†							
Clean water(%)	-0.048	0.008	-0.065	-0.030	<0.001	1.041	
Low birth weight (%)	0.210	0.043	0.121	0.299	<0.001	1.006	0.700
Skilled attendance at birth (%)	-0.032	0.012	-0,057	-0.007	0.014	1.039	
Sanitation instead of female literacy‡							
Sanitation (%)	-0.052	0.011	-0.075	-0.029	<0.001	1.000	
Low birth weight (%)	0.169	0.048	0.070	0.268	0.002	1.003	0.593
Skilled attendance at birth (%)	-0.044	0.014	-0,072	-0.016	0.004	1.003	
TFR instead of contraceptive use§							
Low birth weight (%)	0.197	0.064	0.067	0.327	0.004	1.015	0.335
TFR	1.383	0.434	0.495	2.270	0.003	1.015	

Alternative multivariate regression models for iAMR after refinement considering independent variables excluded from the explanatory models (Tables 2-4) due to collinearity.
†Initial model considered the following variables: clean water, low birth weight, skilled attendance at birth, intimate-partner violence, all-abortion hospitalization ratio, contraceptive use, abortion legislation and constitutional amendment.
‡Initial model considered the following variables: sanitation, low birth weight, skilled attendance at birth, intimate-partner violence, all-abortion hospitalization ratio, contraceptive use, abortion legislation and constitutional amendment.
§Initial model considered the following variables: female literacy, low birth weight, skilled attendance at birth, intimate-partner violence, all-abortion hospitalization ratio, TFR, abortion legislation and constitutional amendment.
R^2 refers to the goodness-of-fit for each model.
CI, confidence interval; iAMR, induced abortion mortality ratio; TFR, average total fertility rate from 2002 to 2011; SE, standard error; VIF, variance inflation factor.

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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
		(*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
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
		(*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
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
Study size	10✔	Explain how the study size was arrived at
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
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

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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
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14✔	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15✔	*Cohort study*—Report numbers of outcome events or summary measures over time
		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
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
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

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Abortion legislation, maternal healthcare, fertility, female literacy, sanitation, violence against women, and maternal deaths: a natural experiment in 32 Mexican states

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Abortion legislation, maternal healthcare, fertility, female literacy, sanitation, violence against women, and maternal deaths: a natural experiment in 32 Mexican states

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Keywords: Maternal mortality, women's education, Millennium Development Goals, developing countries, intimate-partner violence

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ABSTRACT

Objective: To test whether there is an association between abortion legislation and maternal mortality outcomes after controlling for other factors thought to influence maternal health.

Design: Population-based natural experiment.

Setting and data sources: Official maternal mortality data from 32 federal states of Mexico between 2002 and 2011.

Main outcomes: Maternal mortality ratio (MMR), MMR with any abortive outcome (MMR_{AO}), and induced abortion mortality ratio (iAMR).

Independent variables: Abortion legislation grouped as less (n=18) or more permissive (n=14); constitutional amendment protecting the unborn (n=17); skilled attendance at birth; all-abortion hospitalisation ratio; low birth weight rate; contraceptive use; total fertility rates (TFR); clean water; sanitation; female literacy rate and intimate-partner violence.

Main results: Over the 10-year period, states with less permissive abortion legislation exhibited lower MMR (38.3 vs 49.6; $p<0.001$), MMR_{AO} (2.7 vs 3.7; $p<0.001$), and iAMR (0.9 vs 1.7; $p<0.001$), than more permissive states. Multivariate regression models estimating effect sizes (ß-coefficients) for mortality outcomes showed independent associations (*p-values* between 0.001 and 0.055) with female literacy (ß= -0.061 to -1.100), skilled attendance at birth (ß= -0.032 to -0.427), low birth weight (ß= 0.149 to 2.166), all-abortion hospitalisation ratio (ß= -0.566 to -0.962), clean water (ß= -0.048 to -0.730), sanitation (ß= –0.052 to -0.758), and intimate-partner violence (ß= 0.085 to 0.755). TFR showed inverse association with MMR (ß= -14.329) and MMR_{AO} (ß= -1.750) and a direct association with iAMR (ß=1.383). Altogether, these factors accounted for (R^2) 51% to 88% of the variance among states in overall mortality rates. No statistically independent effect was observed for abortion legislation, constitutional amendment, or other covariates.

Conclusion: Although less permissive states exhibited consistently lower maternal mortality rates, this finding was not explained by abortion legislation itself. Rather, these differences were explained by other independent factors, which appeared to have a more favourable distribution in these states.

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STRENGHTS AND LIMITATIONS

- To the best of our knowledge, this is the first population-based natural experiment analysing the impact of less or more permissive abortion legislation on maternal mortality outcomes in Mexico, simultaneously controlling by 10 variables thought to influence maternal health at the population level.

- In this study, relying on virtually complete, official vital statistics data, Mexican states with less permissive abortion legislation displayed lower maternal and abortion mortality ratios than states with more permissive legislation during a 10-year study period. Nevertheless, observed differences among populations were not attributable to abortion legislation by itself.

-In comparison to states with more permissive abortion legislation, those with less permissive legislation showed a more favourable profile in several indicators related to maternal healthcare and human development.

- Exhaustive multivariate analyses showed that observed differences in maternal mortality outcomes among states were largely explained by a combination of variables related to maternal healthcare, fertility, female literacy, intimate-partner violence against women, and sanitation.

- After controlling for confounders, no evidence of deleterious or beneficial effect was found for the presence of constitutional amendments protecting the unborn over a 4-year study period.

- Although inter-state diversity of abortion legislation in terms of permissiveness provided the opportunity to assess its impact on mortality outcomes, intra-state heterogeneity of exemptions from criminal prosecution hampered the allocation of population of individuals to groups univocally defined as less or more permissive. Nevertheless, the exemption of criminal prosecution of abortion on the grounds of genetic or congenital foetal malformations was found to provide clear differences in mortality outcomes.

- Because this study is based on aggregated data, the effect of analysed variables at the individual level cannot be ruled out.

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INTRODUCTION

Promoting maternal health has been a key concern for public health policy makers worldwide, particularly since the United Nations (UN) put forth the Millennium Development Goals (MDGs).[1] As part of the fifth MDG, which focused on improving maternal health, the UN requested all member states to decrease their maternal mortality ratio (MMR)* by 75% by 2015.[2]

Most causes of maternal mortality are preventable, and improved access to antenatal care,[3-5] as well as maternal health facilities equipped with emergency obstetric units,[3,4,6,7] and skilled attendance at childbirth[3,6,8-10] are acknowledged public health interventions that have led to the decrease in maternal mortality worldwide. However, one year away from the 2015 deadline for the MDGs, the MMR has decreased less than 50% globally,[10-12] suggesting that measures taken to address maternal mortality may have been insufficient.[11,13,14] In this regard, although novel complementary public health or social interventions have been encouraged in support of the post-MDG agenda,[13,14] these ought to be supported by data and evidence, for example, population-based natural experiments.[15-17]

It has been proposed that the legal status of abortion, defined as pregnancy termination by removal or expulsion of the foetus, is a factor that influences maternal health in a region, country, or territory.[18,19] There is a widespread perception that less permissive legislation, i.e. legislation that restricts or prohibits pregnancy termination (note that “abortion” or “pregnancy termination” are terms used interchangeably throughout this study) leads to increased maternal mortality due to complications of clandestine, or illegal, or unsafe abortions.[20-22] Accordingly, it has also been suggested that more permissive abortion legislation would lead to a reduction in maternal deaths.[19-21] However, conflicting results have been recently reported in the literature.[10,12,18,23-29] For instance, evidence from settings with less permissive abortion legislation[28,26,29-31] suggests that other factors, such as increasing level of women’s education, complimentary nutrition programmes for poor pregnant women, availability of maternal

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healthcare facilities, emergency obstetric units, changes in reproductive behaviour with increased family planning, and access to clean water and sanitation, may facilitate an epidemiologic transition towards low maternal mortality rates in the absence of more permissive abortion legislation.[30] However, this hypothesis remains to be tested or replicated at the population level in different epidemiological scenarios.

The United Mexican States (Mexico) is a federal republic comprising 32 federal territories (31 states and the Federal District, referred to as “states” henceforth), whose population shares a common history and culture. The Mexican healthcare system reached virtually universal coverage over the past century, assuring equality in access to basic healthcare for most of the population.[32] Each state has its own political constitution, criminal code, and abortion legislation. Moreover, while the Federal District passed a law allowing pregnancy termination on demand during the first trimester of pregnancy, several states have modified their constitutions in the opposite direction, strengthening the protection of the unborn starting at conception.[22] Thus, Mexico offers a unique epidemiological scenario to test whether more or less permissive abortion legislation affects maternal mortality in a population that shares the same history and culture, and which has a homogeneous healthcare system.

This study presents the results of a population-based natural experiment examining factors associated with maternal mortality in the 32 Mexican states during a period spanning 10 years (2002-2011). It analyses trends in maternal and abortion-related mortality according to differences in abortion legislation, controlling for a number of factors thought to influence maternal mortality rates.

MATERIALS AND METHODS

Population data

Official records of maternal deaths and observed live births occurring within the United Mexican States were extracted from the General Directorate of Health Information (DGIS)[33] and the

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National Institute of Statistics, Geography, and Informatics (INEGI)[34] respectively, for every state by place of residence (state where the individual used to dwell) and place of occurrence (state where the vital event took place), between 2002 and 2011 (10-year continuous period). Civil registration of vital statistics in Mexico follows international standards, has been regarded as virtually complete by the World Health Organization, and has been included in List A –with good attribution of causes of death– along with 64 other countries.[12] Since 2002, Mexico has strengthened its active epidemiological surveillance system (Intentional Search and Reclassification of Maternal Deaths)[35] to correctly code maternal deaths that were initially not recognised as maternal, and to reclassify maternal deaths with erroneously attributed codes throughout the entire territory. Because this surveillance increased data reliability, 2002 was selected as the initial year for the study.

Classification of maternal deaths

Maternal deaths were identified using the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10)[36] and were classified by place of residence or occurrence. Mortality ratios were directly calculated as the quotient between maternal deaths and observed live births. Three epidemiological indicators were calculated according to the classification proposed in a recent review.[37] The first indicator is maternal mortality ratio (MMR), which considers all maternal death codes (ICD-10 codes O00-O99, A34, B20-B24, and F53) and is often referred to as overall maternal mortality. The second indicator is maternal mortality ratio with any abortive outcome (MMR_{AO}), which considers maternal death classified following ICD-10 codes O00-O08. The third indicator is termed induced abortion mortality ratio (iAMR), which focuses only on deaths likely associated with complications of pregnancy termination.[37] Specific characteristics of this indicator allows to circumvent the problem of underreporting of deaths from illegal abortions in countries where legal restrictions hamper the assessment of induced abortion counts and rates. First, it includes the code for medical abortion [ICD-10 code O04], which is used for the classification of deaths due to legal termination of pregnancy. Second, it also includes codes for other abortion [ICD-10 code O05], unspecified abortion [ICD-10 code O06],

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and failed attempted abortion [ICD-10 code O07], which are employed in Mexico and other Latin American countries for classifying deaths from induced abortion without a clear cause or when an illegal procedure is suspected. Finally, this indicator parsimoniously excludes deaths associated to well defined pathological conditions or complications that cannot be associated with a voluntary termination of pregnancy, such as ectopic pregnancy (ICD-10 code O00), hydatidiform mole (ICD-10 code O01), other abnormal products of conception (ICD-10 code O02), spontaneous abortion (ICD-10 code O03), and complications following abortion and ectopic and molar pregnancy (ICD-10 code O08).[37]

Abortion legislation

Criminal legislation for each state was reviewed and extracted from the National Office for the Judiciary of the Mexican government.[38] The revision of current criminal codes of each Mexican state is summarized in Table 1. In practical terms, all 32 states provide criminal exemptions from prosecution for abortions performed in case of rape, 29 states provide criminal exemptions in imprudent or accidental cases, 25 states provide exemptions when the life or health of the mother is at risk, 10 states do so in cases of artificial insemination without consent, 1 state for social causes, and 14 states in cases of genetic or congenital foetal conditions resulting in an individual with serious physical or mental deficiencies. In addition, in 2007 the Federal District passed a law allowing legal pregnancy termination on request up to the 12th week of pregnancy.[39] In exploratory analyses, segregating states by the number of exemptions provided in criminal codes did not result in detectable differences in sensitivity analyses, with the exception of abortion allowed by genetic or congenital foetal malformations. The remaining seven exemptions were distributed differentially, in almost every state or very few states, thus offering no discrimination potential. Therefore, to differentiate between states with more or less permissive abortion legislation in subsequent statistical analyses, states allowing pregnancy termination due to serious genetic or congenital conditions were considered more permissive (14 states), while the remaining states were considered less permissive (18 states).

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Table 1 Current abortion legislations based on criminal exemptions from prosecution of abortion in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation

	Rape	Imprudential conduct	Risk to the life of the mother	Genetic or congenital malformation	Serious risk to the health of the mother	Artificial insemination without consent	Economic or social reasons	On demand
Aguascalientes (l)	▯	▯	▯					
Baja California (l)	▯	▯	▯			▯		
Baja California Sur (m)	▯	▯	▯	▯	▯	▯		
Campeche (l)	▯	▯			▯			
Coahuila (m)	▯	▯	▯	▯				
Colima (m)	▯	▯	▯	▯		▯		
Chiapas (m)	▯		▯	▯				
Chihuahua (l)	▯	▯			▯	▯		
Distrito Federal (m)	▯	▯		▯	▯	▯		▯
Durango (l)	▯	▯	▯					
Guanajuato (l)	▯	▯						
Guerrero (m)	▯	▯		▯		▯		
Hidalgo (m)	▯	▯		▯	▯			
Jalisco (l)	▯	▯	▯		▯			
México (m)	▯	▯	▯	▯				
Michoacán (l)	▯	▯	▯		▯			
Morelos (m)	▯	▯	▯	▯		▯		
Nayarit (l)	▯	▯	▯		▯			
Nuevo León (l)	▯		▯		▯			
Oaxaca (m)	▯	▯	▯	▯				
Puebla (m)	▯	▯	▯	▯				
Querétaro (l)	▯	▯						
Quintana Roo (m)	▯	▯	▯	▯				
San Luis Potosí (l)	▯	▯	▯			▯		
Sinaloa (l)	▯	▯	▯					
Sonora (l)	▯	▯	▯					
Tabasco (l)	▯		▯			▯		
Tamaulipas (l)	▯	▯	▯		▯			
Tlaxcala (l)	▯	▯	▯		▯			
Veracruz (m)	▯	▯	▯	▯		▯		
Yucatán (m)	▯	▯	▯	▯			▯	
Zacatecas (l)	▯	▯	▯		▯			
Total	**32**	**29**	**25**	**14**	**12**	**10**	**1**	**1**

Official criminal legislation for each state were reviewed and extracted from the National Office for the Judiciary.[38]
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.

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Political constitution amendments

Data on amendments to the political constitution of each state were extracted from the National Office for the Judiciary of the Mexican government.[38] Specifically, constitutional amendments specifying an explicit protection of the unborn starting at conception were tracked in time and form by examining the political constitution of each state. A number of states amended their constitutions to this effect almost immediately after the legalization of pregnancy termination on request in the Federal District, in April of 2007.[39] These progressive changes required a dynamic allocation of states according to the date of enactment or derogation of the amendment during the 4-year period of analysis between 2008 and 2011 (Figure S1, Supplementary Material). In addition to the state of Chihuahua, which amended its constitution in 1994, 16 other states had enacted these amendments by the end of 2011. In subsequent statistical analysis, a direct comparison of maternal and abortion-related deaths was carried out between groups of states with amendment (17 states) and without an amendment (15 states). In addition, sub-analyses that discriminated maternal and abortion-related mortality between the Federal District and other states were also conducted.

Independent variables

Other independent variables considered were percentage of the population with access to clean water (“clean water”), sanitary sewer coverage (“sanitation”), average total fertility rate between 2002 and 2011 (“TFR”), percentage of contraceptive use by married or in-union female population of fertile age (“contraceptive use”), percentage of skilled attendance at birth (“skilled attendance at birth”), low birth weight rate (“low birth weight”), female literacy rate (“female literacy”), all-abortion hospitalisation ratio, and percentage of intimate-partner violence against married or in-union women over the last year (“intimate-partner violence”). Operational definitions, their significance for epidemiological studies (for subsequent interpretation), measurement scales, and data sources for these variables are detailed in Table S1 (Supplementary Material).

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Statistical analyses

Parallel time series were constructed between 2002 and 2011 for maternal deaths and registered live births according to abortion legislation. Trends for MMR, MMR_{AO}, and iAMR per 100,000 live births were directly calculated for every federal state and were evaluated over time by occurrence and residence using an autoregressive integrated moving average (ARIMA) model. The complete time series data used in this study are presented in Tables S2 through S15 (Supplementary Material). In each ARIMA model, the *β*-coefficient represents the average change per year of the mortality outcome and the *p* for trend indicates the statistical significance of the overall trend. Average mortality ratios over the total time period were also computed and directly matched using *Z*-test. The proportion (%) of induced abortion-related deaths (i.e., proportion of deaths due to pregnancy termination over the total number of maternal deaths) was also computed and comparatively analysed.

The Kolmogorov-Smirnov test was utilised to assess the normal distribution assumption. Multiple regression was used to estimate the effect size of independent variables on average mortality ratios (MMR, MMR_{AO}, and iAMR) and explain the variance among the 32 states controlling for other factors. Because of potential collinearity related to the high number of predictors, a Pearson correlation matrix was used to quantify the magnitude of bivariate linear associations among all independent variables. Pearson coefficients (r) ≥0.70 were considered to suggest collinearity. Exploratory models were conducted to assess collinearity using the variance inflation factor (VIF).[40] The covariates selected for inclusion in explanatory regression models were analysed using the backward stepwise elimination method based on *p*-values of 0.05 and 0.059 as criteria of entry and removal, respectively. *β*-coefficients with 95% confidence intervals were computed to assess the effect size of each predictor on the MMR, MMR_{AO}, and iAMR and the change in the R^2 was used to determine the final models with maximal goodness-of-fit, minimal number of explanatory variables, and minimal collinearity. To examine the stability of *β*-coefficients and obtain unbiased effect sizes, two panels of multivariate explanatory models were considered for

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each mortality outcome, based on diagnostic regression refinement of residual statistics, by eliminating the presence of outliers (higher than 2 standard deviations of predicted mortality outcome) when presented.

RESULTS

Abortion legislation and maternal mortality

During the 10-year study period there were 11,649 maternal deaths and 26,089,498 live births in Mexico, corresponding to a MMR of 44.7 per 100,000 live births. The MMR in 2002 was 48.6, decreasing to 37.7 per 100,000 live births in 2011, representing a total reduction of 22.4%. In the same period, there were 855 deaths with abortive outcome, representing a MMR_{AO} of 3.28 per 100,000 live births. This outcome displayed a 20.5% decrease between 2002 (3.61 per 100,000 live births) and 2011 (2.87 per 100,000 live births). For this period, there were 352 deaths associated with ICD-10 codes O04 through O07, representing an iAMR of 1.35 per 100,000 live births. This outcome decreased by 29.5% between 2002 and 2011, from 1.49 to 1.05 deaths per 100,000 live births.

Regardless of where the vital event took place, MMR, MMR_{AO}, iAMR, and the proportion of induced abortion-related deaths between 2002 and 2011 were lower in the group of states with less permissive abortion legislation (Figures 1 and 2, left panels). Table 2 summarizes the linear trends of all three mortality outcomes in each group of states and the entire Mexican country for the study period, by residence and occurrence, respectively. In each group, the β-coefficient represents the average change per year of the mortality outcome and the *p* for trend indicates the statistical significance of the overall trend. The group of states with less permissive abortion legislation showed apparently stable trends for MMR, MMR_{AO}, and iAMR during the decade analysed. The group of states with more permissive abortion legislation displayed decreasing trends for MMR, MMR_{AO}, iAMR, narrowing the gap between the two groups by 2011 but still exhibited statistically significant differences (*e.g.* MMR of 40.9 *vs.* 33.5 per 100,000 live births for more permissive vs. less permissive states, Z=3.04, rate ratio=0.82, p=0.002). State-by-state

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trends and estimated β-coefficients for the time series of MMR, MMR_{AO}, and iAMR are presented by residence (Tables S10 through S12) and by occurrence (Tables S13 through S15) in the Supplementary Material.

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Table 2 Average change per year in different maternal mortality outcomes by place of residence and occurrence in groups of Mexican states with more or less permissive abortion legislation and the entire country (2002-2011) based on Autoregressive Integrated Moving Average (ARIMA) models.

	MMR			MMR_{AO}			iAMR		
	β†	SE‡	*p*§	β†	SE‡	*p*§	β†	SE‡	*p*§
By place of residence									
Less permissive states (18)	-0.563	0.405	0.202	0.030	0.057	0.615	-0.010	0.019	0.619
More permissive states (14)	-1.766	0.276	<0.001	-0.123	0.040	0.016	-0.096	0.025	0.005
United Mexican States (32)	-1.258	0.286	0.002	-0.056	0.032	0.121	-0.058	0.017	0.010
By place of occurrence									
Less permissive states (18)	-0.487	0.428	0.288	0.025	0.061	0.688	-0.011	0.020	0.602
More permissive states (14)	-1.764	0.275	<0.001	-0.112	0.040	0.022	-0.092	0.023	0.004
United Mexican States (32)	-1.258	0.286	0.002	-0.056	0.032	0.121	-0.058	0.017	0.010

†*β*-coefficient representing the average change per year for trend of MMR per 100,000 live births between 2002 and 2011.
‡Standard error for β-coefficient obtained between 2002 and 2011 with ARIMA.
§*p* for trend between 2002 and 2011.

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Figure 3 illustrates in a blue scale the geographic distribution of average MMR (top panel) and iAMR (bottom panel) for the 10-year period in territories of the whole country. The differences in average mortality outcomes between groups are summarized in Table 3. Average MMR for the 10-year period by place of residence and occurrence in the group of states with less permissive legislation was 23% and 21% lower, respectively, than the value in the group of states with more permissive legislation. Similarly, the group of states with less permissive abortion legislation showed an average MMR_{AO} by place of residence and occurrence of 27% and 24% lower, respectively, than states with more permissive legislation. The highest difference between both groups was for the average iAMR, which was 47% lower in states with less permissive legislation, for analyses by residence and occurrence. Finally, average proportion of induced abortion-related deaths over the total number of maternal deaths by place of residence was 2.4% and 3.4% (p=0.002) in the groups of states with less and more permissive abortion legislation, respectively; by place of occurrence, figures were 2.3% and 3.5% (p<0.001), respectively. Excluding the Federal District from the group of states with more permissive abortion legislation did not significantly modify these results.

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Table 3 Comparative analysis of average mortality outcomes by residence and occurrence for groups of Mexican states exhibiting a more or less permissive abortion legislation, 2002-2011

Indicator		Less permissive	More permissive	Rate ratio†	p value‡
MMR	By residence	38.3	49.6	0.7722	< 0.001
	By occurrence	39.1	49.3	0.7922	< 0.001
MMR_{AO}	By residence	2.7	3.7	0.7110	< 0.001
	By occurrence	2.8	3.7	0.7491	< 0.001
iAMR	By residence	0.9	1.7	0.5358	< 0.001
	By occurrence	0.9	1.7	0.5337	< 0.001
Proportion of induced abortion-related deaths	By residence	2.4%	3.4%	§	< 0.001
	By occurrence	2.3%	3.5%	§	< 0.001

iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.
†*Z*-test rate ratio.
‡*Z*-test p value.
§Not applicable.

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Constitutional amendments and maternal mortality

Regardless of where the vital event took place, iAMR and the proportion of induced abortion-related deaths between 2008 and 2011 –but not MMR and MMR_{AO}, for which rates overlapped– were apparently higher in the group of states that did not amend their constitutions (Figures 4 and 5, left panels); however, these differences were not statistically significant for the 4-year period (*p* for trend=0.670). The differences in average mortality outcomes between groups are summarized in Table 4. Differences were observed in average iAMR and proportion of induced abortion-related deaths for the total period of 4 years. Average iAMR either by place of residence or occurrence in states with constitutional amendments was 31% lower than the value in states without amendments. The average proportion of induced abortion-related deaths over the total number of maternal deaths by place of residence was 2.1% in states with amendment and 3.1% in states without amendment (*p*=0.041); by place of occurrence figures were 2.2% in states with amendment and 3.2% in states without amendment (*p*=0.048).

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Table 4 Comparative analysis of average mortality outcomes by residence and occurrence for groups of states with or without constitutional amendment protecting the unborn from conception, 2008-2011

Indicator		With amendment	Without amendment	Rate ratio†	*p* value‡	Without amendment excluding the FD	Rate ratio§	*p* value¶	FD	Rate ratio††	*p* value‡‡
MMR	By residence	40.5	41.6	0.9413	0.347	41.4	0.9792	0.514	43.3	0.9357	0.310
	By occurrence	40.0	41.2	0.9031	0.114	40.6	0.9856	0.657	56.1	0.7124	<0.001
MMR_{AO}	By residence	2.8	3.2	0.7728	0.273	3.1	0.8959	0.361	3.8	0.7379	0.175
	By occurrence	2.9	3.2	0.8134	0.378	3.0	0.9475	0.656	4.3	0.6663	0.039
iAMR	By residence	0.9	1.3	0.5360	0.042	1.3	0.6522	0.037	1.1	0.7750	0.538
	By occurrence	0.9	1.3	0.5338	0.043	1.3	0.6717	0.054	1.4	0.6014	0.138
Proportion of induced abortion-related deaths	By residence	2.1%	3.1%	§§	0.041	3.2%	§§	0.030	2.6%	§§	0.649
	By occurrence	2.2%	3.2%	§§	0.048	3.2%	§§	0.063	2.6%	§§	0.625

FD, Federal District (Distrito Federal); iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.
†Z-test rate ratio between states with and without amendment.
‡Z-test *p* value between states with and without amendment.
§Z-test rate ratio between states with and without amendment, excluding the Federal District.
¶Z-test *p* value between states with and without amendment, excluding the Federal District.
††Z-test rate ratio between states with amendment and the Federal District.
‡‡Z-test *p* value between states with amendment and the Federal District.
§§Not applicable.

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After removing the Federal District from the group of states without constitutional amendments, differences were observed in average MMR and MMR_{AO} between the groups, but only in the analysis of mortality by place of occurrence (Figures 5 and 7, right panels). The Federal District showed higher average MMR and MMR_{AO} by place of occurrence than the group of states with constitutional amendments. In addition, removal of the Federal District from the group of states without constitutional amendments abolished the differences found in average iAMR and proportion of induced abortion-related deaths by place of occurrence (Figures 5 and 7), but not by place of residence (Figures 4 and 6) between the latter group and the group of states with the amendment. Results for each mortality outcome are compared in Table 4.

Primary explanatory regression models

Table 5 shows data for all covariates for each Mexican state, and includes the results from tests of normal distribution for each variable. Simple regression models illustrating the initial effect size (β-coefficient) for each covariate, including abortion legislation and constitutional amendment are presented in Table 6. For instance, less permissive abortion legislation was associated with an average decrease of 7.31 per 100,000 live births for MMR.

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Table 5 Independent variables in each Mexican state: frequencies and analyses of normal distribution

State	Abortion legislation	Constitutional amendment	Clean water	Sanitation	TFR	Contraceptive use	Skilled attendance at birth	Low birth weight	Female literacy	All-abortion hospitalisation ratio	Intimate-partner violence
Aguascalientes	1	0	98.0	97.8	2.6	71.7	97.5	6.6	95.9	10.8	12.0
Baja California	1	1	95.3	93.7	2.1	78.8	75.7	6.9	96.0	9.2	11.7
Baja California Sur	0	0	88.1	94.2	2.0	75.9	99.5	6.0	95.8	10.6	16.3
Campeche	1	0	85.0	85.7	2.2	73.9	98.2	7.2	89.7	7.8	10.7
Coahuila	0	0	96.8	95.6	2.3	75.2	89.6	8.0	96.5	8.0	14.3
Colima	0	1	97.3	98.7	2.3	78.3	96.4	5.4	94.2	17.4	11.0
Chiapas	0	1	73.8	80.4	2.8	54.9	90.2	8.6	77.5	5.1	7.0
Chihuahua	1	1	94.9	93.2	2.4	78.9	82.2	7.6	95.3	6.2	12.1
Distrito Federal	0	0	97.5	99.2	1.8	79.6	94.3	14.0	96.3	14.2	20.9
Durango	1	1	92.9	88.3	2.4	73.2	93.3	8.0	95.5	8.2	10.2
Guanajuato	1	1	91.9	89.3	2.4	68.3	90.1	8.9	90.1	7.0	6.4
Guerrero	0	0	62.0	71.7	2.8	61.4	80.8	9.3	79.8	3.2	8.3
Hidalgo	0	0	87.2	83.4	2.4	70.9	89.7	8.5	87.2	6.2	8.6
Jalisco	1	1	94.6	96.9	2.4	71.4	93.5	9.0	94.8	7.4	10.0
México	0	0	92.2	92.0	2.2	76.5	84.7	10.9	93.6	4.4	11.9
Michoacán	1	0	88.1	85.4	2.4	63.2	92.1	8.6	88.4	6.1	9.1
Morelos	0	1	87.6	92.4	2.2	75.4	91.7	10.5	91.8	8.8	9.7
Nayarit	1	1	88.3	93.5	2.3	78.7	81.8	6.8	92.9	7.4	14.8
Nuevo León	1	0	96.9	97.2	2.1	79.2	96.6	8.6	95.8	6.5	13.1
Oaxaca	0	1	69.8	69.6	2.6	63.4	95.0	7.8	79.4	3.7	6.3
Puebla	0	1	83.8	84.9	2.6	69.8	90.8	9.6	86.8	4.0	8.6
Querétaro	1	1	91.9	91.0	2.3	70.3	97.6	9.2	91.7	9.1	11.6
Quintana Roo	0	1	91.7	94.0	2.1	73.4	91.5	8.3	92.4	9,7	10.7
San Luis Potosí	1	1	83.1	80.5	2.5	67.4	91.7	8.1	90.5	6.6	10.5
Sinaloa	1	0	90.3	90.9	2.3	79.8	93.4	6.1	94.7	8.1	15.0
Sonora	1	1	94.4	90.0	2.4	79.9	94.6	6.2	96.3	8.7	15.4
Tabasco	1	0	73.8	91.7	2.3	66.3	82.4	8.4	90.9	7.2	9.6
Tamaulipas	1	1	95.1	88.1	2.3	73.2	99.0	7.4	94.2	10.0	14.9
Tlaxcala	1	0	95.6	92.8	2.4	65.2	98.2	10.1	92.8	7.6	9.3
Veracruz	0	0	76.3	80.2	2.2	73.9	97.8	7.1	86.1	4.8	10.9
Yucatán	0	1	94.4	80.1	2.3	74.9	97.5	10.7	88.6	7.2	11.5
Zacatecas	1	0	91.7	89.0	2.5	70.2	89.1	8.6	93.6	8.3	8.2
p-value[*]	†	†	0.189	0.624	0.311	0.730	0.534	0.666	0.399	0.394	0.505

Abortion Legislation: states classified as less permissive (1) or more permissive (0), according to the presence of an exemption from criminal prosecution of abortion in cases of genetic or congenital malformation. Constitutional amendment: states classified as exhibiting (1) or not (0) an amendment to their political constitution protecting the unborn from conception during 2011. Clean water: Percentage of in-use private dwellings with clean water availability during 2010. Sanitation: Percentage of in-use private dwellings with availability of sewer drainage during 2010. TFR: Average total fertility rate between 2002 and 2011. Contraceptive use: Percentage of married or in-union women of 15 and above using contraceptive methods during 2009. Skilled attendance at birth: Percentage of observed live births delivered by a physician, nurse or midwife during 2010. Low birth weight: Percentage of observed live births with low birth weight in each state during 2010. Female literacy: Percentage of the female population of ages 15 and above who can understand,

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read and write a short, simple statement on their everyday life during 2010. All-abortion hospitalisation ratio: Ratio of all-abortion related hospitalisations over observed live births between 2000 and 2008 per 100 live births. Intimate-partner violence: Percentage of married or in-union women of ages 15 and above who have suffered severe intimate partner violence over the past 12 months during 2010.
*Kolmogorov-Smirnov test for normal distribution.
†Not applicable

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Table 6 Univariate associations between 10 independent variables and maternal mortality outcomes for 32 Mexican states, 2002-2011

Variable	MMR						MMR_{AO}						iAMR					
	β	SE	95% CI Lower	95% CI Upper	R^2	*p* value	β	SE	95% CI Lower	95% CI Upper	R^2	*p* value	β	SE	95% CI Lower	95% CI Upper	R^2	*p* value
Female literacy (%)	-1.16	0.26	-1.700	-0.627	0.38	<0.001	-0.08	0.03	-0.155	-0.007	0.11	0.033	-0.07	0.02	-0.117	-0.021	0.20	0.007
Low birth weight (%)	2.05	0.92	0.173	3.937	0.11	0.033	0.33	0.09	0.134	0.534	0.26	0.002	0.17	0.07	0.025	0.319	0.13	0.023
Skilled attendance at birth (%)	-0.52	0.27	-1.067	0.023	0.08	0.060	-0.08	0.03	-0.140	-0.020	0.17	0.010	-0.03	0.02	-0.073	0.015	0.02	0.192
Intimate-partner violence (%)	-0.86	0.52	-1.931	0.205	0.05	0.109	-0.06	0.06	-0.189	0.066	0.00	0.332	-0.05	0.04	-0.138	0.034	0.02	0.230
All-abortion hospitalisation ratio (per 100 live births)	-1.71	0.51	-2.750	-0.678	0.25	0.002	-0.11	0.06	-0.247	0.022	0.05	0.099	-0.10	0.04	-0.187	-0.009	0.11	0.033
Constitutional amendment (yes)	1.93	3.36	-4.946	8.809	0.01	0.571	0.22	0.39	-0.575	1.019	-0.02	0.574	-0.20	0.26	-0.742	0.340	-0.01	0.454
Abortion legislation (less permissive)	-7.31	3.13	-13.710	-0.911	0.12	0.027	-0.47	0.38	-1.263	0.310	0.01	0.226	-0.31	0.26	-0.843	0.232	0.01	0.255
Contraceptive use (%)	-0.64	0.25	-1.165	-0.130	0.15	0.016	-0.04	0.03	-0.106	0.023	0.02	0.195	-0.05	0.02	-0.093	-0.012	0.16	0.013
TFR	9.51	6.56	-3.899	22.927	0.03	0.158	0.46	0.78	-1.134	2.063	-0.02	0.557	1.21	0.48	0.221	2.216	0.14	0.018
Clean water (%)	-0.66	0.15	-0.970	-0.355	0.37	<0.001	-0.03	0.02	-0.076	0.012	0.03	0.152	-0.03	0.01	-0.065	-0.009	0.16	0.012
Sanitation (%)	-0.79	0.18	-1.174	-0.425	0.36	<0.001	-0.03	0.02	-0.090	0.017	0.02	0.177	-0.04	0.01	-0.075	-0.005	0.12	0.026

CI, confidence interval; iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome; SE, standard error; TFR, average total fertility rate between 2002-2011.

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Exploratory regression analyses showed collinearity between independent variables. A full model introducing all independent variables simultaneously (not shown) showed VIF values between 1.537 and 9.082. In particular, five of the nine independent variables showed VIF values higher than 4.0 (clean water, sanitation, TFR, contraceptive use, and female literacy), suggesting the presence of multicollinearity. A correlation matrix showed a high inverse correlation between TFR and contraceptive use (r=-0.76; p<0.001), suggesting that these variables were interchangeable. Other pairs of variables with high Pearson coefficients were clean water with sanitation (r=0.79; p<0.001), and female literacy with clean water (r=0.85; p<0.001) or with sanitation (r=0.86; p<0.001). Thus, contraceptive use and female literacy were selected for primary explanatory models. When TFR, clean water, and sanitation were excluded, VIF substantially decreased to values between 1.087 and 3.338.

Table 7 shows the multivariate explanatory models for MMR, MMR_{AO} and iAMR using the backward stepwise elimination method and after statistical refinement. Models before refinement are presented in Table S16 (Supplementary Material). In general, an increase in β-coefficients and R^2 was observed after statistical refinement. In every multivariate regression model, each β-coefficient represents the average change in the outcome of interest (i.e., MMR, MMR_{AO}, and iAMR) per unit of change in each independent variable (e.g., % skilled attendance at birth, % female literacy, % low birth weight, etc.) controlling for all other covariates in the model, and R^2 represents the proportion of the total variability in the mortality outcome explained by the full model. The refined model for MMR excluded two states as outliers (Chihuahua and Nueva León) and identified four predictors: female literacy, low birth weight, all-abortion hospitalisation ratio, and intimate-partner violence. These variables accounted for 69% of observed differences in MMR among states (R^2 for model). The contribution of each variable for explaining the variance of MMR among states (partial R^2) was 50.9%, 15.1%, 4.4%, and 2.8%, respectively. No independent effect was observed for abortion legislation, constitutional amendment, or other covariates. Regarding MMR_{AO}, the refined model excluded two states as outliers (Aguascalientes and Nayarit), identifying three predictors: female literacy, low birth weight, and skilled attendance

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at birth. These variables accounted for 62% (R^2 for model 0.624; p<0.001) of observed differences in MMR_{AO} among states. Individual contributions of each factor for explaining the variance of MMR_{AO} among states were 11.9%, 40.2%, and 14.2%, respectively. No independent effect was observed for abortion legislation, constitutional amendment, or other covariates. Finally, regarding iAMR, the refined model excluded four states as outliers (Aguascalientes, Durango, Sonora, and Tlaxcala), identifying three predictors: female literacy, low birth weight, skilled attendance at birth, and intimate-partner violence. These variables accounted for 78% (R^2 for model 0.777; p<0.001) of observed differences in iAMR among states. The relative contributions of these variables for explaining the variance of iAMR (partial R^2) among states were 39.9%, 19.1%, 14.8%, and 7.2%, respectively. No statistically independent effect was observed for abortion legislation, constitutional amendment, or other covariates.

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Table 7. Explanatory models for trends on maternal mortality ratio (MMR), maternal mortality ratio with an abortive outcome (MMR_{AO}), and induced abortion mortality ratio (iAMR) in 32 Mexican states after refinement, 2002-2011.

	MMR†						MMR_{AO}‡						iAMR§					
	β	SE	95% CI		P value	VIF	β	SE	95% CI		P value	VIF	β	SE	95% CI		P value	VIF
			Lower	Upper					Lower	Upper					Lower	Upper		
Female literacy (%)	-1.100	0.255	-1.625	-0.574	<0.001	2.250	-0.073	0.024	-0.122	-0.023	0.005	1.014	-0.119	0.018	-0.155	-0.082	<0.001	1.944
Low birth weight (%)	1.637	0.502	0.603	2.671	0.003	1.046	0.361	0.072	0.213	0.508	<0.001	1.013	0.154	0.039	0.074	0.234	0.001	1.051
Skilled attendance at birth (%)	-0.162	0.157	-0.486	0.162	0.312	1.145	-0.065	0.021	-0.108	-0.022	0.005	1.011	-0.052	0.011	-0.075	-0.030	<0.001	1.061
Intimate-partner violence (%)	0.755	0.369	-0.004	1.514	0.051	1.859	0.021	0.055	-0.092	0.135	0.702	1.961	0.085	0.029	0.025	0.144	0.007	2.023
All-abortion hospitalisation ratio (per 100 live births)	-0.817	0.405	-1.652	0.018	0.055	1.882	0.036	0.056	-0.080	0.151	0.533	1.742	-0.004	0.030	-0.067	0.058	0.894	1.854
Constitutional amendment (yes)	0.578	1.827	-3.192	4.348	0.755	1.088	0.286	0.243	-0.214	0.787	0.250	1.019	-0.034	0.137	-0.318	0.250	0.806	1.081
Abortion legislation (less permissive)	-1.456	2.151	-5.896	2.983	0.505	1.531	-0.062	0.279	-0.636	0.513	0.827	1.276	-0.059	0.155	-0.380	0.262	0.705	1.393
Contraceptive use (%)	0.187	0.259	-0.347	0.720	0.477	3.182	0.044	0.032	-0.022	0.111	0.184	2.761	0.023	0.020	-0.018	0.064	0.255	3.622
R-square for model	0.689¶						0.624¶						0.777¶					

†Multivariate model identified and excluded two states (Chihuahua and Nueva León) as outliers after one step of refinement. Four predictors were identified after five steps of backward elimination (Female literacy, Low birth weight, All-abortion hospitalisation ratio and Intimate-partner violence), accounting for 69% (R^2) of the differences in MMR between states.
‡Multivariate model identified and excluded two states (Aguascalientes and Nayarit) as outliers after two steps of refinement. Three predictors were identified after six steps of backward elimination (Female literacy, Low birth weight, and Skilled attendance at birth), accounting for 62% (R^2) of the differences in MMR_{AO} between states.
§Multivariate model identified and excluded four states (Aguascalientes, Durango, Sonora, and Tlaxcala) as outliers after three steps of refinement. Four predictors were identified after five steps of backward elimination (Female literacy, Low birth weight, Skilled attendance at birth, and Intimate-partner violence), accounting for 78% (R^2) of the differences in iAMR between states.
¶p<0.001
CI, confidence interval; iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; $MMR_{AO,}$ maternal mortality ratio with abortive outcome; SE, standard error; VIF, variance inflation factor.

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Alternative explanatory regression models

Alternative multivariate regression models considering variables initially excluded by collinearity are summarized in Table 8. For instance, in the first of these alternative models, female literacy was exchanged with clean water (*i.e.* female literacy was excluded from the model whereas clean water was included). After regression refinement, four factors were identified as independent explanatory variables for the MMR: clean water, low birth weight, all-abortion hospitalisation ratio, and intimate-partner violence. These variables accounted for 88% (R^2 for model 0.886; p<0.001) of observed differences in MMR among states. The individual contribution (partial R^2) of each factor for explaining the variance of MMR among states was 64.7%, 22.0%, 1.9%, and 1.7%, respectively. Regarding MMR_{AO}, the model identified skilled attendance at birth and low birth weight as independent predictors, accounting for 42% of the difference among states, with an individual contribution of 17.8% and 27.9%, respectively. For iAMR, the model selected three factors: clean water, low birth weight, and skilled attendance at birth. These variables explained 70% (R^2 for model 0.70; p<0.001) of the difference among states with an individual contribution of 39.2%, 26.6%, and 7.4% of the differences observed in iAMR among states, respectively. Similarly, when female literacy was exchanged for sanitation, the refined model identified sanitation as inversely associated with MMR and iAMR. Finally, when TFR was incorporated instead of contraceptive use in multivariate models, an inverse independent association of TFR with MMR (β=-14.329; p=0.002) and MMR_{AO} (β=-1.750; p=0.008), and a direct association with iAMR (β=1.383; p=0.003) was found. A full description for other significant predictors in these alternative explanatory models is presented in the Supplementary Material. No statistically significant effects were found for abortion legislation or constitutional amendment in any of the alternative regression models.

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Table 8 Alternative explanatory regression models for MMR, MMR_{AO} and iAMR after refinement considering independent variables excluded from the explanatory models because of collinearity.

Variable	MMR						MMR_{AO}						iAMR					
	β	SE	95% CI		*p* value	VIF	β	SE	95% CI		*p* value	VIF	β	SE	95% CI		*p* value	VIF
			Lower	Upper					Lower	Upper					Lower	Upper		
Clean water (%)	-0.730	0.085	-0.908	-0.553	<0.001	1.928	-0.021	0.017	-0.056	0.014	0.225	1.066	-0.048	0.008	-0.065	-0.030	<0.001	1.041
Low birth weight (%)	1.938	0.318	1.279	2.596	<0.001	1.086	0.321	0.087	0.144	0.498	0.001	1.002	0.210	0.043	0.121	0.299	<0.001	1.006
Skilled attendance at birth (%)	-0.027	0.106	-0.250	0.197	0.806	1.238	-0.076	0.025	-0.126	-0.026	0.004	1.002	-0.032	0.012	-0.057	-0.007	0.014	1.039
Intimate-partner violence (%)	0.554	0.210	0.118	0.990	0.015	1.570	0.010	0.078	-0.150	0.170	0.897	2.446	0.033	0.029	-0.028	0.093	0.276	1.615
All-abortion hospitalisation ratio (Per 100 live births)	-0.566	0.271	-1.129	-0.003	0.049	2.288	-0.010	0.080	-0.176	0.156	0.901	2.107	-0.020	0.036	-0.095	0.055	0.580	2.056
Constitutional amendment (Yes)	-0.312	1.172	-2.765	2.141	0.793	1.136	0.316	0.295	-0.289	0.921	0.294	1.031	0.112	0.148	-0.194	0.418	0.457	1.032
Abortion legislation (less permissive)	1.745	1.361	-1.095	4.585	0.215	1.625	-0.085	0.335	-0.773	0.604	0.803	1.269	-0.158	0.163	-0.496	0.180	0.344	1.266
Contraceptive use (%)	0.167	0.150	-0.144	0.479	0.276	2.756	-0.007	0.037	-0.083	0.068	0.843	2.160	0.009	0.024	-0.042	0.059	0.723	3.798
R-square for model	0.886†						0.420†						0.700†					
Sanitation (%)	-0.758	0.127	-1.019	-0.497	<0.001	1.001	-0.032	0.020	-0.072	0.009	0.121	1.002	-0.052	0.011	-0.075	-0.029	<0.001	1.000
Low birth weight (%)	2.166	0.528	1.082	3.249	<0.001	1.001	0.321	0.087	0.144	0.498	0.001	1.002	0.169	0.048	0.070	0.268	0.002	1.003
Skilled attendance at birth (%)	-0.248	0.154	-0.565	0.069	0.120	1.008	-0.076	0.025	-0.126	-0.026	0.004	1.002	-0.044	0.014	-0.072	-0.016	0.004	1.003
Intimate-partner violence (%)	0.238	0.337	-0.457	0.933	0.487	1.490	0.023	0.078	-0.137	0.183	0.772	2.494	0.055	0.031	-0.010	0.119	0.092	1.592
All-abortion hospitalisation ratio (per 100 live births)	-0.410	0.518	-1.485	0.665	0.438	2.903	0.019	0.090	-0.167	0.205	0.835	2.693	-0.005	0.046	-0.101	0.091	0.920	2.605
Constitutional amendment (Yes)	0.660	1.958	-3.412	4.732	0.739	1.175	0.232	0.292	-0.368	0.831	0.434	1.026	0.090	0.166	-0.254	0.434	0.593	1.083
Abortion legislation (less permissive)	-3.148	1.875	-7.010	0.714	0.106	1.164	-0.104	0.322	-0.767	0.558	0.749	1.194	-0.192	0.172	-0.546	0.163	0.276	1.206
Contraceptive use (%)	-0.241	0.239	-0.737	0.254	0.324	2.671	-0.005	0.033	-0.072	0.062	0.873	1.743	-0.011	0.022	-0.058	0.036	0.632	2.898
R-square for model	0.640†						0.420†						0.593†					
Female literacy (%)	-1.013	0.218	-1.463	-0.563	<0.001	1.876	-0.125	0.029	-0.184	-0.066	<0,001	2.043	-0.029	0.029	-0.089	0.030	0.321	1.833
Low birth weight (%)	1.260	0.446	0.339	2.180	0.009	1.127	0.271	0.064	0.138	0.404	<0,001	1.096	0.197	0.064	0.067	0.327	0.004	1.015
Skilled attendance at birth (%)	0.004	0.158	-0.326	0.335	0.978	1.223	-0.064	0.018	-0.102	-0.027	0.002	1.031	-0.023	0.018	-0.060	0.013	0.200	1.037
Intimate-partner violence (%)	0.247	0.371	-0.521	1.016	0.511	2.419	0.012	0.055	-0.101	0.125	0.828	2.416	0.075	0.051	-0.029	0.179	0.152	2.239
All-abortion hospitalisation ratio (per 100 live births)	-0.962	0.352	-1.689	-0.236	0.012	1.779	-0.016	0.051	-0.121	0.089	0.755	1.961	0.011	0.053	-0.099	0.121	0.834	2.021
Constitutional amendment (Yes)	1.195	1.563	-2.037	4.428	0.452	1.076	0.235	0.209	-0.198	0.667	0.273	1.046	-0.172	0.215	-0.614	0.270	0.430	1.056
Abortion legislation (less permissive)	-0.226	1.972	-4.327	3.875	0.910	1.597	-0.053	0.293	-0.663	0.557	0.858	1.796	0.060	0.287	-0.534	0.653	0.837	1.722
TFR	-14.329	4.158	-22.911	-5.747	0.002	1.728	-1.750	0.606	-3.001	-0.500	0.008	2.143	1.383	0.434	0.495	2.270	0.003	1.015
R-square for model	0.714†						0.666†						0.335†					

CI, confidence interval; iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome; SE, standard error; TFR, average total fertility rate between 2002-2011; VIF, variance inflation factor.
†*p*<0.001

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DISCUSSION

Diversity of abortion legislation in different regions, countries, and territories may partially reflect different cultural values and attitudes towards motherhood, childhood, the unborn, and abortion itself.[22,41,43-47] Theoretically, in Mexican states exhibiting less permissive legislation, maternal mortality should have been higher because the practice of unsafe abortion should be more frequent.[19-22] Paradoxically, over a 10-year period, those states almost univocally exhibited lower figures for MMR, MMR_{AO}, and iAMR. Nevertheless, after an exhaustive analysis adjusting for multiple confounders, the initial estimated effects for all mortality outcomes were explained by differences in other independent factors known to influence maternal health rather than by abortion legislation itself. In fact, most of the independent variables considered in the present study were more favourably distributed in the group of states with less permissive legislation in a weighted comparative analysis (Table 9). Consequently, making a direct or independent causal link between a less permissive abortion law and a lower incidence of maternal deaths –or conversely by considering a more permissive abortion law– would be a premature or even erroneous conclusion. Rather, from an epidemiological perspective, the Mexican natural experiment provides evidence to support three complementary assumptions at the population level: first, abortion legislation *per se* did not appear to have an independent effect on overall maternal mortality rates; second, a less permissive abortion law, in terms of not considering exemptions from criminal prosecution of abortion in cases of genetic or congenital foetal anomalies, was not associated with increased maternal and abortion-related deaths; and third, differences in maternal mortality incidence in the context of different abortion legislation (more or less permissive), appear mainly explained by the distribution of other major independent factors likely facilitating an epidemiologic transition toward low maternal mortality rates independently from abortion legislation itself.

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Table 9 Comparison of different indicators of maternal healthcare and human development between groups of states with less and more permissive abortion legislation

Variable	Less permissive states (n=18)	More permissive states (n=14)	Rate ratio†	*p* value
Clean water§, %	91.9	85.6	1.07	< 0.001‡
Sanitation§, %	91.3	87.0	1.05	< 0.001‡
Total Fertility Rate (TFR)	2.4	2.3	¶	0.781¶¶
Contraceptive use††, %	72.3	73.3	0.99	< 0.001‡
Skilled attendance at birth‡‡, %	91.4	90.3	1.01	< 0.001‡
Low birth weight‡‡, %	8.1	9.6	0.84	< 0.001‡
Female literacy§§, %	93.3	89.3	1.05	< 0.001‡
All-abortion hospitalisation ratio‡‡, per 100 live births	7.6	6.1	1.25	< 0.001‡
Intimate-partner violence§§, %	11.1	11.9	0.93	< 0.001‡

§Proportions were weighted using specific denominator of exposed populations for each state.
††Proportions were weighted using specific denominator of exposed female populations ages 15-49 for each state.
‡‡Proportions and ratio were weighted using specific denominator of observed live births in each state.
§§Proportions were weighted using specific denominator of exposed female populations ages 15 and above for each state.
†*Z*-test rate ratio
‡*Z*-test *p* value
¶ Not applicable
¶¶ *t*-test *p* value

On the other hand, whether state constitutional amendments protecting the unborn translate into higher or lower maternal mortality rates has not yet been explored. Theoretically, these states might be culturally more reluctant to accept changes in abortion legislation,[22,43,45,46] and therefore, maternal deaths might be higher, particularly if practice of unsafe abortions is frequent.[21,47] At least in the short-term, this natural experiment found no evidence of any detrimental impact on maternal mortality outcomes related to constitutional amendments protecting the unborn. Some differences were noted between groups of states with and without amendments between 2008 and 2011, *i.e.* lower average iAMR and lower average proportion of abortion-related deaths in the group of states with amendments compared with the group without amendments. Nevertheless, in multivariate models these differences appeared to be explained by other independent factors distributed more favourably in the group of states with less permissive legislation but unrelated to constitutional amendment.

Interestingly, between 2008 and 2011, the Federal District displayed higher MMR and MMR_{AO} than the group of states with the constitutional amendment, when the outcome was measured by

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place of occurrence, but not by place of residence. Indeed, when mortality ratios by occurrence or residence are compared state-by-state, the Federal District showed the highest difference in maternal mortality outcomes (*e.g.,* 61.9 *vs* 48.7 for MMR per 100,000 live births, respectively). From an epidemiological perspective, such disparities often reflect a pattern of temporary mobility among the population.[48] Similarly, the difference in iAMR and the proportion of abortion-related deaths by place of occurrence between states with and without amendment was abolished when the Federal District was removed from the latter group. Thus, inter-state mobility into the Federal District appears to be associated with an increased risk of maternal mortality for pregnant women arriving from other states. Determinants of this phenomenon are largely unknown and warrant further research.

Multivariate regression in both primary and alternative models (refined or unrefined) revealed that a combination of factors related to maternal healthcare, reproductive behaviour, access to clean water, sanitation, female literacy, and intimate-partner violence against women explained 51% to 88% of the variance among states in overall maternal mortality rates. Proportional contributions of each variable explaining the variance of maternal mortality outcomes analysed among Mexican states are summarized in Figure 8. These percentages also represent the potential impact of addressing each factor individually to decrease mortality ratios in Mexico. Box 1 summarises public health interventions based on the results of the present study to improve maternal health in this country.

Box 1 Evidence-based public health interventions to improve maternal health in Mexico

- Increase access to antenatal care and coverage of institutional deliveries.
- Increase number of and access to emergency obstetric units.
- Expand specialised diagnostic centres and prenatal care for high-risk pregnancies, with incorporation of other medical specialties.
- Increase access to adequate pre-conception counselling and family planning programs to promote healthy childbearing before 35 years of age and to prevent unplanned pregnancies.
- Strenghten public policies directed to increase the number of schooling years of the female population.
- Improve detection of violence against pregnant women during prenatal visits and intervention by skilled health professionals.
- Address disparities in human development indicators by increasing access to clean water and sanitation coverage

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Regarding maternal healthcare, three factors resulted independently associated to maternal mortality outcomes. First, consistent with the general consensus,[3,6,8-10,49,50,51] skilled attendance at birth showed an inverse relationship with mortality ratios: for each 1% increase in skilled attendance at birth, decreases of 0.42 in MMR (Table S16, Supplementary Material), 0.06 in MMR_{AO}, and 0.05 in iAMR per 100,000 live births were estimated. This factor –ranging from 75% to 99% among states (Table 5)– likely reflects important disparities in access to antenatal care and institutional deliveries.[4,5,50,51] Second, all-abortion hospitalisation ratio showed an inverse relationship with MMR in refined explanatory models. For each incremental unit of this variable, a decrease of 0.8 maternal deaths per 100,000 live births was estimated among states. This inverse relationship has been previously identified as an indicator of improved access to emergency obstetric units, specialised obstetric and post-abortion care.[27,30,52,53,54] In contrast, a direct relationship between all-abortion hospitalisation ratio and MMR may indicate high rates of in-hospital deaths secondary to obstetric complications or alternatively, that an important number of unsafe abortions are being conducted (Table 5).[27,30,54-57] This second interpretation seems not to be the case in Mexico. Finally, low birth weight rate showed strong direct associations with all mortality ratios in multivariate models: for each 1% increase in low birth weight, increases of 1.6 in MMR, 0.3 in MMR_{AO}, and 0.1 in iAMR per 100,000 live births were estimated, explaining from 15.1% to 40.2% of the variance among states. An association between low birth weight and mortality ratios may be explained by the fact that low birth weight and pre-term birth are *proxies* for adverse pregnancy outcomes related to a series of antecedent individual risk factors and medical conditions, such as advanced maternal age, poor nutrition, infections, preeclampsia, placental abnormalities, cervical incompetence, cardiovascular conditions, pre-existing chronic diseases, drug addiction, adverse social situation, alcohol abuse, insufficient prenatal care, and a gynaecological history of previous termination of pregnancy.[58,59,60,61,62] Taking into consideration the wide disparity in low birth weight rates among states (from 5.4% to 14.0%), individual-level risk factors likely make a major contribution

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to current maternal mortality rates in Mexico. This suggests the need for an expansion of emergency obstetric units, specialised diagnostic centres and prenatal care for high-risk pregnancies, and the incorporation of other medical specialities, which in turn may favourably impact maternal health.[4,7,30,63-65]

Reproductive behaviour is another factor likely influencing maternal health. In this study, two variables were considered as *proxies* of the reproductive behaviour: contraceptive use and the average TFR between 2002 and 2011 for each state (Table 5).[10,30,66,67,68,69] This study provided little evidence that contraceptive use exerts an independent primary influence on maternal mortality differences among Mexican states over the last decade. Nevertheless, alternative multivariate models considering TFR instead of contraceptive use revealed two opposite effects of TFR on mortality ratios: while displaying an inverse relationship with MMR and MMR_{AO}, TFR showed a direct association with iAMR, explaining 17.2% of the difference in abortion-related mortality among states. The direct association of TFR with iAMR may be related to an increased number of unplanned pregnancies terminated with abortion. In contrast, the inverse association between TFR and MMR or MMR_{AO} is more difficult to interpret. Simple direct correlations between TFR and MMR across multiple countries support the common notion that decreasing fertility reduces maternal mortality by reducing a woman's exposure to pregnancy during her reproductive lifetime.[10,66,67,70] However, results from recent studies show that the relationship between TFR and maternal mortality is much more complex and may vary from one country to another.[30,65,71,72] A plausible mechanism to explain an inverse correlation between TFR and maternal mortality has been referred to as the "fertility paradox" emerging in advanced stages of demographic transition, when TFR falls under 2.5.[30] While early stages of fertility reduction would be associated with a decreased number of children per woman without a substantial delay of motherhood, later stages of fertility reduction appear to be primarily associated with delayed motherhood.[30,40,63,65,72,73] The net effect of this change would be an increase in pregnancies among women over 35 years old, which in turn increases the risk of complications and mortality from non-obstetric pre-existing medical conditions such as

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hypertension, diabetes, renal disease, and obesity, as well as obstetric conditions such as gestational hypertension, pre-eclampsia, gestational diabetes, postpartum haemorrhage, recurrent miscarriage, caesarean section, and indirect causes.[40,65,71-77] A recent study in Mexico showed that over 75% of maternal deaths are related to these causes.[37] Considering a TFR of 2.3 for this country in 2011, a fertility paradox phenomenon may be underlying the inverse correlations between TFR and MMR or MMR_{AO} observed in this study. Access to adequate pre-conception counselling and family planning programs to promote healthy childbearing before 35 years of age may be useful for addressing the problem of an excessively delayed motherhood, in addition to preventing unplanned pregnancies.

Alternative multivariate models identified clean water and sanitation as variables influencing maternal and abortion-related mortality in Mexican states. These findings are consistent with the association of such environmental risk factors with maternal mortality.[30,78,79] A recent systematic review and meta-analysis proposed plausible mechanisms to explain this association:[79] first, poor hygiene conditions may lead to sepsis during childbirth, one of the main causes of maternal deaths worldwide.[78] Second, exposure to poor water and sanitation increases the likelihood of repeated water-borne infections, which may lead to long-term detrimental effects on the female population of fertile age.[79] Considering current disparities among Mexican states in the access to clean water and sanitation (ranging from 62.0% to 99.2%), this study's findings highlight the potential positive impact of these basic elements of human development to continue improving maternal health in Mexico and other developing countries.

The present study found that female literacy was a major variable influencing all mortality outcomes studied, explaining between 11.9% and 50.9% of the variance among Mexican states. For each 1% increase in female literacy, decreases of 1.1 in MMR, 0.07 in MMR_{AO}, and 0.12 in iAMR per 100,000 live births were estimated. The gap in female literacy among states, ranging from 77.5% to 96.5%, suggests that public programmes directed to increase women's education

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level may have a positive impact on maternal health in Mexico. In addition to a direct impact on maternal mortality,[10,30,80,81,82] women's education is correlated with other major predictors of maternal health, such as skilled attendance at birth,[30,83,84] access to antenatal care,[3-5] fertility rate,[10,30,85] family planning,[86] and contraceptive use.[87,88] Since education is likely to indicate early life circumstances and future socioeconomic outcomes,[89-91] women's education level may represent an antecedent variable impacting the reproductive behaviour, use of maternal health facilities and family planning programs, and access to improved sanitation.[30] Furthermore, because women's literacy can explain territorial differences in maternal mortality, predictive models of MMR considering differences in women's education level[10] are likely to be more precise than models neglecting to consider education,[12,68] as a recent comparative analysis suggests.[92]

Finally, intimate-partner violence against women over the last year was identified as an additional factor influencing maternal and induced abortion-related mortality. For each 1% increase in intimate-partner violence, increases of 0.8 in MMR and 0.1 in iAMR per 100,000 live births were estimated, explaining 2.8% and 7.2% of the variance among Mexican states, respectively. An association between intimate-partner violence [93,94] and several detrimental maternal outcomes such as antenatal haemorrhage,[95] vaginal bleeding,[96] antenatal hospitalisation,[96] caesarean section,[96] pre-term birth,[96] miscarriages,[97] pregnancy termination,[97,98] repeated abortion,[99] perinatal death,[95] femicide,[100] and poor mental health outcomes,[101] including suicide attempt,[102] has been previously described. In addition, because sexual coercion[103-106] and abuse[93] have been identified as strong predictors of induced abortion, these factors may influence MMR and iAMR, which warrants further research. Recent reports suggest that detection of violence against pregnant women during prenatal visits[107,108] and subsequent interventions by skilled health professionals may improve maternal outcomes.[109,110] Given the current statistics of intimate-partner violence against women observed in Mexican states (ranging from 6.3% in Oaxaca to 20.9% in the Federal District), such interventions may contribute to improve maternal health.

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Limitations

Paraphrasing Geoffrey Rose,[111] epidemiological research traditionally distinguishes two kinds of etiological questions. For instance, the question “Why do some pregnant women die from abortion or gestational hypertension and others do not?” is different from “Why do some populations exhibit more deaths of pregnant women because of abortion or gestational hypertension?” While the first question asks for the causes of “cases” at the individual level, the second asks for the causes of “incidence” at the population level; consequently, to answer these questions, different kinds of epidemiological studies are required. In this context, the examination of current abortion laws in 32 Mexican states provided an interesting natural experiment to assess whether more or less permissive legislation were associated to lower or higher incidences of maternal and abortion-related deaths, simultaneously controlling for multiple confounders at the population level. However, this study – based on aggregated data – cannot conclusively rule out the influence of different factors impacting maternal health to an individual level of analysis and therefore, an ecological fallacy,[112,113] should be avoided. In contrast, an individualistic fallacy[113,114] based on the “high-risk”[111] approach should also be avoided in the interpretation of these results.

A major limitation to evaluate the impact of abortion legislation in terms of permissiveness is the intra-state heterogeneity in criminal codes and the inability to randomly allocate population of individuals to univocally defined groups, apparently making the criterion to segregate into each group somewhat arbitrary. However, after thorough exploratory analyses considering both the number and the type of legal exemptions for the criminal prosecution of abortion, only the exemption of prosecution of abortion in cases of genetic or congenital foetal malformations in their criminal codes was found to provide clear differences in mortality outcomes. In the case of Mexican states, this criminal exemption hinges on the opinion of a physician stating that there are sufficient reasons to think that such alterations would result in an individual with serious physical

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or mental deficiencies.[38] Thus, this exemption would not contemplate criminal prosecution for an induced abortion in extreme cases of foetal malformation, such as holoprosencephaly (a failure to develop two cerebral hemispheres, lethal *in utero* or shortly after birth), or less extreme conditions, such as Down syndrome (trisomy of chromosome 21, characterized by survival into adulthood). In addition, it is reasonable to think that the presence or absence of this exemption, may reflect different cultural values and attitudes toward abortion itself.

This study relies on official sources of data for mortality outcomes, live births and covariates. Errors such as underreported deaths cannot be definitively ruled out. However, minimal errors are expected since 2002 because of the strengthening of the epidemiological surveillance system that year, incorporating maternal deaths audits to identify misclassifications and minimising underreport.[115] For instance, in a 2009 audit of maternal deaths conducted in Mexico identifying causes of deaths during the influenza A H1N1 epidemic, authors were able to distinguish subcategories of causes of deaths, including complications of spontaneous abortion, induced abortion, and unspecified abortion.[116] On the other hand, instrumental bias because of different methodologies used to assess the same variable in different populations is a frequent problem in studies of multiple populations. Nevertheless, each independent variable used for this study was compiled with a single instrument applied in all Mexican states, making instrumental bias unlikely.

A problem in countries with legal restrictions for pregnancy termination is the difficulty to obtain counts and rates of illegal abortions. Nevertheless, the problem of underreporting of illegal abortions does not translate necessarily to underreporting of deaths from complications of illegal procedures when specific codes of the ICD-10 are in use. Recent studies in Mexico [37] and Chile [117] suggest that both mortality and morbidity from complications of illegal abortions, or abortions without a known cause are registered using specific codes O05, O06 and O07 to differentiate them from complications of other types of abortions with a well-known cause. Consequently, these specific codes were considered for the construction of iAMR in the present

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study. Another concern is the possibility of misreporting or misclassification of deaths from induced abortion as deaths for other causes, for example, haemorrhage or sepsis. However, in Mexico this seems unlikely because of the maternal mortality audit discussed above and the parallel decreasing trend in overall maternal mortality observed in the present study. For instance, deaths from haemorrhage have decreased 17% between 2002 (10.6 deaths per 100,000 live births) and 2011 (8.8 per 100,000 live births). In addition, there is no reason to misreport deaths from a suspected illegal abortion considering the use of ICD10 codes O05, O06 and O07. Thus, iAMR appears to be an indicator that provides a reasonable method to circumvent the problem of underreporting of maternal deaths from complications of illegal procedures in subsequent epidemiological studies in Latin America.

Finally, although most variables, including those for abortion legislation, showed significant correlations with maternal mortality outcomes in Mexico, this study emphasises the importance of multivariate analyses correcting for multicollinearity between covariates and the presence of outliers on mortality outcomes. For instance, because it is not possible to completely separate statistical effect sizes of highly correlated terms in multiple regression equations, separate alternative analyses are required. In addition to seeking unbiased effect sizes for significant predictors, any statistical association requires a plausible mechanism before making causal inferences at the population level.

CONCLUSION

This population-based natural experiment, using virtually complete official vital statistics of live births and maternal deaths in 32 Mexican states between 2002 and 2011, showed that maternal and abortion-related mortality ratios were lower in states with less permissive abortion legislation compared to states with more permissive legislation. Nevertheless, the observed differences between populations were not attributable to abortion legislation by itself. In fact, exhaustive multivariate analyses showed that these differences were largely explained by other factors such

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as women's literacy, maternal healthcare, water, sanitation, fertility rate and violence against women. These findings suggest that favourably addressing disparities in these factors may facilitate an epidemiologic transition toward low maternal mortality rates in developing countries during the post-MDG agenda.

FOOTNOTES

*MMR is the quotient between the number of deaths from conditions related to or aggravated by pregnancy, childbirth or puerperium, and the number of live births during the same period of time. For purposes of comparison, this ratio is usually amplified by 10,000 or 100,000 observed live births.

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CONTRIBUTORS

EK was the leading author. EK and MC conceptualized the study. EK, MC, FP, JS, and SH contributed to the study design. MB, FP, SH, and SG were directly involved in the acquisition of data. SG reviewed abortion legislation for each state with the advice of FP, SH, and PA. EK, MC, PA, and MB had the main responsibility for data analysis and FP, JS, SH, BC, SG, and JT had full access to data, including results of statistical analyses. EK, MC, PA, MB, and SG drafted the

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manuscript, and FP, JS, SH, BC, and JT reviewed and commented on drafts and approved the final manuscript. EK is the guarantor of the study, accepts full responsibility for the research, had access to the data, and controlled the decision to publish.

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COMPETING INTERESTS

None.

ETHICS APPROVAL, DATA SHARING AND TRANSPARENCY

Ethical approval: The study did not require any ethics committee approval.

Transparency: As guarantor of the study, EK assures that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Data sharing: All datasets employed are included in the supplementary material. Any additional information can be requested to the corresponding author at ekoch@melisainstitute.org

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FIGURE LEGENDS

Figure 1. Mortality ratios and the proportion of abortion-related deaths by place of residence in states with less and more permissive abortion legislation. Left panels illustrate trends in MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of residence between 2002 and 2011 in Mexican states, grouped as with less permissive (in dark green) or more permissive (in cyan) in terms of abortion legislation in their criminal code (see Material and Methods). For comparison, trends for the whole Mexican country (all states) are depicted as dotted lines. Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively), and the whole Mexican country (hollow bars).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with an abortive outcome.

Figure 2. Mortality ratios and the proportion of abortion-related deaths by place of occurrence in states with less and more permissive abortion legislation. Left panels illustrate trends in MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of occurrence between 2002 and 2011 in Mexican states, grouped as with less permissive (in dark green) or more permissive (in cyan) in terms of abortion legislation in their criminal code (see Material and Methods). For comparison, trends for the whole Mexican country (all states) are depicted as dotted lines. Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively), and the whole Mexican country (hollow bars).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

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Figure 3. Average mortality ratios in states with more or less permissive abortion legislation between 2002 and 2011. Political maps of Mexican states are shown for average MMR (top panel) and average iAMR (bottom panel) for the 2002-2011 period, indicating whether they exhibit less (orange dots) or more (yellow dots) permissive abortion legislation, in terms of abortion legislation in their criminal code (see Material and Methods). Increasing blue colour indicates an increase in MMR or iAMR, on a quintile scale (see legend of each panel).
Abbreviations: Ag., Aguascalientes; Co., Colima; FD., Federal District; iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; Mo., Morelos; Tl., Tlaxcala.

Figure 4. Mortality ratios and the proportion of abortion-related deaths by place of residence in states with or without a constitutional amendment to protect the unborn starting at conception. Left panels illustrate trends for MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of residence between 2008 and 2011 in Mexican states, grouped as with amendment (in dark green) or without amendment (in cyan) in terms of abortion legislation in their criminal code (see Material and Methods). Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively).
* $p<0.05$ using *Z*-test.
Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

Figure 5. Mortality ratios and the proportion of abortion-related deaths by place of occurrence in states with or without a constitutional amendment to protect the unborn starting at conception. Left panels illustrate trends for MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of occurrence between 2008 and 2011 in Mexican states, grouped as with amendment (in dark green) or without amendment (in cyan) in terms of exhibiting or not a constitutional amendment to protect the unborn starting at conception (Figure S1, Supplementary Material).

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Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

Figure 6. Mortality ratios and the proportion of abortion-related deaths by place of residence in states with or without a constitutional amendment to protect the unborn starting at conception: focus on the Federal District. Left panels illustrate trends for MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of residence between 2008 and 2011 in Mexican states, grouped as with amendment" (in dark green), without amendment (in cyan), and the Federal District (in green) in terms of exhibiting or not an constitutional amendment (the Federal District of Mexico was not included in this group to be illustrated separately) to protect the unborn starting at conception (Figure S1, Supplementary Material). Right panels show average ratios and proportion of abortion-related deaths for each group (dark green, cyan, and green bars, respectively).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

Figure 7. Mortality ratios and the proportion of abortion-related deaths by place of occurrence in states with or without constitutional amendment to protect the unborn starting at conception: focus on the Federal District. Left panels illustrate trends for MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of occurrence between 2008 and 2011 in Mexican states, grouped as with amendment (in dark green), without amendment (in cyan), and the Federal District (in green) in terms of exhibiting or not a constitutional amendment (the Federal District of

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Mexico was not included in this group to be illustrated separately) to protect the unborn starting at conception (Figure S1, Supplementary Material). Right panels show average ratios and proportion of abortion-related deaths for each group (dark green, cyan, and green bars, respectively).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

Figure 8. Proportional contribution of independent variables to observed differences in maternal mortality outcomes among Mexican states in primary and alternative multivariate regression models.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

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Abortion legislation, maternal healthcare, fertility, female literacy, sanitation, violence against women, and maternal deaths: a natural experiment in 32 Mexican states

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ABSTRACT

Objective: To test whether there is an association between abortion legislation and maternal mortality outcomes after controlling for other factors thought to influence maternal health.

Design: Population-based natural experiment.

Setting and data sources: Official maternal mortality data from 32 federal states of Mexico between 2002 and 2011.

Main outcomes: Maternal mortality ratio (MMR), MMR with any abortive outcome (MMR_{AO}), and induced abortion mortality ratio (iAMR).

Independent variables: Abortion legislation grouped as less (n=18) or more permissive (n=14); constitutional amendment protecting the unborn (n=17); skilled attendance at birth; all-abortion hospitalisation ratio; low birth weight rate; contraceptive use; total fertility rates (TFR); clean water; sanitation; female literacy rate and intimate-partner violence.

Main results: Over the 10-year period, states with less permissive abortion legislation exhibited lower MMR (38.3 vs 49.6; $p<0.001$), MMR_{AO} (2.7 vs 3.7; $p<0.001$), and iAMR (0.9 vs 1.7; $p<0.001$), than more permissive states. Multivariate regression models estimating effect sizes (ß-coefficients) for mortality outcomes showed independent associations (*p-values* between 0.001 and 0.055) with female literacy (ß= -0.061 to -1.100), skilled attendance at birth (ß= -0.032 to -0.427), low birth weight (ß= 0.149 to 2.166), all-abortion hospitalisation ratio (ß= -0.566 to -0.962), clean water (ß= -0.048 to -0.730), sanitation (ß= –0.052 to -0.758), and intimate-partner violence (ß= 0.085 to 0.755). TFR showed inverse association with MMR (ß= -14.329) and MMR_{AO} (ß= -1.750) and a direct association with iAMR (ß=1.383). Altogether, these factors accounted for (R^2) 51% to 88% of the variance among states in overall mortality rates. No statistically independent effect was observed for abortion legislation, constitutional amendment, or other covariates.

Conclusion: Although less permissive states exhibited consistently lower maternal mortality rates, this finding was not explained by abortion legislation itself. Rather, these differences were explained by other independent factors, which appeared to have a more favourable distribution in these states.

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STRENGHTS AND LIMITATIONS

- To the best of our knowledge, this is the first population-based natural experiment analysing the impact of less or more permissive abortion legislation on maternal mortality outcomes in Mexico, simultaneously controlling by 10 variables thought to influence maternal health at the population level.

- In this study, relying on virtually complete, official vital statistics data, Mexican states with less permissive abortion legislation displayed lower maternal and abortion mortality ratios than states with more permissive legislation during a 10-year study period. Nevertheless, observed differences among populations were not attributable to abortion legislation by itself.

-In comparison to states with more permissive abortion legislation, those with less permissive legislation showed a more favourable profile in several indicators related to maternal healthcare and human development.

- Exhaustive multivariate analyses showed that observed differences in maternal mortality outcomes among states were largely explained by a combination of variables related to maternal healthcare, fertility, female literacy, intimate-partner violence against women, and sanitation.

- After controlling for confounders, no evidence of deleterious or beneficial effect was found for the presence of constitutional amendments protecting the unborn over a 4-year study period.

- Although inter-state diversity of abortion legislation in terms of permissiveness provided the opportunity to assess its impact on mortality outcomes, intra-state heterogeneity of exemptions from criminal prosecution hampered the allocation of population of individuals to groups univocally defined as less or more permissive. Nevertheless, the exemption of criminal prosecution of abortion on the grounds of genetic or congenital foetal malformations was found to provide clear differences in mortality outcomes.

- Because this study is based on aggregated data, the effect of analysed variables at the individual level cannot be ruled out.

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INTRODUCTION

Promoting maternal health has been a key concern for public health policy makers worldwide, particularly since the United Nations (UN) put forth the Millennium Development Goals (MDGs).[1] As part of the fifth MDG, which focused on improving maternal health, the UN requested all member states to decrease their maternal mortality ratio (MMR)* by 75% by 2015.[2]

Most causes of maternal mortality are preventable, and improved access to antenatal care,[3-5] as well as maternal health facilities equipped with emergency obstetric units,[3,4,6,7] and skilled attendance at childbirth[3,6,8-10] are acknowledged public health interventions that have led to the decrease in maternal mortality worldwide. However, one year away from the 2015 deadline for the MDGs, the MMR has decreased less than 50% globally,[10-12] suggesting that measures taken to address maternal mortality may have been insufficient.[11,13,14] In this regard, although novel complementary public health or social interventions have been encouraged in support of the post-MDG agenda,[13,14] these ought to be supported by data and evidence, for example, population-based natural experiments.[15-17]

It has been proposed that the legal status of abortion, defined as pregnancy termination by removal or expulsion of the foetus, is a factor that influences maternal health in a region, country, or territory.[18,19] There is a widespread perception that less permissive legislation, i.e. legislation that restricts or prohibits pregnancy termination (note that “abortion” or “pregnancy termination” are terms used interchangeably throughout this study) leads to increased maternal mortality due to complications of clandestine, or illegal, or unsafe abortions.[20-22] Accordingly, it has also been suggested that more permissive abortion legislation would lead to a reduction in maternal deaths.[19-21] However, conflicting results have been recently reported in the literature.[10,12,18,23-29] For instance, evidence from settings with less permissive abortion legislation[28,26,29-31] suggests that other factors, such as increasing level of women’s education, complimentary nutrition programmes for poor pregnant women, availability of maternal

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healthcare facilities, emergency obstetric units, changes in reproductive behaviour with increased family planning, and access to clean water and sanitation, may facilitate an epidemiologic transition towards low maternal mortality rates in the absence of more permissive abortion legislation.[30] However, this hypothesis remains to be tested or replicated at the population level in different epidemiological scenarios.

The United Mexican States (Mexico) is a federal republic comprising 32 federal territories (31 states and the Federal District, referred to as “states” henceforth), whose population shares a common history and culture. The Mexican healthcare system reached virtually universal coverage over the past century, assuring equality in access to basic healthcare for most of the population.[32] Each state has its own political constitution, criminal code, and abortion legislation. Moreover, while the Federal District passed a law allowing pregnancy termination on demand during the first trimester of pregnancy, several states have modified their constitutions in the opposite direction, strengthening the protection of the unborn starting at conception.[22] Thus, Mexico offers a unique epidemiological scenario to test whether more or less permissive abortion legislation affects maternal mortality in a population that shares the same history and culture, and which has a homogeneous healthcare system.

This study presents the results of a population-based natural experiment examining factors associated with maternal mortality in the 32 Mexican states during a period spanning 10 years (2002-2011). It analyses trends in maternal and abortion-related mortality according to differences in abortion legislation, controlling for a number of factors thought to influence maternal mortality rates.

MATERIALS AND METHODS

Population data

Official records of maternal deaths and observed live births occurring within the United Mexican States were extracted from the General Directorate of Health Information (DGIS)[33] and the

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National Institute of Statistics, Geography, and Informatics (INEGI)[34] respectively, for every state by place of residence (state where the individual used to dwell) and place of occurrence (state where the vital event took place), between 2002 and 2011 (10-year continuous period). Civil registration of vital statistics in Mexico follows international standards, has been regarded as virtually complete by the World Health Organization, and has been included in List A –with good attribution of causes of death– along with 64 other countries.[12] Since 2002, Mexico has strengthened its active epidemiological surveillance system (Intentional Search and Reclassification of Maternal Deaths)[35] to correctly code maternal deaths that were initially not recognised as maternal, and to reclassify maternal deaths with erroneously attributed codes throughout the entire territory. Because this surveillance increased data reliability, 2002 was selected as the initial year for the study.

Classification of maternal deaths

Maternal deaths were identified using the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10)[36] and were classified by place of residence or occurrence. Mortality ratios were directly calculated as the quotient between maternal deaths and observed live births. Three epidemiological indicators were calculated according to the classification proposed in a recent review.[37] The first indicator is maternal mortality ratio (MMR), which considers all maternal death codes (ICD-10 codes O00-O99, A34, B20-B24, and F53) and is often referred to as overall maternal mortality. The second indicator is maternal mortality ratio with any abortive outcome (MMR_{AO}), which considers maternal death classified following ICD-10 codes O00-O08. The third indicator is termed induced abortion mortality ratio (iAMR), which focuses only on deaths likely associated with complications of pregnancy termination.[37] Specific characteristics of this indicator allows to circumvent the problem of underreporting of deaths from illegal abortions in countries where legal restrictions hamper the assessment of induced abortion counts and rates. First, it includes the code for medical abortion [ICD-10 code O04], which is used for the classification of deaths due to legal termination of pregnancy. Second, it also includes codes for other abortion [ICD-10 code O05], unspecified abortion [ICD-10 code O06],

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and failed attempted abortion [ICD-10 code O07], which are employed in Mexico and other Latin American countries for classifying deaths from induced abortion without a clear cause or when an illegal procedure is suspected. Finally, this indicator parsimoniously excludes deaths associated to well defined pathological conditions or complications that cannot be associated with a voluntary termination of pregnancy, such as ectopic pregnancy (ICD-10 code O00), hydatidiform mole (ICD-10 code O01), other abnormal products of conception (ICD-10 code O02), spontaneous abortion (ICD-10 code O03), and complications following abortion and ectopic and molar pregnancy (ICD-10 code O08).[37]

Abortion legislation

Criminal legislation for each state was reviewed and extracted from the National Office for the Judiciary of the Mexican government.[38] The revision of current criminal codes of each Mexican state is summarized in Table 1. In practical terms, all 32 states provide criminal exemptions from prosecution for abortions performed in case of rape, 29 states provide criminal exemptions in imprudent or accidental cases, 25 states provide exemptions when the life or health of the mother is at risk, 10 states do so in cases of artificial insemination without consent, 1 state for social causes, and 14 states in cases of genetic or congenital foetal conditions resulting in an individual with serious physical or mental deficiencies. In addition, in 2007 the Federal District passed a law allowing legal pregnancy termination on request up to the 12th week of pregnancy.[39] In exploratory analyses, segregating states by the number of exemptions provided in criminal codes did not result in detectable differences in sensitivity analyses, with the exception of abortion allowed by genetic or congenital foetal malformations. The remaining seven exemptions were distributed differentially, in almost every state or very few states, thus offering no discrimination potential. Therefore, to differentiate between states with more or less permissive abortion legislation in subsequent statistical analyses, states allowing pregnancy termination due to serious genetic or congenital conditions were considered more permissive (14 states), while the remaining states were considered less permissive (18 states).

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Table 1 Current abortion legislations based on criminal exemptions from prosecution of abortion in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation

	Rape	Imprudential conduct	Risk to the life of the mother	Genetic or congenital malformation	Serious risk to the health of the mother	Artificial insemination without consent	Economic or social reasons	On demand
Aguascalientes (l)	▯	▯	▯					
Baja California (l)	▯	▯	▯			▯		
Baja California Sur (m)	▯	▯	▯	▯	▯	▯		
Campeche (l)	▯	▯			▯			
Coahuila (m)	▯	▯	▯	▯				
Colima (m)	▯	▯	▯	▯		▯		
Chiapas (m)	▯		▯	▯				
Chihuahua (l)	▯	▯			▯	▯		
Distrito Federal (m)	▯	▯		▯	▯	▯		▯
Durango (l)	▯	▯	▯					
Guanajuato (l)	▯	▯						
Guerrero (m)	▯	▯		▯		▯		
Hidalgo (m)	▯	▯		▯	▯			
Jalisco (l)	▯	▯	▯		▯			
México (m)	▯	▯	▯	▯				
Michoacán (l)	▯	▯	▯		▯			
Morelos (m)	▯	▯	▯	▯		▯		
Nayarit (l)	▯	▯	▯		▯			
Nuevo León (l)	▯		▯		▯			
Oaxaca (m)	▯	▯	▯	▯				
Puebla (m)	▯	▯	▯	▯				
Querétaro (l)	▯	▯						
Quintana Roo (m)	▯	▯	▯	▯				
San Luis Potosí (l)	▯	▯	▯			▯		
Sinaloa (l)	▯	▯	▯					
Sonora (l)	▯	▯	▯					
Tabasco (l)	▯		▯			▯		
Tamaulipas (l)	▯	▯	▯		▯			
Tlaxcala (l)	▯	▯	▯		▯			
Veracruz (m)	▯	▯	▯	▯		▯		
Yucatán (m)	▯	▯	▯	▯			▯	
Zacatecas (l)	▯	▯	▯		▯			
Total	**32**	**29**	**25**	**14**	**12**	**10**	**1**	**1**

Official criminal legislation for each state were reviewed and extracted from the National Office for the Judiciary.[38]
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.

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Political constitution amendments

Data on amendments to the political constitution of each state were extracted from the National Office for the Judiciary of the Mexican government.[38] Specifically, constitutional amendments specifying an explicit protection of the unborn starting at conception were tracked in time and form by examining the political constitution of each state. A number of states amended their constitutions to this effect almost immediately after the legalization of pregnancy termination on request in the Federal District, in April of 2007.[39] These progressive changes required a dynamic allocation of states according to the date of enactment or derogation of the amendment during the 4-year period of analysis between 2008 and 2011 (Figure S1, Supplementary Material). In addition to the state of Chihuahua, which amended its constitution in 1994, 16 other states had enacted these amendments by the end of 2011. In subsequent statistical analysis, a direct comparison of maternal and abortion-related deaths was carried out between groups of states with amendment (17 states) and without an amendment (15 states). In addition, sub-analyses that discriminated maternal and abortion-related mortality between the Federal District and other states were also conducted.

Independent variables

Other independent variables considered were percentage of the population with access to clean water ("clean water"), sanitary sewer coverage ("sanitation"), average total fertility rate between 2002 and 2011 ("TFR"), percentage of contraceptive use by married or in-union female population of fertile age ("contraceptive use"), percentage of skilled attendance at birth ("skilled attendance at birth"), low birth weight rate ("low birth weight"), female literacy rate ("female literacy"), all-abortion hospitalisation ratio, and percentage of intimate-partner violence against married or in-union women over the last year ("intimate-partner violence"). Operational definitions, their significance for epidemiological studies (for subsequent interpretation), measurement scales, and data sources for these variables are detailed in Table S1 (Supplementary Material).

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Statistical analyses

Parallel time series were constructed between 2002 and 2011 for maternal deaths and registered live births according to abortion legislation. Trends for MMR, MMR_{AO}, and iAMR per 100,000 live births were directly calculated for every federal state and were evaluated over time by occurrence and residence using an autoregressive integrated moving average (ARIMA) model. The complete time series data used in this study are presented in Tables S2 through S15 (Supplementary Material). In each ARIMA model, the *β*-coefficient represents the average change per year of the mortality outcome and the *p* for trend indicates the statistical significance of the overall trend. Average mortality ratios over the total time period were also computed and directly matched using *Z*-test. The proportion (%) of induced abortion-related deaths (i.e., proportion of deaths due to pregnancy termination over the total number of maternal deaths) was also computed and comparatively analysed.

The Kolmogorov-Smirnov test was utilised to assess the normal distribution assumption. Multiple regression was used to estimate the effect size of independent variables on average mortality ratios (MMR, MMR_{AO}, and iAMR) and explain the variance among the 32 states controlling for other factors. Because of potential collinearity related to the high number of predictors, a Pearson correlation matrix was used to quantify the magnitude of bivariate linear associations among all independent variables. Pearson coefficients (r) ≥0.70 were considered to suggest collinearity. Exploratory models were conducted to assess collinearity using the variance inflation factor (VIF).[40] The covariates selected for inclusion in explanatory regression models were analysed using the backward stepwise elimination method based on *p*-values of 0.05 and 0.059 as criteria of entry and removal, respectively. *β*-coefficients with 95% confidence intervals were computed to assess the effect size of each predictor on the MMR, MMR_{AO}, and iAMR and the change in the R^2 was used to determine the final models with maximal goodness-of-fit, minimal number of explanatory variables, and minimal collinearity. To examine the stability of *β*-coefficients and obtain unbiased effect sizes, two panels of multivariate explanatory models were considered for

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each mortality outcome, based on diagnostic regression refinement of residual statistics, by eliminating the presence of outliers (higher than 2 standard deviations of predicted mortality outcome) when presented.

RESULTS

Abortion legislation and maternal mortality

During the 10-year study period there were 11,649 maternal deaths and 26,089,498 live births in Mexico, corresponding to a MMR of 44.7 per 100,000 live births. The MMR in 2002 was 48.6, decreasing to 37.7 per 100,000 live births in 2011, representing a total reduction of 22.4%. In the same period, there were 855 deaths with abortive outcome, representing a MMR_{AO} of 3.28 per 100,000 live births. This outcome displayed a 20.5% decrease between 2002 (3.61 per 100,000 live births) and 2011 (2.87 per 100,000 live births). For this period, there were 352 deaths associated with ICD-10 codes O04 through O07, representing an iAMR of 1.35 per 100,000 live births. This outcome decreased by 29.5% between 2002 and 2011, from 1.49 to 1.05 deaths per 100,000 live births.

Regardless of where the vital event took place, MMR, MMR_{AO}, iAMR, and the proportion of induced abortion-related deaths between 2002 and 2011 were lower in the group of states with less permissive abortion legislation (Figures 1 and 2, left panels). Table 2 summarizes the linear trends of all three mortality outcomes in each group of states and the entire Mexican country for the study period, by residence and occurrence, respectively. In each group, the β-coefficient represents the average change per year of the mortality outcome and the *p* for trend indicates the statistical significance of the overall trend. The group of states with less permissive abortion legislation showed apparently stable trends for MMR, MMR_{AO}, and iAMR during the decade analysed. The group of states with more permissive abortion legislation displayed decreasing trends for MMR, MMR_{AO}, iAMR, narrowing the gap between the two groups by 2011 but still exhibited statistically significant differences (*e.g.* MMR of 40.9 *vs.* 33.5 per 100,000 live births for more permissive vs. less permissive states, Z=3.04, rate ratio=0.82, p=0.002). State-by-state

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trends and estimated β-coefficients for the time series of MMR, MMR_{AO}, and iAMR are presented by residence (Tables S10 through S12) and by occurrence (Tables S13 through S15) in the Supplementary Material.

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Table 2 Average change per year in different maternal mortality outcomes by place of residence and occurrence in groups of Mexican states with more or less permissive abortion legislation and the entire country (2002-2011) based on Autoregressive Integrated Moving Average (ARIMA) models.

	MMR			MMR_{AO}			iAMR		
	β†	SE‡	*p*§	β†	SE‡	*p*§	β†	SE‡	*p*§
By place of residence									
Less permissive states (18)	-0.563	0.405	0.202	0.030	0.057	0.615	-0.010	0.019	0.619
More permissive states (14)	-1.766	0.276	<0.001	-0.123	0.040	0.016	-0.096	0.025	0.005
United Mexican States (32)	-1.258	0.286	0.002	-0.056	0.032	0.121	-0.058	0.017	0.010
By place of occurrence									
Less permissive states (18)	-0.487	0.428	0.288	0.025	0.061	0.688	-0.011	0.020	0.602
More permissive states (14)	-1.764	0.275	<0.001	-0.112	0.040	0.022	-0.092	0.023	0.004
United Mexican States (32)	-1.258	0.286	0.002	-0.056	0.032	0.121	-0.058	0.017	0.010

†*β*-coefficient representing the average change per year for trend of MMR per 100,000 live births between 2002 and 2011.
‡Standard error for β-coefficient obtained between 2002 and 2011 with ARIMA.
§*p* for trend between 2002 and 2011.

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Figure 3 illustrates in a blue scale the geographic distribution of average MMR (top panel) and iAMR (bottom panel) for the 10-year period in territories of the whole country. The differences in average mortality outcomes between groups are summarized in Table 3. Average MMR for the 10-year period by place of residence and occurrence in the group of states with less permissive legislation was 23% and 21% lower, respectively, than the value in the group of states with more permissive legislation. Similarly, the group of states with less permissive abortion legislation showed an average MMR_{AO} by place of residence and occurrence of 27% and 24% lower, respectively, than states with more permissive legislation. The highest difference between both groups was for the average iAMR, which was 47% lower in states with less permissive legislation, for analyses by residence and occurrence. Finally, average proportion of induced abortion-related deaths over the total number of maternal deaths by place of residence was 2.4% and 3.4% (p=0.002) in the groups of states with less and more permissive abortion legislation, respectively; by place of occurrence, figures were 2.3% and 3.5% (p<0.001), respectively. Excluding the Federal District from the group of states with more permissive abortion legislation did not significantly modify these results.

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Table 3 Comparative analysis of average mortality outcomes by residence and occurrence for groups of Mexican states exhibiting a more or less permissive abortion legislation, 2002-2011

Indicator		Less permissive	More permissive	Rate ratio†	p value‡
MMR	By residence	38.3	49.6	0.7722	< 0.001
	By occurrence	39.1	49.3	0.7922	< 0.001
MMR_{AO}	By residence	2.7	3.7	0.7110	< 0.001
	By occurrence	2.8	3.7	0.7491	< 0.001
iAMR	By residence	0.9	1.7	0.5358	< 0.001
	By occurrence	0.9	1.7	0.5337	< 0.001
Proportion of induced abortion-related deaths	By residence	2.4%	3.4%	§	< 0.001
	By occurrence	2.3%	3.5%	§	< 0.001

iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.
†*Z*-test rate ratio.
‡*Z*-test p value.
§Not applicable.

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Constitutional amendments and maternal mortality

Regardless of where the vital event took place, iAMR and the proportion of induced abortion-related deaths between 2008 and 2011 –but not MMR and MMR_{AO}, for which rates overlapped– were apparently higher in the group of states that did not amend their constitutions (Figures 4 and 5, left panels); however, these differences were not statistically significant for the 4-year period (*p* for trend=0.670). The differences in average mortality outcomes between groups are summarized in Table 4. Differences were observed in average iAMR and proportion of induced abortion-related deaths for the total period of 4 years. Average iAMR either by place of residence or occurrence in states with constitutional amendments was 31% lower than the value in states without amendments. The average proportion of induced abortion-related deaths over the total number of maternal deaths by place of residence was 2.1% in states with amendment and 3.1% in states without amendment (*p*=0.041); by place of occurrence figures were 2.2% in states with amendment and 3.2% in states without amendment (*p*=0.048).

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Table 4 Comparative analysis of average mortality outcomes by residence and occurrence for groups of states with or without constitutional amendment protecting the unborn from conception, 2008-2011

Indicator		With amendment	Without amendment	Rate ratio†	*p* value‡	Without amendment excluding the FD	Rate ratio§	*p* value¶	FD	Rate ratio††	*p* value‡‡
MMR	By residence	40.5	41.6	0.9413	0.347	41.4	0.9792	0.514	43.3	0.9357	0.310
	By occurrence	40.0	41.2	0.9031	0.114	40.6	0.9856	0.657	56.1	0.7124	<0.001
MMR_{AO}	By residence	2.8	3.2	0.7728	0.273	3.1	0.8959	0.361	3.8	0.7379	0.175
	By occurrence	2.9	3.2	0.8134	0.378	3.0	0.9475	0.656	4.3	0.6663	0.039
iAMR	By residence	0.9	1.3	0.5360	0.042	1.3	0.6522	0.037	1.1	0.7750	0.538
	By occurrence	0.9	1.3	0.5338	0.043	1.3	0.6717	0.054	1.4	0.6014	0.138
Proportion of induced abortion-related deaths	By residence	2.1%	3.1%	§§	0.041	3.2%	§§	0.030	2.6%	§§	0.649
	By occurrence	2.2%	3.2%	§§	0.048	3.2%	§§	0.063	2.6%	§§	0.625

FD, Federal District (Distrito Federal); iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.
†Z-test rate ratio between states with and without amendment.
‡Z-test *p* value between states with and without amendment.
§Z-test rate ratio between states with and without amendment, excluding the Federal District.
¶Z-test *p* value between states with and without amendment, excluding the Federal District.
††Z-test rate ratio between states with amendment and the Federal District.
‡‡Z-test *p* value between states with amendment and the Federal District.
§§Not applicable.

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After removing the Federal District from the group of states without constitutional amendments, differences were observed in average MMR and MMR_{AO} between the groups, but only in the analysis of mortality by place of occurrence (Figures 5 and 7, right panels). The Federal District showed higher average MMR and MMR_{AO} by place of occurrence than the group of states with constitutional amendments. In addition, removal of the Federal District from the group of states without constitutional amendments abolished the differences found in average iAMR and proportion of induced abortion-related deaths by place of occurrence (Figures 5 and 7), but not by place of residence (Figures 4 and 6) between the latter group and the group of states with the amendment. Results for each mortality outcome are compared in Table 4.

Primary explanatory regression models

Table 5 shows data for all covariates for each Mexican state, and includes the results from tests of normal distribution for each variable. Simple regression models illustrating the initial effect size (β-coefficient) for each covariate, including abortion legislation and constitutional amendment are presented in Table 6. For instance, less permissive abortion legislation was associated with an average decrease of 7.31 per 100,000 live births for MMR.

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Table 5 Independent variables in each Mexican state: frequencies and analyses of normal distribution

State	Abortion legislation	Constitutional amendment	Clean water	Sanitation	TFR	Contraceptive use	Skilled attendance at birth	Low birth weight	Female literacy	All-abortion hospitalisation ratio	Intimate-partner violence
Aguascalientes	1	0	98.0	97.8	2.6	71.7	97.5	6.6	95.9	10.8	12.0
Baja California	1	1	95.3	93.7	2.1	78.8	75.7	6.9	96.0	9.2	11.7
Baja California Sur	0	0	88.1	94.2	2.0	75.9	99.5	6.0	95.8	10.6	16.3
Campeche	1	0	85.0	85.7	2.2	73.9	98.2	7.2	89.7	7.8	10.7
Coahuila	0	0	96.8	95.6	2.3	75.2	89.6	8.0	96.5	8.0	14.3
Colima	0	1	97.3	98.7	2.3	78.3	96.4	5.4	94.2	17.4	11.0
Chiapas	0	1	73.8	80.4	2.8	54.9	90.2	8.6	77.5	5.1	7.0
Chihuahua	1	1	94.9	93.2	2.4	78.9	82.2	7.6	95.3	6.2	12.1
Distrito Federal	0	0	97.5	99.2	1.8	79.6	94.3	14.0	96.3	14.2	20.9
Durango	1	1	92.9	88.3	2.4	73.2	93.3	8.0	95.5	8.2	10.2
Guanajuato	1	1	91.9	89.3	2.4	68.3	90.1	8.9	90.1	7.0	6.4
Guerrero	0	0	62.0	71.7	2.8	61.4	80.8	9.3	79.8	3.2	8.3
Hidalgo	0	0	87.2	83.4	2.4	70.9	89.7	8.5	87.2	6.2	8.6
Jalisco	1	1	94.6	96.9	2.4	71.4	93.5	9.0	94.8	7.4	10.0
México	0	0	92.2	92.0	2.2	76.5	84.7	10.9	93.6	4.4	11.9
Michoacán	1	0	88.1	85.4	2.4	63.2	92.1	8.6	88.4	6.1	9.1
Morelos	0	1	87.6	92.4	2.2	75.4	91.7	10.5	91.8	8.8	9.7
Nayarit	1	1	88.3	93.5	2.3	78.7	81.8	6.8	92.9	7.4	14.8
Nuevo León	1	0	96.9	97.2	2.1	79.2	96.6	8.6	95.8	6.5	13.1
Oaxaca	0	1	69.8	69.6	2.6	63.4	95.0	7.8	79.4	3.7	6.3
Puebla	0	1	83.8	84.9	2.6	69.8	90.8	9.6	86.8	4.0	8.6
Querétaro	1	1	91.9	91.0	2.3	70.3	97.6	9.2	91.7	9.1	11.6
Quintana Roo	0	1	91.7	94.0	2.1	73.4	91.5	8.3	92.4	9,7	10.7
San Luis Potosí	1	1	83.1	80.5	2.5	67.4	91.7	8.1	90.5	6.6	10.5
Sinaloa	1	0	90.3	90.9	2.3	79.8	93.4	6.1	94.7	8.1	15.0
Sonora	1	1	94.4	90.0	2.4	79.9	94.6	6.2	96.3	8.7	15.4
Tabasco	1	0	73.8	91.7	2.3	66.3	82.4	8.4	90.9	7.2	9.6
Tamaulipas	1	1	95.1	88.1	2.3	73.2	99.0	7.4	94.2	10.0	14.9
Tlaxcala	1	0	95.6	92.8	2.4	65.2	98.2	10.1	92.8	7.6	9.3
Veracruz	0	0	76.3	80.2	2.2	73.9	97.8	7.1	86.1	4.8	10.9
Yucatán	0	1	94.4	80.1	2.3	74.9	97.5	10.7	88.6	7.2	11.5
Zacatecas	1	0	91.7	89.0	2.5	70.2	89.1	8.6	93.6	8.3	8.2
p-value[*]	†	†	0.189	0.624	0.311	0.730	0.534	0.666	0.399	0.394	0.505

Abortion Legislation: states classified as less permissive (1) or more permissive (0), according to the presence of an exemption from criminal prosecution of abortion in cases of genetic or congenital malformation. Constitutional amendment: states classified as exhibiting (1) or not (0) an amendment to their political constitution protecting the unborn from conception during 2011. Clean water: Percentage of in-use private dwellings with clean water availability during 2010. Sanitation: Percentage of in-use private dwellings with availability of sewer drainage during 2010. TFR: Average total fertility rate between 2002 and 2011. Contraceptive use: Percentage of married or in-union women of 15 and above using contraceptive methods during 2009. Skilled attendance at birth: Percentage of observed live births delivered by a physician, nurse or midwife during 2010. Low birth weight: Percentage of observed live births with low birth weight in each state during 2010. Female literacy: Percentage of the female population of ages 15 and above who can understand,

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read and write a short, simple statement on their everyday life during 2010. All-abortion hospitalisation ratio: Ratio of all-abortion related hospitalisations over observed live births between 2000 and 2008 per 100 live births. Intimate-partner violence: Percentage of married or in-union women of ages 15 and above who have suffered severe intimate partner violence over the past 12 months during 2010.
*Kolmogorov-Smirnov test for normal distribution.
†Not applicable

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Table 6 Univariate associations between 10 independent variables and maternal mortality outcomes for 32 Mexican states, 2002-2011

Variable	MMR						MMR_{AO}						iAMR					
	β	SE	95% CI Lower	95% CI Upper	R^2	*p* value	β	SE	95% CI Lower	95% CI Upper	R^2	*p* value	β	SE	95% CI Lower	95% CI Upper	R^2	*p* value
Female literacy (%)	-1.16	0.26	-1.700	-0.627	0.38	<0.001	-0.08	0.03	-0.155	-0.007	0.11	0.033	-0.07	0.02	-0.117	-0.021	0.20	0.007
Low birth weight (%)	2.05	0.92	0.173	3.937	0.11	0.033	0.33	0.09	0.134	0.534	0.26	0.002	0.17	0.07	0.025	0.319	0.13	0.023
Skilled attendance at birth (%)	-0.52	0.27	-1.067	0.023	0.08	0.060	-0.08	0.03	-0.140	-0.020	0.17	0.010	-0.03	0.02	-0.073	0.015	0.02	0.192
Intimate-partner violence (%)	-0.86	0.52	-1.931	0.205	0.05	0.109	-0.06	0.06	-0.189	0.066	0.00	0.332	-0.05	0.04	-0.138	0.034	0.02	0.230
All-abortion hospitalisation ratio (per 100 live births)	-1.71	0.51	-2.750	-0.678	0.25	0.002	-0.11	0.06	-0.247	0.022	0.05	0.099	-0.10	0.04	-0.187	-0.009	0.11	0.033
Constitutional amendment (yes)	1.93	3.36	-4.946	8.809	0.01	0.571	0.22	0.39	-0.575	1.019	-0.02	0.574	-0.20	0.26	-0.742	0.340	-0.01	0.454
Abortion legislation (less permissive)	-7.31	3.13	-13.710	-0.911	0.12	0.027	-0.47	0.38	-1.263	0.310	0.01	0.226	-0.31	0.26	-0.843	0.232	0.01	0.255
Contraceptive use (%)	-0.64	0.25	-1.165	-0.130	0.15	0.016	-0.04	0.03	-0.106	0.023	0.02	0.195	-0.05	0.02	-0.093	-0.012	0.16	0.013
TFR	9.51	6.56	-3.899	22.927	0.03	0.158	0.46	0.78	-1.134	2.063	-0.02	0.557	1.21	0.48	0.221	2.216	0.14	0.018
Clean water (%)	-0.66	0.15	-0.970	-0.355	0.37	<0.001	-0.03	0.02	-0.076	0.012	0.03	0.152	-0.03	0.01	-0.065	-0.009	0.16	0.012
Sanitation (%)	-0.79	0.18	-1.174	-0.425	0.36	<0.001	-0.03	0.02	-0.090	0.017	0.02	0.177	-0.04	0.01	-0.075	-0.005	0.12	0.026

CI, confidence interval; iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome; SE, standard error; TFR, average total fertility rate between 2002-2011.

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Exploratory regression analyses showed collinearity between independent variables. A full model introducing all independent variables simultaneously (not shown) showed VIF values between 1.537 and 9.082. In particular, five of the nine independent variables showed VIF values higher than 4.0 (clean water, sanitation, TFR, contraceptive use, and female literacy), suggesting the presence of multicollinearity. A correlation matrix showed a high inverse correlation between TFR and contraceptive use (r=-0.76; $p<0.001$), suggesting that these variables were interchangeable. Other pairs of variables with high Pearson coefficients were clean water with sanitation (r=0.79; $p<0.001$), and female literacy with clean water (r=0.85; $p<0.001$) or with sanitation (r=0.86; $p<0.001$). Thus, contraceptive use and female literacy were selected for primary explanatory models. When TFR, clean water, and sanitation were excluded, VIF substantially decreased to values between 1.087 and 3.338.

Table 7 shows the multivariate explanatory models for MMR, MMR_{AO} and iAMR using the backward stepwise elimination method and after statistical refinement. Models before refinement are presented in Table S16 (Supplementary Material). In general, an increase in β-coefficients and R^2 was observed after statistical refinement. In every multivariate regression model, each β-coefficient represents the average change in the outcome of interest (i.e., MMR, MMR_{AO}, and iAMR) per unit of change in each independent variable (e.g., % skilled attendance at birth, % female literacy, % low birth weight, etc.) controlling for all other covariates in the model, and R^2 represents the proportion of the total variability in the mortality outcome explained by the full model. The refined model for MMR excluded two states as outliers (Chihuahua and Nueva León) and identified four predictors: female literacy, low birth weight, all-abortion hospitalisation ratio, and intimate-partner violence. These variables accounted for 69% of observed differences in MMR among states (R^2 for model). The contribution of each variable for explaining the variance of MMR among states (partial R^2) was 50.9%, 15.1%, 4.4%, and 2.8%, respectively. No independent effect was observed for abortion legislation, constitutional amendment, or other covariates. Regarding MMR_{AO}, the refined model excluded two states as outliers (Aguascalientes and Nayarit), identifying three predictors: female literacy, low birth weight, and skilled attendance

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at birth. These variables accounted for 62% (R^2 for model 0.624; p<0.001) of observed differences in MMR_{AO} among states. Individual contributions of each factor for explaining the variance of MMR_{AO} among states were 11.9%, 40.2%, and 14.2%, respectively. No independent effect was observed for abortion legislation, constitutional amendment, or other covariates. Finally, regarding iAMR, the refined model excluded four states as outliers (Aguascalientes, Durango, Sonora, and Tlaxcala), identifying three predictors: female literacy, low birth weight, skilled attendance at birth, and intimate-partner violence. These variables accounted for 78% (R^2 for model 0.777; p<0.001) of observed differences in iAMR among states. The relative contributions of these variables for explaining the variance of iAMR (partial R^2) among states were 39.9%, 19.1%, 14.8%, and 7.2%, respectively. No statistically independent effect was observed for abortion legislation, constitutional amendment, or other covariates.

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Table 7. Explanatory models for trends on maternal mortality ratio (MMR), maternal mortality ratio with an abortive outcome (MMR_{AO}), and induced abortion mortality ratio (iAMR) in 32 Mexican states after refinement, 2002-2011.

	MMR†						MMR_{AO}‡						iAMR§					
	β	SE	95% CI		P value	VIF	β	SE	95% CI		P value	VIF	β	SE	95% CI		P value	VIF
			Lower	Upper					Lower	Upper					Lower	Upper		
Female literacy (%)	-1.100	0.255	-1.625	-0.574	<0.001	2.250	-0.073	0.024	-0.122	-0.023	0.005	1.014	-0.119	0.018	-0.155	-0.082	<0.001	1.944
Low birth weight (%)	1.637	0.502	0.603	2.671	0.003	1.046	0.361	0.072	0.213	0.508	<0.001	1.013	0.154	0.039	0.074	0.234	0.001	1.051
Skilled attendance at birth (%)	-0.162	0.157	-0.486	0.162	0.312	1.145	-0.065	0.021	-0.108	-0.022	0.005	1.011	-0.052	0.011	-0.075	-0.030	<0.001	1.061
Intimate-partner violence (%)	0.755	0.369	-0.004	1.514	0.051	1.859	0.021	0.055	-0.092	0.135	0.702	1.961	0.085	0.029	0.025	0.144	0.007	2.023
All-abortion hospitalisation ratio (per 100 live births)	-0.817	0.405	-1.652	0.018	0.055	1.882	0.036	0.056	-0.080	0.151	0.533	1.742	-0.004	0.030	-0.067	0.058	0.894	1.854
Constitutional amendment (yes)	0.578	1.827	-3.192	4.348	0.755	1.088	0.286	0.243	-0.214	0.787	0.250	1.019	-0.034	0.137	-0.318	0.250	0.806	1.081
Abortion legislation (less permissive)	-1.456	2.151	-5.896	2.983	0.505	1.531	-0.062	0.279	-0.636	0.513	0.827	1.276	-0.059	0.155	-0.380	0.262	0.705	1.393
Contraceptive use (%)	0.187	0.259	-0.347	0.720	0.477	3.182	0.044	0.032	-0.022	0.111	0.184	2.761	0.023	0.020	-0.018	0.064	0.255	3.622
R-square for model	0.689¶						0.624¶						0.777¶					

†Multivariate model identified and excluded two states (Chihuahua and Nueva León) as outliers after one step of refinement. Four predictors were identified after five steps of backward elimination (Female literacy, Low birth weight, All-abortion hospitalisation ratio and Intimate-partner violence), accounting for 69% (R^2) of the differences in MMR between states.
‡Multivariate model identified and excluded two states (Aguascalientes and Nayarit) as outliers after two steps of refinement. Three predictors were identified after six steps of backward elimination (Female literacy, Low birth weight, and Skilled attendance at birth), accounting for 62% (R^2) of the differences in MMR_{AO} between states.
§Multivariate model identified and excluded four states (Aguascalientes, Durango, Sonora, and Tlaxcala) as outliers after three steps of refinement. Four predictors were identified after five steps of backward elimination (Female literacy, Low birth weight, Skilled attendance at birth, and Intimate-partner violence), accounting for 78% (R^2) of the differences in iAMR between states.
¶p<0.001
CI, confidence interval; iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; $MMR_{AO,}$ maternal mortality ratio with abortive outcome; SE, standard error; VIF, variance inflation factor.

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Alternative explanatory regression models

Alternative multivariate regression models considering variables initially excluded by collinearity are summarized in Table 8. For instance, in the first of these alternative models, female literacy was exchanged with clean water (*i.e.* female literacy was excluded from the model whereas clean water was included). After regression refinement, four factors were identified as independent explanatory variables for the MMR: clean water, low birth weight, all-abortion hospitalisation ratio, and intimate-partner violence. These variables accounted for 88% (R^2 for model 0.886; $p<0.001$) of observed differences in MMR among states. The individual contribution (partial R^2) of each factor for explaining the variance of MMR among states was 64.7%, 22.0%, 1.9%, and 1.7%, respectively. Regarding MMR_{AO}, the model identified skilled attendance at birth and low birth weight as independent predictors, accounting for 42% of the difference among states, with an individual contribution of 17.8% and 27.9%, respectively. For iAMR, the model selected three factors: clean water, low birth weight, and skilled attendance at birth. These variables explained 70% (R^2 for model 0.70; $p<0.001$) of the difference among states with an individual contribution of 39.2%, 26.6%, and 7.4% of the differences observed in iAMR among states, respectively. Similarly, when female literacy was exchanged for sanitation, the refined model identified sanitation as inversely associated with MMR and iAMR. Finally, when TFR was incorporated instead of contraceptive use in multivariate models, an inverse independent association of TFR with MMR (β=-14.329; p=0.002) and MMR_{AO} (β=-1.750; p=0.008), and a direct association with iAMR (β=1.383; p=0.003) was found. A full description for other significant predictors in these alternative explanatory models is presented in the Supplementary Material. No statistically significant effects were found for abortion legislation or constitutional amendment in any of the alternative regression models.

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Table 8 Alternative explanatory regression models for MMR, MMR_{AO} and iAMR after refinement considering independent variables excluded from the explanatory models because of collinearity.

Variable	MMR						MMR_{AO}						iAMR					
	β	SE	95% CI		*p* value	VIF	β	SE	95% CI		*p* value	VIF	β	SE	95% CI		*p* value	VIF
			Lower	Upper					Lower	Upper					Lower	Upper		
Clean water (%)	-0.730	0.085	-0.908	-0.553	<0.001	1.928	-0.021	0.017	-0.056	0.014	0.225	1.066	-0.048	0.008	-0.065	-0.030	<0.001	1.041
Low birth weight (%)	1.938	0.318	1.279	2.596	<0.001	1.086	0.321	0.087	0.144	0.498	0.001	1.002	0.210	0.043	0.121	0.299	<0.001	1.006
Skilled attendance at birth (%)	-0.027	0.106	-0.250	0.197	0.806	1.238	-0.076	0.025	-0.126	-0.026	0.004	1.002	-0.032	0.012	-0.057	-0.007	0.014	1.039
Intimate-partner violence (%)	0.554	0.210	0.118	0.990	0.015	1.570	0.010	0.078	-0.150	0.170	0.897	2.446	0.033	0.029	-0.028	0.093	0.276	1.615
All-abortion hospitalisation ratio (Per 100 live births)	-0.566	0.271	-1.129	-0.003	0.049	2.288	-0.010	0.080	-0.176	0.156	0.901	2.107	-0.020	0.036	-0.095	0.055	0.580	2.056
Constitutional amendment (Yes)	-0.312	1.172	-2.765	2.141	0.793	1.136	0.316	0.295	-0.289	0.921	0.294	1.031	0.112	0.148	-0.194	0.418	0.457	1.032
Abortion legislation (less permissive)	1.745	1.361	-1.095	4.585	0.215	1.625	-0.085	0.335	-0.773	0.604	0.803	1.269	-0.158	0.163	-0.496	0.180	0.344	1.266
Contraceptive use (%)	0.167	0.150	-0.144	0.479	0.276	2.756	-0.007	0.037	-0.083	0.068	0.843	2.160	0.009	0.024	-0.042	0.059	0.723	3.798
R-square for model	0.886†						0.420†						0.700†					
Sanitation (%)	-0.758	0.127	-1.019	-0.497	<0.001	1.001	-0.032	0.020	-0.072	0.009	0.121	1.002	-0.052	0.011	-0.075	-0.029	<0.001	1.000
Low birth weight (%)	2.166	0.528	1.082	3.249	<0.001	1.001	0.321	0.087	0.144	0.498	0.001	1.002	0.169	0.048	0.070	0.268	0.002	1.003
Skilled attendance at birth (%)	-0.248	0.154	-0.565	0.069	0.120	1.008	-0.076	0.025	-0.126	-0.026	0.004	1.002	-0.044	0.014	-0.072	-0.016	0.004	1.003
Intimate-partner violence (%)	0.238	0.337	-0.457	0.933	0.487	1.490	0.023	0.078	-0.137	0.183	0.772	2.494	0.055	0.031	-0.010	0.119	0.092	1.592
All-abortion hospitalisation ratio (per 100 live births)	-0.410	0.518	-1.485	0.665	0.438	2.903	0.019	0.090	-0.167	0.205	0.835	2.693	-0.005	0.046	-0.101	0.091	0.920	2.605
Constitutional amendment (Yes)	0.660	1.958	-3.412	4.732	0.739	1.175	0.232	0.292	-0.368	0.831	0.434	1.026	0.090	0.166	-0.254	0.434	0.593	1.083
Abortion legislation (less permissive)	-3.148	1.875	-7.010	0.714	0.106	1.164	-0.104	0.322	-0.767	0.558	0.749	1.194	-0.192	0.172	-0.546	0.163	0.276	1.206
Contraceptive use (%)	-0.241	0.239	-0.737	0.254	0.324	2.671	-0.005	0.033	-0.072	0.062	0.873	1.743	-0.011	0.022	-0.058	0.036	0.632	2.898
R-square for model	0.640†						0.420†						0.593†					
Female literacy (%)	-1.013	0.218	-1.463	-0.563	<0.001	1.876	-0.125	0.029	-0.184	-0.066	<0,001	2.043	-0.029	0.029	-0.089	0.030	0.321	1.833
Low birth weight (%)	1.260	0.446	0.339	2.180	0.009	1.127	0.271	0.064	0.138	0.404	<0,001	1.096	0.197	0.064	0.067	0.327	0.004	1.015
Skilled attendance at birth (%)	0.004	0.158	-0.326	0.335	0.978	1.223	-0.064	0.018	-0.102	-0.027	0.002	1.031	-0.023	0.018	-0.060	0.013	0.200	1.037
Intimate-partner violence (%)	0.247	0.371	-0.521	1.016	0.511	2.419	0.012	0.055	-0.101	0.125	0.828	2.416	0.075	0.051	-0.029	0.179	0.152	2.239
All-abortion hospitalisation ratio (per 100 live births)	-0.962	0.352	-1.689	-0.236	0.012	1.779	-0.016	0.051	-0.121	0.089	0.755	1.961	0.011	0.053	-0.099	0.121	0.834	2.021
Constitutional amendment (Yes)	1.195	1.563	-2.037	4.428	0.452	1.076	0.235	0.209	-0.198	0.667	0.273	1.046	-0.172	0.215	-0.614	0.270	0.430	1.056
Abortion legislation (less permissive)	-0.226	1.972	-4.327	3.875	0.910	1.597	-0.053	0.293	-0.663	0.557	0.858	1.796	0.060	0.287	-0.534	0.653	0.837	1.722
TFR	-14.329	4.158	-22.911	-5.747	0.002	1.728	-1.750	0.606	-3.001	-0.500	0.008	2.143	1.383	0.434	0.495	2.270	0.003	1.015
R-square for model	0.714†						0.666†						0.335†					

CI, confidence interval; iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome; SE, standard error; TFR, average total fertility rate between 2002-2011; VIF, variance inflation factor.
†*p*<0.001

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DISCUSSION

Diversity of abortion legislation in different regions, countries, and territories may partially reflect different cultural values and attitudes towards motherhood, childhood, the unborn, and abortion itself.[22,41,43-47] Theoretically, in Mexican states exhibiting less permissive legislation, maternal mortality should have been higher because the practice of unsafe abortion should be more frequent.[19-22] Paradoxically, over a 10-year period, those states almost univocally exhibited lower figures for MMR, MMR_{AO}, and iAMR. Nevertheless, after an exhaustive analysis adjusting for multiple confounders, the initial estimated effects for all mortality outcomes were explained by differences in other independent factors known to influence maternal health rather than by abortion legislation itself. In fact, most of the independent variables considered in the present study were more favourably distributed in the group of states with less permissive legislation in a weighted comparative analysis (Table 9). Consequently, making a direct or independent causal link between a less permissive abortion law and a lower incidence of maternal deaths –or conversely by considering a more permissive abortion law– would be a premature or even erroneous conclusion. Rather, from an epidemiological perspective, the Mexican natural experiment provides evidence to support three complementary assumptions at the population level: first, abortion legislation *per se* did not appear to have an independent effect on overall maternal mortality rates; second, a less permissive abortion law, in terms of not considering exemptions from criminal prosecution of abortion in cases of genetic or congenital foetal anomalies, was not associated with increased maternal and abortion-related deaths; and third, differences in maternal mortality incidence in the context of different abortion legislation (more or less permissive), appear mainly explained by the distribution of other major independent factors likely facilitating an epidemiologic transition toward low maternal mortality rates independently from abortion legislation itself.

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Table 9 Comparison of different indicators of maternal healthcare and human development between groups of states with less and more permissive abortion legislation

Variable	Less permissive states (n=18)	More permissive states (n=14)	Rate ratio†	*p* value
Clean water§, %	91.9	85.6	1.07	< 0.001‡
Sanitation§, %	91.3	87.0	1.05	< 0.001‡
Total Fertility Rate (TFR)	2.4	2.3	¶	0.781¶¶
Contraceptive use††, %	72.3	73.3	0.99	< 0.001‡
Skilled attendance at birth‡‡, %	91.4	90.3	1.01	< 0.001‡
Low birth weight‡‡, %	8.1	9.6	0.84	< 0.001‡
Female literacy§§, %	93.3	89.3	1.05	< 0.001‡
All-abortion hospitalisation ratio‡‡, per 100 live births	7.6	6.1	1.25	< 0.001‡
Intimate-partner violence§§, %	11.1	11.9	0.93	< 0.001‡

§Proportions were weighted using specific denominator of exposed populations for each state.
††Proportions were weighted using specific denominator of exposed female populations ages 15-49 for each state.
‡‡Proportions and ratio were weighted using specific denominator of observed live births in each state.
§§Proportions were weighted using specific denominator of exposed female populations ages 15 and above for each state.
†*Z*-test rate ratio
‡*Z*-test *p* value
¶ Not applicable
¶¶ *t*-test *p* value

On the other hand, whether state constitutional amendments protecting the unborn translate into higher or lower maternal mortality rates has not yet been explored. Theoretically, these states might be culturally more reluctant to accept changes in abortion legislation,[22,43,45,46] and therefore, maternal deaths might be higher, particularly if practice of unsafe abortions is frequent.[21,47] At least in the short-term, this natural experiment found no evidence of any detrimental impact on maternal mortality outcomes related to constitutional amendments protecting the unborn. Some differences were noted between groups of states with and without amendments between 2008 and 2011, *i.e.* lower average iAMR and lower average proportion of abortion-related deaths in the group of states with amendments compared with the group without amendments. Nevertheless, in multivariate models these differences appeared to be explained by other independent factors distributed more favourably in the group of states with less permissive legislation but unrelated to constitutional amendment.

Interestingly, between 2008 and 2011, the Federal District displayed higher MMR and MMR_{AO} than the group of states with the constitutional amendment, when the outcome was measured by

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place of occurrence, but not by place of residence. Indeed, when mortality ratios by occurrence or residence are compared state-by-state, the Federal District showed the highest difference in maternal mortality outcomes (*e.g.,* 61.9 *vs* 48.7 for MMR per 100,000 live births, respectively). From an epidemiological perspective, such disparities often reflect a pattern of temporary mobility among the population.[48] Similarly, the difference in iAMR and the proportion of abortion-related deaths by place of occurrence between states with and without amendment was abolished when the Federal District was removed from the latter group. Thus, inter-state mobility into the Federal District appears to be associated with an increased risk of maternal mortality for pregnant women arriving from other states. Determinants of this phenomenon are largely unknown and warrant further research.

Multivariate regression in both primary and alternative models (refined or unrefined) revealed that a combination of factors related to maternal healthcare, reproductive behaviour, access to clean water, sanitation, female literacy, and intimate-partner violence against women explained 51% to 88% of the variance among states in overall maternal mortality rates. Proportional contributions of each variable explaining the variance of maternal mortality outcomes analysed among Mexican states are summarized in Figure 8. These percentages also represent the potential impact of addressing each factor individually to decrease mortality ratios in Mexico. Box 1 summarises public health interventions based on the results of the present study to improve maternal health in this country.

Box 1 Evidence-based public health interventions to improve maternal health in Mexico

- Increase access to antenatal care and coverage of institutional deliveries.
- Increase number of and access to emergency obstetric units.
- Expand specialised diagnostic centres and prenatal care for high-risk pregnancies, with incorporation of other medical specialties.
- Increase access to adequate pre-conception counselling and family planning programs to promote healthy childbearing before 35 years of age and to prevent unplanned pregnancies.
- Strenghten public policies directed to increase the number of schooling years of the female population.
- Improve detection of violence against pregnant women during prenatal visits and intervention by skilled health professionals.
- Address disparities in human development indicators by increasing access to clean water and sanitation coverage

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Regarding maternal healthcare, three factors resulted independently associated to maternal mortality outcomes. First, consistent with the general consensus,[3,6,8-10,49,50,51] skilled attendance at birth showed an inverse relationship with mortality ratios: for each 1% increase in skilled attendance at birth, decreases of 0.42 in MMR (Table S16, Supplementary Material), 0.06 in MMR_{AO}, and 0.05 in iAMR per 100,000 live births were estimated. This factor –ranging from 75% to 99% among states (Table 5)– likely reflects important disparities in access to antenatal care and institutional deliveries.[4,5,50,51] Second, all-abortion hospitalisation ratio showed an inverse relationship with MMR in refined explanatory models. For each incremental unit of this variable, a decrease of 0.8 maternal deaths per 100,000 live births was estimated among states. This inverse relationship has been previously identified as an indicator of improved access to emergency obstetric units, specialised obstetric and post-abortion care.[27,30,52,53,54] In contrast, a direct relationship between all-abortion hospitalisation ratio and MMR may indicate high rates of in-hospital deaths secondary to obstetric complications or alternatively, that an important number of unsafe abortions are being conducted (Table 5).[27,30,54-57] This second interpretation seems not to be the case in Mexico. Finally, low birth weight rate showed strong direct associations with all mortality ratios in multivariate models: for each 1% increase in low birth weight, increases of 1.6 in MMR, 0.3 in MMR_{AO}, and 0.1 in iAMR per 100,000 live births were estimated, explaining from 15.1% to 40.2% of the variance among states. An association between low birth weight and mortality ratios may be explained by the fact that low birth weight and pre-term birth are *proxies* for adverse pregnancy outcomes related to a series of antecedent individual risk factors and medical conditions, such as advanced maternal age, poor nutrition, infections, preeclampsia, placental abnormalities, cervical incompetence, cardiovascular conditions, pre-existing chronic diseases, drug addiction, adverse social situation, alcohol abuse, insufficient prenatal care, and a gynaecological history of previous termination of pregnancy.[58,59,60,61,62] Taking into consideration the wide disparity in low birth weight rates among states (from 5.4% to 14.0%), individual-level risk factors likely make a major contribution

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to current maternal mortality rates in Mexico. This suggests the need for an expansion of emergency obstetric units, specialised diagnostic centres and prenatal care for high-risk pregnancies, and the incorporation of other medical specialities, which in turn may favourably impact maternal health.[4,7,30,63-65]

Reproductive behaviour is another factor likely influencing maternal health. In this study, two variables were considered as *proxies* of the reproductive behaviour: contraceptive use and the average TFR between 2002 and 2011 for each state (Table 5).[10,30,66,67,68,69] This study provided little evidence that contraceptive use exerts an independent primary influence on maternal mortality differences among Mexican states over the last decade. Nevertheless, alternative multivariate models considering TFR instead of contraceptive use revealed two opposite effects of TFR on mortality ratios: while displaying an inverse relationship with MMR and MMR_{AO}, TFR showed a direct association with iAMR, explaining 17.2% of the difference in abortion-related mortality among states. The direct association of TFR with iAMR may be related to an increased number of unplanned pregnancies terminated with abortion. In contrast, the inverse association between TFR and MMR or MMR_{AO} is more difficult to interpret. Simple direct correlations between TFR and MMR across multiple countries support the common notion that decreasing fertility reduces maternal mortality by reducing a woman's exposure to pregnancy during her reproductive lifetime.[10,66,67,70] However, results from recent studies show that the relationship between TFR and maternal mortality is much more complex and may vary from one country to another.[30,65,71,72] A plausible mechanism to explain an inverse correlation between TFR and maternal mortality has been referred to as the "fertility paradox" emerging in advanced stages of demographic transition, when TFR falls under 2.5.[30] While early stages of fertility reduction would be associated with a decreased number of children per woman without a substantial delay of motherhood, later stages of fertility reduction appear to be primarily associated with delayed motherhood.[30,40,63,65,72,73] The net effect of this change would be an increase in pregnancies among women over 35 years old, which in turn increases the risk of complications and mortality from non-obstetric pre-existing medical conditions such as

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hypertension, diabetes, renal disease, and obesity, as well as obstetric conditions such as gestational hypertension, pre-eclampsia, gestational diabetes, postpartum haemorrhage, recurrent miscarriage, caesarean section, and indirect causes.[40,65,71-77] A recent study in Mexico showed that over 75% of maternal deaths are related to these causes.[37] Considering a TFR of 2.3 for this country in 2011, a fertility paradox phenomenon may be underlying the inverse correlations between TFR and MMR or MMR_{AO} observed in this study. Access to adequate pre-conception counselling and family planning programs to promote healthy childbearing before 35 years of age may be useful for addressing the problem of an excessively delayed motherhood, in addition to preventing unplanned pregnancies.

Alternative multivariate models identified clean water and sanitation as variables influencing maternal and abortion-related mortality in Mexican states. These findings are consistent with the association of such environmental risk factors with maternal mortality.[30,78,79] A recent systematic review and meta-analysis proposed plausible mechanisms to explain this association:[79] first, poor hygiene conditions may lead to sepsis during childbirth, one of the main causes of maternal deaths worldwide.[78] Second, exposure to poor water and sanitation increases the likelihood of repeated water-borne infections, which may lead to long-term detrimental effects on the female population of fertile age.[79] Considering current disparities among Mexican states in the access to clean water and sanitation (ranging from 62.0% to 99.2%), this study's findings highlight the potential positive impact of these basic elements of human development to continue improving maternal health in Mexico and other developing countries.

The present study found that female literacy was a major variable influencing all mortality outcomes studied, explaining between 11.9% and 50.9% of the variance among Mexican states. For each 1% increase in female literacy, decreases of 1.1 in MMR, 0.07 in MMR_{AO}, and 0.12 in iAMR per 100,000 live births were estimated. The gap in female literacy among states, ranging from 77.5% to 96.5%, suggests that public programmes directed to increase women's education

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level may have a positive impact on maternal health in Mexico. In addition to a direct impact on maternal mortality,[10,30,80,81,82] women's education is correlated with other major predictors of maternal health, such as skilled attendance at birth,[30,83,84] access to antenatal care,[3-5] fertility rate,[10,30,85] family planning,[86] and contraceptive use.[87,88] Since education is likely to indicate early life circumstances and future socioeconomic outcomes,[89-91] women's education level may represent an antecedent variable impacting the reproductive behaviour, use of maternal health facilities and family planning programs, and access to improved sanitation.[30] Furthermore, because women's literacy can explain territorial differences in maternal mortality, predictive models of MMR considering differences in women's education level[10] are likely to be more precise than models neglecting to consider education,[12,68] as a recent comparative analysis suggests.[92]

Finally, intimate-partner violence against women over the last year was identified as an additional factor influencing maternal and induced abortion-related mortality. For each 1% increase in intimate-partner violence, increases of 0.8 in MMR and 0.1 in iAMR per 100,000 live births were estimated, explaining 2.8% and 7.2% of the variance among Mexican states, respectively. An association between intimate-partner violence [93,94] and several detrimental maternal outcomes such as antenatal haemorrhage,[95] vaginal bleeding,[96] antenatal hospitalisation,[96] caesarean section,[96] pre-term birth,[96] miscarriages,[97] pregnancy termination,[97,98] repeated abortion,[99] perinatal death,[95] femicide,[100] and poor mental health outcomes,[101] including suicide attempt,[102] has been previously described. In addition, because sexual coercion[103-106] and abuse[93] have been identified as strong predictors of induced abortion, these factors may influence MMR and iAMR, which warrants further research. Recent reports suggest that detection of violence against pregnant women during prenatal visits[107,108] and subsequent interventions by skilled health professionals may improve maternal outcomes.[109,110] Given the current statistics of intimate-partner violence against women observed in Mexican states (ranging from 6.3% in Oaxaca to 20.9% in the Federal District), such interventions may contribute to improve maternal health.

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Limitations

Paraphrasing Geoffrey Rose,[111] epidemiological research traditionally distinguishes two kinds of etiological questions. For instance, the question “Why do some pregnant women die from abortion or gestational hypertension and others do not?” is different from “Why do some populations exhibit more deaths of pregnant women because of abortion or gestational hypertension?” While the first question asks for the causes of “cases” at the individual level, the second asks for the causes of “incidence” at the population level; consequently, to answer these questions, different kinds of epidemiological studies are required. In this context, the examination of current abortion laws in 32 Mexican states provided an interesting natural experiment to assess whether more or less permissive legislation were associated to lower or higher incidences of maternal and abortion-related deaths, simultaneously controlling for multiple confounders at the population level. However, this study – based on aggregated data – cannot conclusively rule out the influence of different factors impacting maternal health to an individual level of analysis and therefore, an ecological fallacy,[112,113] should be avoided. In contrast, an individualistic fallacy[113,114] based on the “high-risk”[111] approach should also be avoided in the interpretation of these results.

A major limitation to evaluate the impact of abortion legislation in terms of permissiveness is the intra-state heterogeneity in criminal codes and the inability to randomly allocate population of individuals to univocally defined groups, apparently making the criterion to segregate into each group somewhat arbitrary. However, after thorough exploratory analyses considering both the number and the type of legal exemptions for the criminal prosecution of abortion, only the exemption of prosecution of abortion in cases of genetic or congenital foetal malformations in their criminal codes was found to provide clear differences in mortality outcomes. In the case of Mexican states, this criminal exemption hinges on the opinion of a physician stating that there are sufficient reasons to think that such alterations would result in an individual with serious physical

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or mental deficiencies.[38] Thus, this exemption would not contemplate criminal prosecution for an induced abortion in extreme cases of foetal malformation, such as holoprosencephaly (a failure to develop two cerebral hemispheres, lethal *in utero* or shortly after birth), or less extreme conditions, such as Down syndrome (trisomy of chromosome 21, characterized by survival into adulthood). In addition, it is reasonable to think that the presence or absence of this exemption, may reflect different cultural values and attitudes toward abortion itself.

This study relies on official sources of data for mortality outcomes, live births and covariates. Errors such as underreported deaths cannot be definitively ruled out. However, minimal errors are expected since 2002 because of the strengthening of the epidemiological surveillance system that year, incorporating maternal deaths audits to identify misclassifications and minimising underreport.[115] For instance, in a 2009 audit of maternal deaths conducted in Mexico identifying causes of deaths during the influenza A H1N1 epidemic, authors were able to distinguish subcategories of causes of deaths, including complications of spontaneous abortion, induced abortion, and unspecified abortion.[116] On the other hand, instrumental bias because of different methodologies used to assess the same variable in different populations is a frequent problem in studies of multiple populations. Nevertheless, each independent variable used for this study was compiled with a single instrument applied in all Mexican states, making instrumental bias unlikely.

A problem in countries with legal restrictions for pregnancy termination is the difficulty to obtain counts and rates of illegal abortions. Nevertheless, the problem of underreporting of illegal abortions does not translate necessarily to underreporting of deaths from complications of illegal procedures when specific codes of the ICD-10 are in use. Recent studies in Mexico [37] and Chile [117] suggest that both mortality and morbidity from complications of illegal abortions, or abortions without a known cause are registered using specific codes O05, O06 and O07 to differentiate them from complications of other types of abortions with a well-known cause. Consequently, these specific codes were considered for the construction of iAMR in the present

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study. Another concern is the possibility of misreporting or misclassification of deaths from induced abortion as deaths for other causes, for example, haemorrhage or sepsis. However, in Mexico this seems unlikely because of the maternal mortality audit discussed above and the parallel decreasing trend in overall maternal mortality observed in the present study. For instance, deaths from haemorrhage have decreased 17% between 2002 (10.6 deaths per 100,000 live births) and 2011 (8.8 per 100,000 live births). In addition, there is no reason to misreport deaths from a suspected illegal abortion considering the use of ICD10 codes O05, O06 and O07. Thus, iAMR appears to be an indicator that provides a reasonable method to circumvent the problem of underreporting of maternal deaths from complications of illegal procedures in subsequent epidemiological studies in Latin America.

Finally, although most variables, including those for abortion legislation, showed significant correlations with maternal mortality outcomes in Mexico, this study emphasises the importance of multivariate analyses correcting for multicollinearity between covariates and the presence of outliers on mortality outcomes. For instance, because it is not possible to completely separate statistical effect sizes of highly correlated terms in multiple regression equations, separate alternative analyses are required. In addition to seeking unbiased effect sizes for significant predictors, any statistical association requires a plausible mechanism before making causal inferences at the population level.

CONCLUSION

This population-based natural experiment, using virtually complete official vital statistics of live births and maternal deaths in 32 Mexican states between 2002 and 2011, showed that maternal and abortion-related mortality ratios were lower in states with less permissive abortion legislation compared to states with more permissive legislation. Nevertheless, the observed differences between populations were not attributable to abortion legislation by itself. In fact, exhaustive multivariate analyses showed that these differences were largely explained by other factors such

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as women's literacy, maternal healthcare, water, sanitation, fertility rate and violence against women. These findings suggest that favourably addressing disparities in these factors may facilitate an epidemiologic transition toward low maternal mortality rates in developing countries during the post-MDG agenda.

FOOTNOTES

*MMR is the quotient between the number of deaths from conditions related to or aggravated by pregnancy, childbirth or puerperium, and the number of live births during the same period of time. For purposes of comparison, this ratio is usually amplified by 10,000 or 100,000 observed live births.

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CONTRIBUTORS

EK was the leading author. EK and MC conceptualized the study. EK, MC, FP, JS, and SH contributed to the study design. MB, FP, SH, and SG were directly involved in the acquisition of data. SG reviewed abortion legislation for each state with the advice of FP, SH, and PA. EK, MC, PA, and MB had the main responsibility for data analysis and FP, JS, SH, BC, SG, and JT had full access to data, including results of statistical analyses. EK, MC, PA, MB, and SG drafted the

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manuscript, and FP, JS, SH, BC, and JT reviewed and commented on drafts and approved the final manuscript. EK is the guarantor of the study, accepts full responsibility for the research, had access to the data, and controlled the decision to publish.

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COMPETING INTERESTS

None.

ETHICS APPROVAL, DATA SHARING AND TRANSPARENCY

Ethical approval: The study did not require any ethics committee approval.

Transparency: As guarantor of the study, EK assures that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Data sharing: All datasets employed are included in the supplementary material. Any additional information can be requested to the corresponding author at ekoch@melisainstitute.org

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FIGURE LEGENDS

Figure 1. Mortality ratios and the proportion of abortion-related deaths by place of residence in states with less and more permissive abortion legislation. Left panels illustrate trends in MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of residence between 2002 and 2011 in Mexican states, grouped as with less permissive (in dark green) or more permissive (in cyan) in terms of abortion legislation in their criminal code (see Material and Methods). For comparison, trends for the whole Mexican country (all states) are depicted as dotted lines. Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively), and the whole Mexican country (hollow bars).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with an abortive outcome.

Figure 2. Mortality ratios and the proportion of abortion-related deaths by place of occurrence in states with less and more permissive abortion legislation. Left panels illustrate trends in MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of occurrence between 2002 and 2011 in Mexican states, grouped as with less permissive (in dark green) or more permissive (in cyan) in terms of abortion legislation in their criminal code (see Material and Methods). For comparison, trends for the whole Mexican country (all states) are depicted as dotted lines. Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively), and the whole Mexican country (hollow bars).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

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Figure 3. Average mortality ratios in states with more or less permissive abortion legislation between 2002 and 2011. Political maps of Mexican states are shown for average MMR (top panel) and average iAMR (bottom panel) for the 2002-2011 period, indicating whether they exhibit less (orange dots) or more (yellow dots) permissive abortion legislation, in terms of abortion legislation in their criminal code (see Material and Methods). Increasing blue colour indicates an increase in MMR or iAMR, on a quintile scale (see legend of each panel).

Abbreviations: Ag., Aguascalientes; Co., Colima; FD., Federal District; iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; Mo., Morelos; Tl., Tlaxcala.

Figure 4. Mortality ratios and the proportion of abortion-related deaths by place of residence in states with or without a constitutional amendment to protect the unborn starting at conception. Left panels illustrate trends for MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of residence between 2008 and 2011 in Mexican states, grouped as with amendment (in dark green) or without amendment (in cyan) in terms of abortion legislation in their criminal code (see Material and Methods). Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

Figure 5. Mortality ratios and the proportion of abortion-related deaths by place of occurrence in states with or without a constitutional amendment to protect the unborn starting at conception. Left panels illustrate trends for MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of occurrence between 2008 and 2011 in Mexican states, grouped as with amendment (in dark green) or without amendment (in cyan) in terms of exhibiting or not a constitutional amendment to protect the unborn starting at conception (Figure S1, Supplementary Material).

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Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

Figure 6. Mortality ratios and the proportion of abortion-related deaths by place of residence in states with or without a constitutional amendment to protect the unborn starting at conception: focus on the Federal District. Left panels illustrate trends for MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of residence between 2008 and 2011 in Mexican states, grouped as with amendment" (in dark green), without amendment (in cyan), and the Federal District (in green) in terms of exhibiting or not an constitutional amendment (the Federal District of Mexico was not included in this group to be illustrated separately) to protect the unborn starting at conception (Figure S1, Supplementary Material). Right panels show average ratios and proportion of abortion-related deaths for each group (dark green, cyan, and green bars, respectively).

* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

Figure 7. Mortality ratios and the proportion of abortion-related deaths by place of occurrence in states with or without constitutional amendment to protect the unborn starting at conception: focus on the Federal District. Left panels illustrate trends for MMR (top panel), MMR_{AO} (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of occurrence between 2008 and 2011 in Mexican states, grouped as with amendment (in dark green), without amendment (in cyan), and the Federal District (in green) in terms of exhibiting or not a constitutional amendment (the Federal District of

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* $p<0.05$ using *Z*-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

Figure 8. Proportional contribution of independent variables to observed differences in maternal mortality outcomes among Mexican states in primary and alternative multivariate regression models.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMR_{AO}, maternal mortality ratio with abortive outcome.

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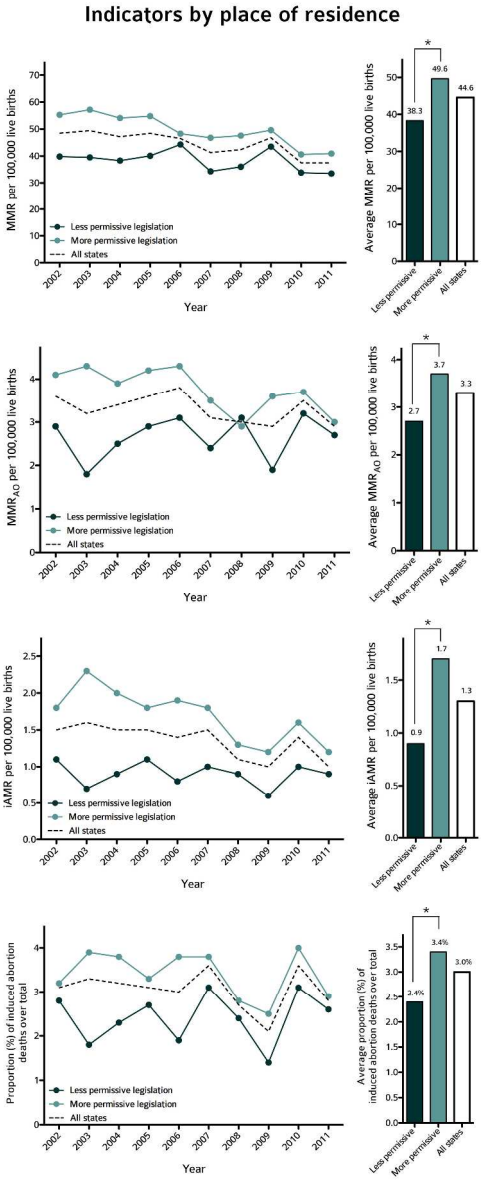

Mortality ratios and the proportion of abortion-related deaths by place of residence in states with less and more permissive abortion legislation. Left panels illustrate trends in MMR (top panel), MMRAO (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of residence between 2002 and 2011 in Mexican states, grouped as with less permissive (in dark green) or more permissive (in cyan) in terms of abortion legislation in their criminal code (see Material and Methods). For comparison, trends for the whole Mexican country (all states) are depicted as dotted lines. Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively), and the whole Mexican country (hollow bars).

* p<0.05 using Z-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMRAO, maternal mortality ratio with an abortive outcome.

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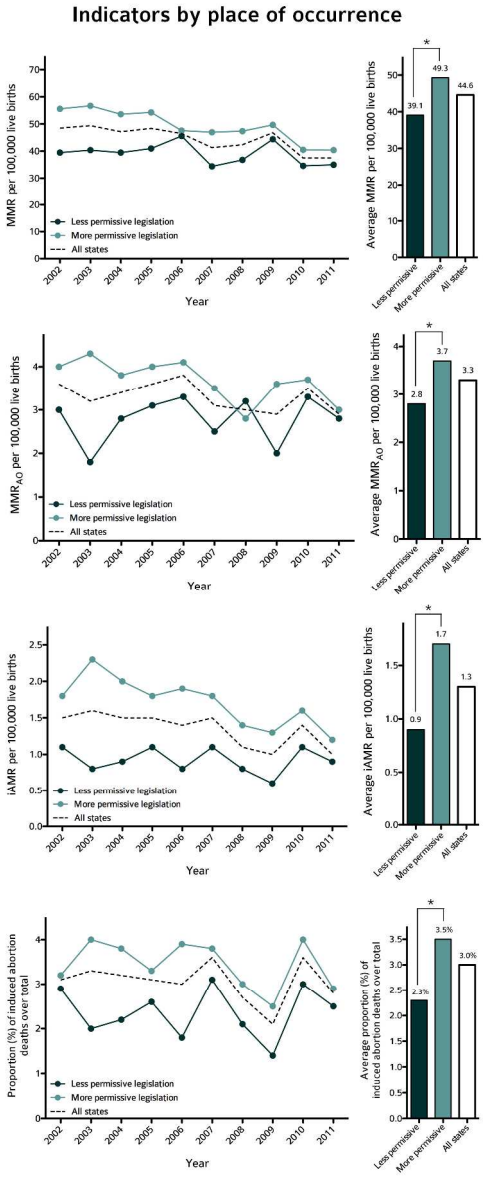

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Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMRAO, maternal mortality ratio with abortive outcome.

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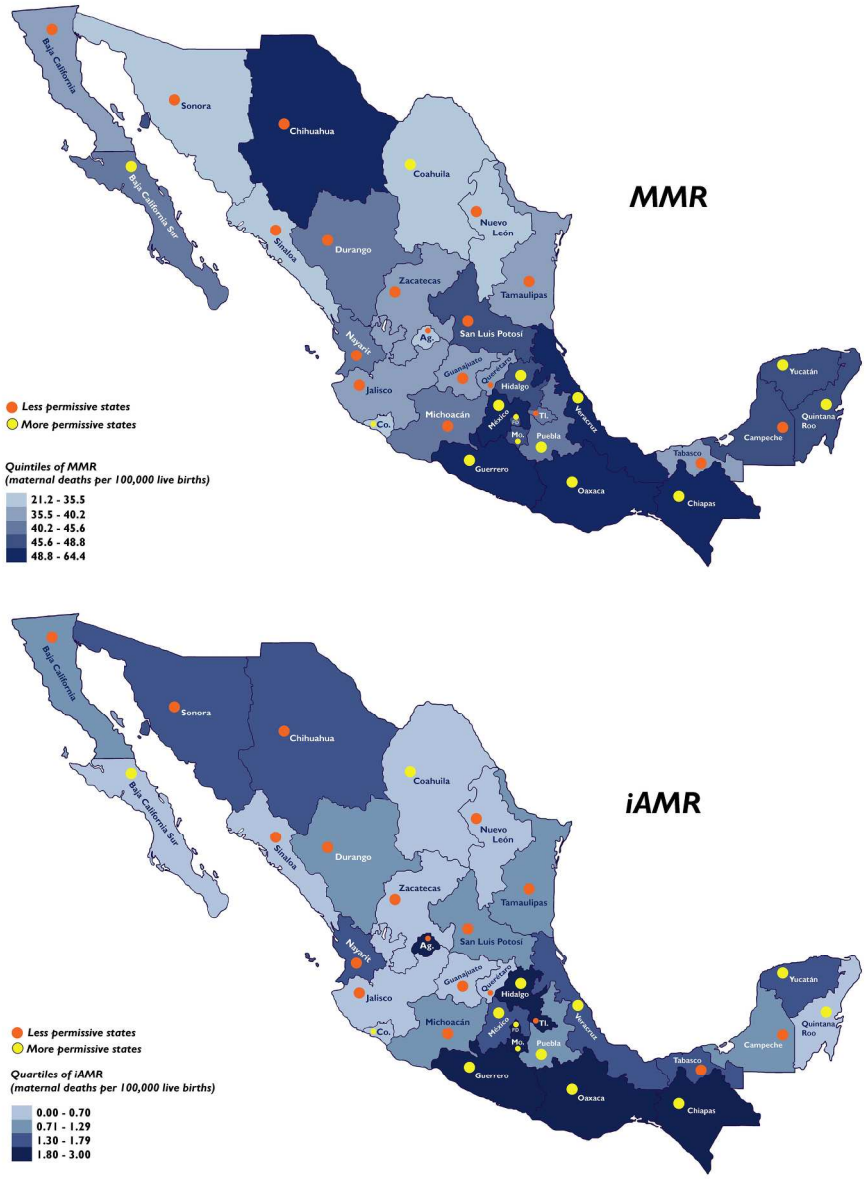

Average mortality ratios in states with more or less permissive abortion legislation between 2002 and 2011. Political maps of Mexican states are shown for average MMR (top panel) and average iAMR (bottom panel) for the 2002-2011 period, indicating whether they exhibit less (orange dots) or more (yellow dots) permissive abortion legislation, in terms of abortion legislation in their criminal code (see Material and Methods). Increasing blue colour indicates an increase in MMR or iAMR, on a quintile scale (see legend of each panel).

Abbreviations: Ag., Aguascalientes; Co., Colima; FD., Federal District; iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; Mo., Morelos; Tl., Tlaxcala.

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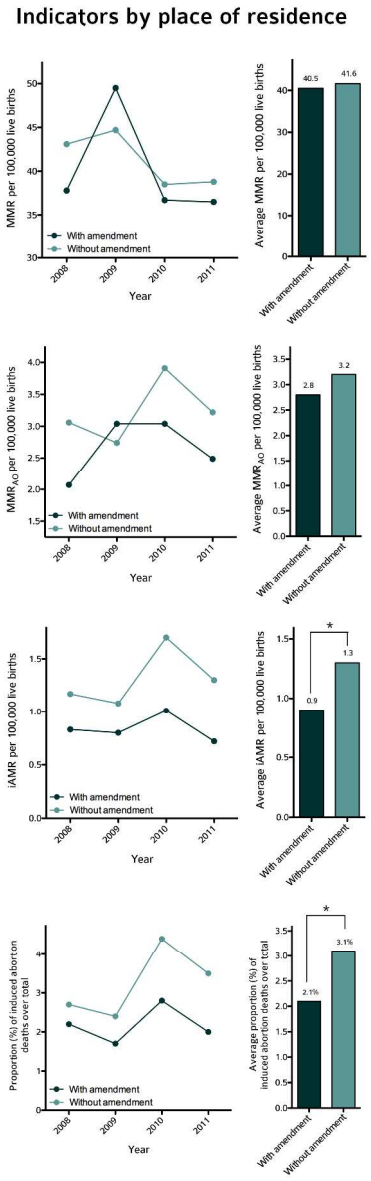

Mortality ratios and the proportion of abortion-related deaths by place of residence in states with or without a constitutional amendment to protect the unborn starting at conception. Left panels illustrate trends for MMR (top panel), MMRAO (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of residence between 2008 and 2011 in Mexican states, grouped as with amendment (in dark green) or without amendment (in cyan) in terms of abortion legislation in their criminal code (see Material and Methods). Right panels show average ratios and proportion of abortion-related deaths for each group (dark green and cyan bars, respectively).

* p<0.05 using Z-test.

Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMRAO, maternal mortality ratio with abortive outcome.

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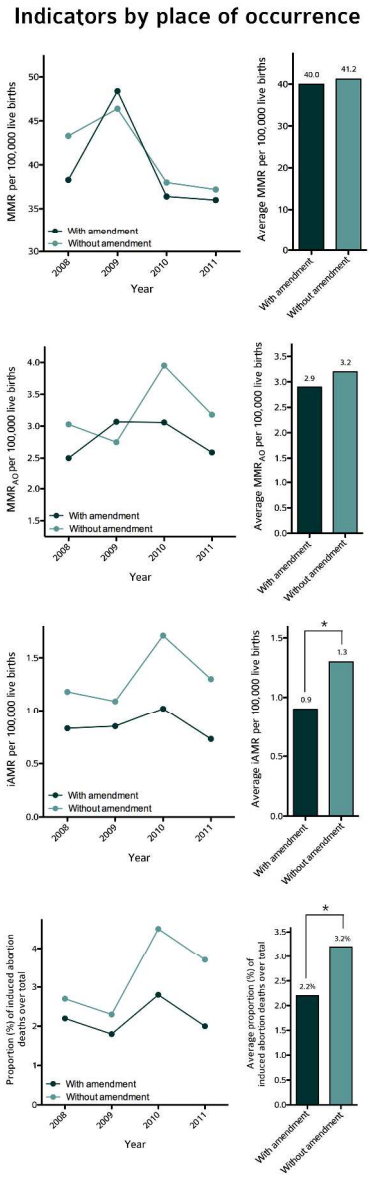

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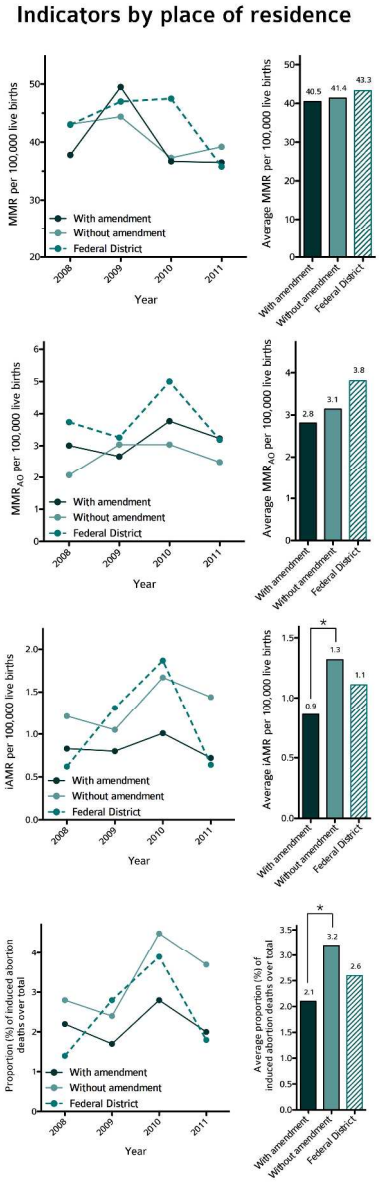

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Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMRAO, maternal mortality ratio with abortive outcome.
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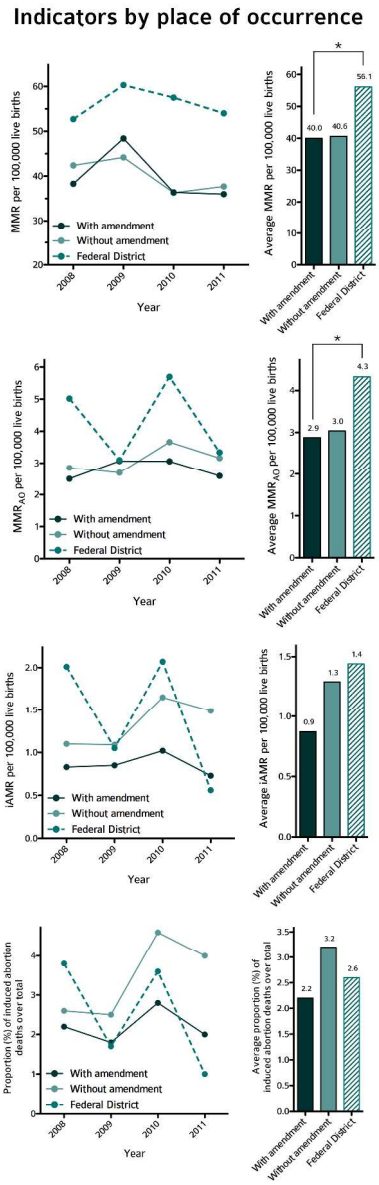

Mortality ratios and the proportion of abortion-related deaths by place of occurrence in states with or without constitutional amendment to protect the unborn starting at conception: focus on the Federal District. Left panels illustrate trends for MMR (top panel), MMRAO (middle top panel), iAMR (middle bottom panel), and the proportion of abortion-related deaths (bottom panel) by place of occurrence between 2008 and 2011 in Mexican states, grouped as with amendment (in dark green), without amendment (in cyan), and the Federal District (in green) in terms of exhibiting or not a constitutional amendment (the Federal District of Mexico was not included in this group to be illustrated separately) to protect the unborn starting at conception (Figure S1, Supplementary Material). Right panels show average ratios and proportion of abortion-related deaths for each group (dark green, cyan, and green bars, respectively).
* p<0.05 using Z-test.
Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMRAO, maternal mortality ratio with abortive outcome.
312x912mm (300 x 300 DPI)

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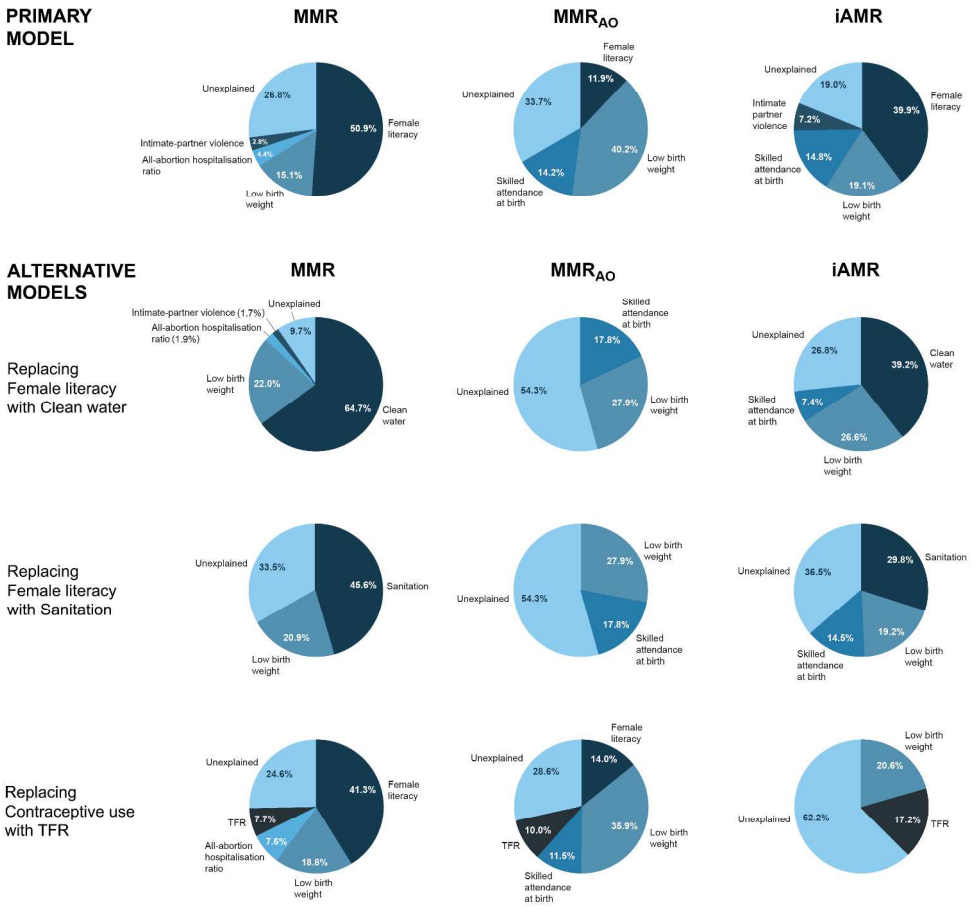

Proportional contribution of independent variables to observed differences in maternal mortality outcomes among Mexican states in primary and alternative multivariate regression models.
Abbreviations: iAMR, induced abortion mortality ratio; MMR, maternal mortality ratio; MMRAO, maternal mortality ratio with abortive outcome.
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Abortion legislation, maternal healthcare, fertility, female literacy, sanitation, violence against women, and maternal deaths: a natural experiment in 32 Mexican states

Elard Koch, Monique Chireau, Fernando Pliego, Joseph Stanford, Sebastián Haddad, Byron Calhoun, Paula Aracena, Miguel Bravo, Sebastián Gatica, and John Thorp

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Figure S1 Mexican states with and without constitutional amendment to protect the unborn starting at conception between 2008 and 2011

Political maps of Mexican states are shown for 2008 (top panel), 2009 (middle panel), and 2010 (bottom panel), indicating whether they exhibit a constitutional amendment to protect the unborn starting at conception[1] in dark green (with amendment) and cyan (without amendment). The state of Chihuahua enacted its political constitution in 1994; Baja California, Morelos, and Sonora in 2008; Campeche, Chiapas, Colima, Durango, Guanajuato, Jalisco, Nayarit, Oaxaca, Puebla, Querétaro, Quintana Roo, San Luis Potosí, and Yucatán in 2009; and Tamaulipas in 2010. Campeche revoked the amendment in 2010.

Ag, Aguascalientes; Co, Colima; FD, Federal District; Mo, Morelos; Tl, Tlaxcala.

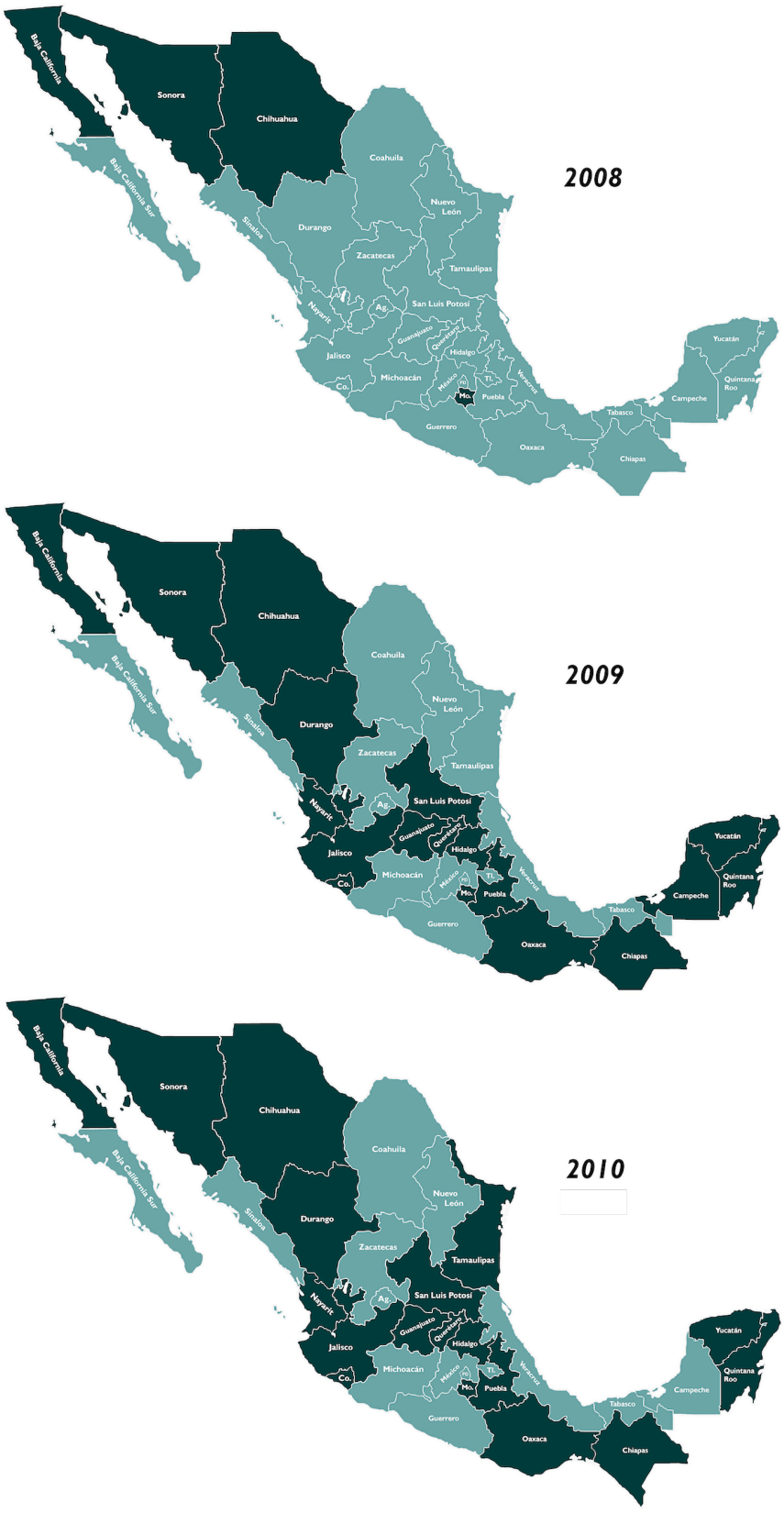

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Table S1 Detailed description of independent variables considered in the natural experiment of 32 Mexican states on maternal mortality outcomes

Independent variable (abbreviated name)	International Definition	Significance for epidemiological studies	Scale of measure	Source of data
Abortion legislation	Exemption from prosecution of abortion when performed with the consent of the mother and when a physician's opinion dictates there are sufficient reasons to suppose that the foetus suffers from genetic or congenital conditions yielding serious physical or mental deficiencies.	It has been proposed that restriction of induced abortion is detrimental to maternal mortality.[2-4] Among the eight exemptions for criminal prosecution of abortion in Mexico, serious genetic and congenital foetal malformation was selected as suggestive of more permissive abortion legislation. It is reasonable to think that states excluding this exemption may be culturally less willing to accept pregnancy termination as a legal practice.[5-8]	Dichotomous data: states with less permissive (1) and more permissive (0) abortion legislations.	National Office for the Judiciary of the Mexican government.[1]
Constitutional amendment	Enactment of an amendment to the constitution that explicitly protects the unborn starting at conception.	It is plausible that states including such amendment may be culturally less willing to accept the legal practice of pregnancy termination.[5-8]	Dichotomous data: states with (1) and without (0) constitutional amendment.	National Office for the Judiciary of the Mexican government.[1]
Clean water	Proportion of people with access to a source of clean drinking water less than 1 kilometre away from its place of use, and that it is possible to reliably obtain at least 20 litres per member of a household per day.[9]	Pregnant women may be particularly vulnerable to water-related diseases such as vitamin deficiency, trachoma and hepatitis. In addition, access to clean water is an integral part of preventing infections in pregnant women, especially in medical facilities. Puerperal sepsis introduced at the time of delivery through unhygienic environment or practices may be a plausible mechanism.[10] Increased water access has been associated with decreased maternal mortality ratio.[9-11]	Percentage of occupied private dwellings with clean water availability in each state during 2010.	INEGI: 2010 Census of Population and Housing.[12]
Sanitary sewer coverage (Sanitation)	Proportion of people using improved sanitation facilities (*e.g.*, public sewer connection, septic system connection, pour-flush latrine, simple pit latrine, ventilated improved pit latrine).[9]	Increased access to sanitary sewer has been associated with decreased maternal mortality ratio.[9-11] Puerperal sepsis introduced at the time of delivery through unhygienic environment or practices, or repeated exposure to infections during pregnancy may be a plausible mechanism.[10]	Percentage of occupied private dwellings with availability of sewer drainage in each state during 2010.	INEGI: 2010 Census of Population and Housing.[12]
Total fertility rate (TFR)	Average number of children that would be born per woman if all women lived to the end of their childbearing years and bore children according to a given fertility rate at each age.[13]	TFR is considered to be a result of the overall factors influencing the reproductive behaviour of the entire female population over time. It has been proposed that fertility is an important determinant of reduced maternal mortality.[11,14-16] However, it has been reported that the effect of TFR on maternal mortality trends disappears when controlling for the education level of women.[11,17,18]	Average total fertility rate of each state between 2002 and 2011.	INEGI: Populations, Homes, and Housing.[19]
Contraceptive use	Percentage of women who are currently using, or whose sexual partner is currently using, at least one method of contraception, regardless of the method used.[20]	Contraceptive use is considered a major component of family planning, and it is thought to decrease unplanned pregnancies, unsafe abortion, and fertility rates, leading to a decrease in maternal mortality.[16,21,22]	Percentage of married or in-union women 15 years and older who were using contraceptive methods in each state during 2009.	INEGI: National Survey of Demographics Dynamics 2009.[23]

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Table S1 Detailed description of independent variables considered in the natural experiment of 32 Mexican states on maternal mortality outcomes (Continued)

Independent variable (abbreviated name)	International Definition	Significance for epidemiological studies	Scale of measure	Source of data
Skilled attendance at birth	Childbirth attended by a health professional.[24]	This is an indicator of women's use of maternal healthcare care services and a measure of the health system's functioning and potential to provide adequate coverage for deliveries.[25-28] In addition, this factor is positively correlated to access to antenatal care and institutional delivery.[11,29,30]	Percentage of observed live births delivered by a physician, nurse or midwife in each state during 2010.	INEGI: Live births registry.[31]
Low birth weight	Birth weight of a live born infant of less than 2,500g (5.5 pounds), regardless of the gestational age.[32]	Risk factors in the mother that likely contribute to low birth weight and pre-term birth include extreme ages, multiple pregnancies, previous infants with low birth weight, poor nutrition, heart disease or hypertension, substance and alcohol abuse, and insufficient prenatal care. Environmental risk factors include smoking, lead exposure, and other types of air pollutions. In addition, induced abortion by itself has been identified as major individual risk factor for preterm birth and low birth weight en subsequent pregnancies.[33-37]	Percentage of observed live births with low birth weight in each state during 2010.	INEGI: Society and Government.[38]
Female literacy	Percentage of the female population of ages 15 and above who can understand, read and write a short, simple statement on their everyday life. Generally, 'literacy' also encompasses 'numeracy', the ability to make simple arithmetic calculations. This indicator is calculated by dividing the number of literates aged 15 years and over by the corresponding age group population and multiplying the result by 100.[39]	The relationship between literacy on maternal morality is both direct and indirect. Literate women are more likely to maintain adequate care during and after pregnancy, make better decisions regarding their health and well-being, better access and use information, and are better able to control their own fertility.[11,14,28,40-42] Recently, education of women has been shown to be a major determinant in the improvement of maternal health.[11]	Percentage of the female population of ages 15 and above who can understand, read and write a short, simple statement on their everyday life in each state during 2010.	INEGI: 2010 Census of Population and Housing.[12]
All-abortion hospitalisation ratio	Ratio of all abortion-related hospitalisations per women of fertile age over 100 live births.	Recent studies in low maternal mortality settings, show that this indicator is a measure of access to opportune or immediate emergency care for women experiencing complications due to any kind of abortion.[11,43-46] However, the relationship between all-abortion hospitalisation ratio and MMR may be bidirectional. A direct correlation may be an indicator of high rates of in-hospital deaths secondary to complications of pregnancy termination[47] or alternatively that an important number of unsafe abortions are being conducted.[48,49]	Ratio of all-abortion related hospitalisations in each state between 2000 and 2008 per 100 live births	Schiavon *et al.*: Series of all-abortion hospitalisations.[43] INEGI: Live births registry.[31]
Intimate-partner violence	Any act of gender-based violence that results in, or is likely to result in, physical, sexual or mental harm or suffering to women, including threats of such acts, coercion or arbitrary deprivation of liberty, whether occurring in public or in private life.[50]	Violence against pregnant women increases the risk of death, which makes this variable a potential factor influencing maternal mortality of a territory.[51,52] In addition, factors such as coercion, sexual or intimate partner violence have been consistently identified in the literature as strong predictors of abortion.[51,53-55]	Percentage of married or in-union women of ages 15 and above who have suffered severe intimate partner violence during the past 12 months in each state during 2010.	INEGI: Overview of Violence Against Women in the United Mexican States.[56]

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Table S2 Observed live births by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (*l*)	27524	26165	26527	25619	25434	25822	26509	25800	26583	27427	263410
Baja California (*l*)	58347	57938	60925	61844	64909	66114	65060	63709	63559	65631	628036
Baja California Sur (*m*)	11714	12030	12461	11509	12256	13110	13993	13343	13988	13412	127816
Campeche (*l*)	15138	15808	17144	18246	16629	16962	18105	17307	20380	22138	177857
Coahuila (*m*)	60052	56410	57393	55962	56458	58898	58575	58132	56972	58882	577734
Colima (*m*)	13012	12477	13272	12276	11762	12765	12723	13447	13796	14054	129584
Chiapas (*m*)	187312	144410	133979	137488	132205	155885	153738	145085	175382	168256	1533740
Chihuahua (*l*)	84086	78192	75468	77840	72731	76154	82263	76300	74063	69376	766473
Distrito Federal (*m*)	170405	159844	167285	163212	155703	160735	160377	153237	160057	156549	1607404
Durango (*l*)	45135	44437	39519	39519	38424	40284	39292	39736	42514	41922	410782
Guanajuato (*l*)	123313	130183	123312	127290	118270	127270	125187	125272	126741	124003	1250841
Guerrero (*m*)	103732	137277	116293	101699	101972	116033	101554	98945	119780	113692	1110977
Hidalgo (*m*)	65715	62757	68906	61410	62985	67543	64237	61431	62185	63380	640549
Jalisco (*l*)	160145	157618	158748	155082	153636	157334	156782	154738	161543	163123	1578749
México (*m*)	334352	332666	343150	335257	330108	346720	342830	355392	335898	327165	3383538
Michoacán (*l*)	114588	121624	112451	104243	99531	104550	107123	107287	116260	111362	1099019
Morelos (*m*)	38714	36373	35648	35810	34072	40061	38295	36760	40210	40230	376173
Nayarit (*l*)	23667	24240	24517	22338	24213	24548	24972	24598	24639	24949	242681
Nuevo León (*l*)	91424	88195	90440	87645	87634	91855	91247	91490	94119	93747	907796
Oaxaca (*m*)	120286	119465	122467	112991	106831	122579	118307	108978	109624	98888	1140416
Puebla (*m*)	172667	169725	158391	165560	156914	158165	164257	155738	160571	146865	1608853
Querétaro (*l*)	36928	38113	40075	41902	39504	43459	42460	41260	40863	41714	406278
Quintana Roo (*m*)	24370	23754	23711	24363	27235	29110	29311	29539	28999	28848	269240
San Luis Potosí (*l*)	60240	59917	61214	59005	58021	60223	59365	58300	58583	57549	592417
Sinaloa (*l*)	68625	63456	65065	61615	59947	60668	61559	59942	61233	60208	622318
Sonora (*l*)	57435	54811	53631	53609	53347	55481	55372	53930	54110	54756	546482
Tabasco (*l*)	52202	51146	55720	52744	52545	54978	51979	55402	49844	49575	526135
Tamaulipas (*l*)	70513	66497	72847	74080	71556	76472	74492	72381	69211	66892	714941
Tlaxcala (*l*)	28347	27896	29225	26754	27507	29011	27522	27276	27076	27867	278481
Veracruz (*m*)	195458	199471	190790	189414	179690	184287	187560	173101	174086	171417	1845274

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Table S2 Observed live births by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Yucatán (*m*)	38006	38251	33855	35655	36576	37872	38562	38147	37703	36860	371487
Zacatecas (*l*)	36937	35198	35099	34131	33746	35722	35277	35304	35974	36629	354017
Less permissive states	**1154594**	**1141434**	**1141927**	**1123506**	**1097584**	**1146907**	**1144566**	**1130032**	**1147295**	**1138868**	**11366713**
More permissive states	**1535795**	**1504910**	**1477601**	**1442606**	**1404767**	**1503763**	**1484319**	**1441275**	**1489251**	**1438498**	**14722785**
United Mexican States	**2690389**	**2646344**	**2619528**	**2566112**	**2502351**	**2650670**	**2628885**	**2571307**	**2636546**	**2577366**	**26089498**

Official records of observed live births by place of residence were extracted from the National Institute of Statistics and Geography (INEGI),[31] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of observed live births by place of residence between 2002 and 2011.

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Table S3 Observed live births by place of occurrence in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (l)	29805	28378	28395	28002	27714	27888	28375	27509	28154	28282	282502
Baja California (l)	59327	58040	59776	60739	61643	62491	63053	61566	61071	61988	609694
Baja California Sur (m)	11355	11512	11877	11196	11816	12733	13639	14041	13673	13303	125145
Campeche (l)	14462	15027	16095	17045	15657	16103	17345	16585	18664	18844	165767
Coahuila (m)	60724	56967	57588	56463	57082	59170	58766	58343	57057	59060	581230
Colima (m)	13102	12742	13194	12716	12672	13786	13505	14075	14565	14990	135287
Chiapas (m)	188933	146005	135507	138955	133619	159278	157916	144841	175324	168480	1548858
Chihuahua (l)	83124	78214	74479	78215	73640	76752	82939	76888	74620	69785	768656
Distrito Federal (m)	222105	212947	222547	216405	201419	203892	199060	190625	193039	179731	2041830
Durango (l)	43980	43297	38845	38677	37564	39225	38531	38677	40960	39929	399625
Guanajuato (l)	123622	130878	130786	130367	121672	130727	128647	123935	125246	122593	1268473
Guerrero (m)	102376	135613	114506	100139	100033	113906	99358	96411	117110	111205	1090657
Hidalgo (m)	67275	64988	71342	64326	64373	68911	65372	62939	63052	63531	656109
Jalisco (l)	159163	156651	157292	154817	153363	157254	156862	155387	161748	163808	1576345
México (m)	283436	280954	287806	282571	285229	304542	304096	317021	300447	304178	2950280
Michoacán (l)	114859	120825	109175	100663	96497	100507	101936	101990	110477	104895	1061824
Morelos (m)	38860	36151	35763	36338	34955	40431	38923	37595	40690	40126	379832
Nayarit (l)	22171	22451	22560	20520	22231	22183	22278	22642	22809	22566	222411
Nuevo León (l)	91343	88209	90564	88382	88849	93185	92571	92973	95372	94857	916305
Oaxaca (m)	121148	119893	122401	112168	105733	120642	115788	106971	108721	98685	1132155
Puebla (m)	171432	168018	157109	163621	155048	155559	160850	150847	155177	142171	1579832
Querétaro (l)	39387	40634	42002	43149	41062	44894	43704	42704	42768	43548	423852
Quintana Roo (m)	24190	23498	23590	24291	26920	28610	28453	29310	28801	28819	266482
San Luis Potosí (l)	59804	59554	60102	58300	57005	59039	57808	55865	57063	57101	581661
Sinaloa (l)	68197	63287	64588	61592	59939	60684	61359	59350	61034	60445	620475
Sonora (l)	57453	54683	53751	53789	53586	55534	55199	53815	54147	54724	546675
Tabasco (l)	52715	51371	56024	53081	52951	55256	52593	56625	51958	52358	534933
Tamaulipas (l)	71498	67620	73925	74932	72248	76469	74640	73076	70312	68526	723306
Tlaxcala (l)	26924	26673	27663	25328	26007	27086	26241	26430	26543	27350	266245
Veracruz (m)	189144	193812	184046	183161	173955	178486	180907	167664	169126	165522	1785823

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Table S3 Observed live births by place of occurrence in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Yucatán (m)	38777	39015	34834	36673	37763	38923	39574	39065	38490	37605	380719
Zacatecas (l)	35920	34298	34064	33095	32630	34592	34294	34565	35423	35323	344204
Less permissive states	**1153754**	**1140090**	**1140086**	**1120693**	**1094258**	**1139869**	**1138375**	**1120582**	**1138324**	**1126922**	**11312953**
More permissive states	**1532857**	**1502115**	**1472110**	**1439023**	**1400617**	**1498869**	**1476207**	**1429748**	**1475287**	**1427406**	**14654239**
United Mexican States	**2686611**	**2642205**	**2612196**	**2559716**	**2494875**	**2638738**	**2614582**	**2550330**	**2613611**	**2554328**	**25967192**

Official records of observed live births by place of occurrence were extracted from the National Institute of Statistics and Geography (INEGI),[31] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of observed live births by place of occurrence between 2002 and 2011.

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Table S4 Total maternal deaths by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total †
Aguascalientes (*l*)	6	12	5	7	12	4	9	13	10	5	83
Baja California (*l*)	17	22	33	28	23	22	24	30	24	21	244
Baja California Sur (*m*)	6	9	4	3	4	8	5	5	4	4	52
Campeche (*l*)	11	9	7	11	10	3	7	8	8	10	84
Coahuila (*m*)	23	21	15	24	14	13	19	15	24	22	190
Colima (*m*)	2	3	4	1	6	2	4	3	‡	5	30
Chiapas (*m*)	94	106	96	82	82	78	92	71	69	60	830
Chihuahua (*l*)	50	33	34	57	43	46	38	55	39	46	441
Distrito Federal (*m*)	77	99	87	80	78	89	69	72	76	56	783
Durango (*l*)	14	19	24	14	26	14	23	13	15	13	175
Guanajuato (*l*)	58	62	53	42	43	40	39	60	42	42	481
Guerrero (*m*)	77	85	69	85	84	64	62	68	53	69	716
Hidalgo (*m*)	31	32	34	37	26	30	28	30	29	16	293
Jalisco (*l*)	50	56	66	52	77	46	52	81	48	36	564
México (*m*)	192	210	198	197	149	144	154	166	119	127	1656
Michoacán (*l*)	39	47	39	46	53	39	44	41	49	53	450
Morelos (*m*)	25	28	14	23	17	15	15	23	10	13	183
Nayarit (*l*)	16	15	10	18	7	5	9	12	8	10	110
Nuevo León (*l*)	22	10	12	20	24	17	23	25	14	25	192
Oaxaca (*m*)	80	50	64	70	54	70	67	66	59	50	630
Puebla (*m*)	88	89	87	74	63	58	62	78	58	59	716
Querétaro (*l*)	19	17	18	15	20	17	16	12	13	16	163
Quintana Roo (*m*)	12	14	11	13	13	14	17	10	13	13	130
San Luis Potosí (*l*)	42	38	32	25	19	30	17	28	22	24	277
Sinaloa (*l*)	19	11	18	23	20	25	18	18	18	9	179
Sonora (*l*)	23	18	18	19	25	20	14	21	12	22	192
Tabasco (*l*)	15	22	21	21	21	23	28	23	14	21	209
Tamaulipas (*l*)	23	22	26	31	35	25	33	24	26	10	255
Tlaxcala (*l*)	19	16	12	14	14	7	6	11	14	7	120
Veracruz (*m*)	113	94	100	82	79	99	98	93	78	81	917
Yucatán (*m*)	29	21	17	19	10	20	15	15	12	14	172
Zacatecas (*l*)	16	22	9	8	14	10	12	17	12	12	132
Less permissive states	**459**	**451**	**437**	**451**	**486**	**393**	**412**	**492**	**388**	**382**	**4351**
More permissive states	**849**	**861**	**800**	**790**	**679**	**704**	**707**	**715**	**604**	**589**	**7298**
United Mexican States	**1308**	**1312**	**1237**	**1241**	**1165**	**1097**	**1119**	**1207**	**992**	**971**	**11649**

Official records of maternal deaths (ICD-10 codes O00-O99, A34, B20-B24, and F53) by place of residence were extracted from the General Directorate of Health Information (DGIS),[57] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of maternal deaths by place of residence between 2002 and 2011.
‡ Not available.

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Table S5 Maternal deaths with abortive outcome by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (*l*)	0	1	0	0	3	2	2	0	1	0	9
Baja California (*l*)	3	1	7	1	2	1	0	2	4	3	24
Baja California Sur (*m*)	0	0	0	0	0	0	0	0	0	0	0
Campeche (*l*)	1	0	0	0	0	0	1	0	2	0	4
Coahuila (*m*)	1	2	0	0	2	1	0	0	2	1	9
Colima (*m*)	1	0	0	0	0	1	0	0	0	0	2
Chiapas (*m*)	9	11	9	5	10	5	6	2	4	4	65
Chihuahua (*l*)	2	3	1	5	2	0	3	2	6	3	27
Distrito Federal (*m*)	9	9	7	8	8	13	6	5	8	5	78
Durango (*l*)	1	0	0	0	1	0	7	0	1	1	11
Guanajuato (*l*)	5	0	3	5	4	2	2	4	2	2	29
Guerrero (*m*)	9	7	8	4	5	1	2	4	3	3	46
Hidalgo (*m*)	3	2	3	1	3	5	2	3	1	0	23
Jalisco (*l*)	3	2	3	4	6	5	5	6	6	2	42
México (*m*)	8	14	14	15	21	8	13	15	18	15	141
Michoacán (*l*)	3	2	5	5	5	4	2	1	3	6	36
Morelos (*m*)	2	2	3	2	0	0	1	2	2	0	14
Nayarit (*l*)	3	2	0	2	1	1	0	0	1	1	11
Nuevo León (*l*)	2	2	1	3	2	4	2	0	1	3	20
Oaxaca (*m*)	4	3	3	3	5	6	1	7	3	4	39
Puebla (*m*)	8	5	4	6	2	5	2	5	3	4	44
Querétaro (*l*)	0	0	0	2	2	1	0	0	1	2	8
Quintana Roo (*m*)	0	2	1	2	0	2	1	2	0	0	10
San Luis Potosí (*l*)	4	3	2	0	0	0	3	2	3	2	19
Sinaloa (*l*)	1	1	1	1	0	0	0	0	1	0	5
Sonora (*l*)	2	1	0	0	3	2	1	0	1	1	11
Tabasco (*l*)	0	0	4	1	2	3	2	0	0	3	15
Tamaulipas (*l*)	1	0	2	2	1	1	2	4	1	1	15
Tlaxcala (*l*)	1	2	0	2	0	1	2	0	1	0	9
Veracruz (*m*)	8	6	6	10	4	6	7	5	10	6	68
Yucatán (*m*)	1	2	0	4	0	0	2	2	1	1	13
Zacatecas (*l*)	2	0	0	0	0	1	1	1	2	1	8
Less permissive states	**34**	**20**	**29**	**33**	**34**	**28**	**35**	**22**	**37**	**31**	**303**
More permissive states	**63**	**65**	**58**	**60**	**60**	**53**	**43**	**52**	**55**	**43**	**552**
United Mexican States	**97**	**85**	**87**	**93**	**94**	**81**	**78**	**74**	**92**	**74**	**855**

Official records of maternal deaths with abortive outcome (ICD-10 codes O00-O08) by place of residence were extracted from the General Directorate of Health Information (DGIS),[57] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of maternal deaths with abortive outcome by place of residence between 2002 and 2011.

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Table S6 Induced abortion-related deaths by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (*l*)	0	1	0	0	2	2	1	0	0	0	6
Baja California (*l*)	0	1	3	0	0	0	0	0	1	0	5
Baja California Sur (*m*)	0	0	0	0	0	0	0	0	0	0	0
Campeche (*l*)	1	0	0	0	0	0	0	0	1	0	2
Coahuila (*m*)	1	1	0	0	0	1	0	0	1	0	4
Colima (*m*)	0	0	0	0	0	0	0	0	0	0	0
Chiapas (*m*)	7	7	3	1	5	2	3	2	1	0	31
Chihuahua (*l*)	2	2	0	2	0	0	1	1	2	1	11
Distrito Federal (*m*)	3	3	2	6	2	7	1	2	3	1	30
Durango (*l*)	1	0	0	0	0	0	3	0	1	0	5
Guanajuato (*l*)	1	0	1	2	0	0	0	0	1	1	6
Guerrero (*m*)	5	6	6	3	4	1	2	1	2	3	33
Hidalgo (*m*)	1	0	3	0	2	3	1	1	1	0	12
Jalisco (*l*)	0	0	0	1	2	3	1	1	1	0	9
México (*m*)	0	9	6	6	9	3	8	4	7	7	59
Michoacán (*l*)	2	1	1	3	0	1	0	0	1	3	12
Morelos (*m*)	0	2	2	0	0	0	0	2	1	0	7
Nayarit (*l*)	1	1	0	0	1	1	0	0	0	0	4
Nuevo León (*l*)	1	0	0	0	0	0	1	0	0	0	2
Oaxaca (*m*)	4	2	2	1	3	4	1	2	2	1	22
Puebla (*m*)	4	1	2	3	0	4	1	2	1	1	19
Querétaro (*l*)	0	0	0	1	0	1	0	0	0	1	3
Quintana Roo (*m*)	0	1	1	0	0	0	0	0	0	0	2
San Luis Potosí (*l*)	1	0	0	0	0	0	1	0	1	2	5
Sinaloa (*l*)	0	0	0	0	0	0	0	0	0	0	0
Sonora (*l*)	1	1	0	0	2	1	1	0	1	1	8
Tabasco (*l*)	0	0	4	0	2	2	0	0	0	1	9
Tamaulipas (*l*)	1	0	1	1	0	0	0	4	0	0	7
Tlaxcala (*l*)	1	1	0	2	0	1	1	0	1	0	7
Veracruz (*m*)	2	2	3	4	1	2	1	2	5	3	25
Yucatán (*m*)	0	0	0	2	0	0	2	0	0	1	5
Zacatecas (*l*)	0	0	0	0	0	0	0	1	1	0	2
Less permissive states	**13**	**8**	**10**	**12**	**9**	**12**	**10**	**7**	**12**	**10**	**103**
More permissive states	**27**	**34**	**30**	**26**	**26**	**27**	**20**	**18**	**24**	**17**	**249**
United Mexican States	**40**	**42**	**40**	**38**	**35**	**39**	**30**	**25**	**36**	**27**	**352**

Official records of induced abortion related deaths (ICD-10 codes O04-O07) by place of residence were extracted from the General Directorate of Health Information (DGIS),[57] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of induced abortion related deaths by place of residence between 2002 and 2011.

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Table S7 Total maternal deaths by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (*l*)	7	14	5	8	12	5	9	19	10	5	94
Baja California (*l*)	17	20	34	27	24	23	24	33	26	22	250
Baja California Sur (*m*)	6	9	4	4	4	8	5	5	3	3	51
Campeche (*l*)	10	8	8	9	10	3	7	8	8	10	81
Coahuila (*m*)	25	17	16	22	17	14	19	18	20	20	188
Colima (*m*)	2	4	2	1	4	3	5	3	1	3	28
Chiapas (*m*)	92	104	93	79	77	75	86	63	65	55	789
Chihuahua (*l*)	49	33	35	56	43	43	39	56	39	47	440
Distrito Federal (*m*)	134	159	152	140	129	122	105	115	111	97	1264
Durango (*l*)	11	19	20	15	20	13	22	11	14	9	154
Guanajuato (*l*)	58	61	51	38	45	35	40	62	39	41	470
Guerrero (*m*)	78	85	67	79	80	61	58	67	51	62	688
Hidalgo (*m*)	28	32	29	34	24	29	26	29	26	13	270
Jalisco (*l*)	52	58	67	51	76	48	51	74	51	40	568
México (*m*)	145	159	142	145	109	119	128	129	91	99	1266
Michoacán (*l*)	36	43	37	45	49	33	42	40	46	52	423
Morelos (*m*)	24	25	12	23	14	16	15	25	9	13	176
Nayarit (*l*)	14	14	11	16	7	4	10	11	6	11	104
Nuevo León (*l*)	26	17	14	25	26	22	24	27	23	33	237
Oaxaca (*m*)	76	48	60	71	53	66	66	63	59	50	612
Puebla (*m*)	89	87	89	71	58	60	61	79	59	58	711
Querétaro (*l*)	19	18	22	23	22	21	16	11	14	15	181
Quintana Roo (*m*)	9	15	9	9	10	12	15	9	11	12	111
San Luis Potosí (*l*)	43	38	29	23	20	29	16	27	23	22	270
Sinaloa (*l*)	19	13	17	24	23	27	17	18	18	10	186
Sonora (*l*)	23	18	18	19	23	21	14	17	11	22	186
Tabasco (*l*)	17	27	24	26	23	26	32	30	19	23	247
Tamaulipas (*l*)	24	26	36	35	47	22	38	29	23	11	291
Tlaxcala (*l*)	17	13	11	13	13	6	4	8	12	8	105
Veracruz (*m*)	111	87	95	80	75	98	94	90	78	78	886
Yucatán (*m*)	33	21	19	24	13	22	17	15	13	14	191
Zacatecas (*l*)	14	21	11	7	16	11	14	16	12	13	135
Less permissive states	**456**	**461**	**450**	**460**	**499**	**392**	**419**	**497**	**394**	**394**	**4422**
More permissive states	**852**	**852**	**789**	**782**	**667**	**705**	**700**	**710**	**597**	**577**	**7231**
United Mexican States	**1308**	**1313**	**1239**	**1242**	**1166**	**1097**	**1119**	**1207**	**991**	**971**	**11653**

Official records of maternal deaths (ICD-10 codes O00-O99, A34, B20-B24, and F53) by place of occurrence were extracted from the General Directorate of Health Information (DGIS),[57] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of maternal deaths by place of occurrence between 2002 and 2011.

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Table S8 Maternal deaths with abortive outcome by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (*l*)	0	1	0	0	2	2	2	0	1	0	8
Baja California (*l*)	3	1	7	1	2	1	0	2	5	3	25
Baja California Sur (*m*)	0	0	0	0	0	0	0	0	0	0	0
Campeche (*l*)	1	0	0	0	0	0	1	0	3	0	5
Coahuila (*m*)	1	1	0	0	2	1	0	0	2	1	8
Colima (*m*)	1	0	0	0	0	1	0	0	0	0	2
Chiapas (*m*)	8	12	9	4	9	5	6	2	4	4	63
Chihuahua (*l*)	2	3	1	5	2	0	4	2	5	3	27
Distrito Federal (*m*)	13	14	10	12	14	13	10	6	11	6	109
Durango (*l*)	1	0	0	0	1	0	6	0	1	1	10
Guanajuato (*l*)	6	0	3	5	4	2	2	4	2	2	30
Guerrero (*m*)	8	7	7	4	3	2	2	3	3	3	42
Hidalgo (*m*)	3	2	2	0	3	5	2	3	1	1	22
Jalisco (*l*)	3	2	4	4	6	7	5	6	7	2	46
México (*m*)	5	9	11	11	13	7	9	15	15	14	109
Michoacán (*l*)	2	2	6	5	5	3	2	1	4	6	36
Morelos (*m*)	3	2	2	2	1	0	1	2	2	0	15
Nayarit (*l*)	3	2	1	2	1	0	0	0	0	1	10
Nuevo León (*l*)	3	3	1	3	2	4	2	0	1	3	22
Oaxaca (*m*)	3	3	3	3	6	5	1	7	3	4	38
Puebla (*m*)	7	5	4	5	3	5	2	5	3	5	44
Querétaro (*l*)	0	0	0	3	4	1	0	0	1	2	11
Quintana Roo (*m*)	0	2	0	2	0	2	1	2	0	0	9
San Luis Potosí (*l*)	4	3	1	0	0	0	3	2	3	2	18
Sinaloa (*l*)	1	1	0	1	0	0	0	0	1	0	4
Sonora (*l*)	2	1	0	0	3	2	1	0	1	1	11
Tabasco (*l*)	1	0	4	2	3	3	2	0	0	3	18
Tamaulipas (*l*)	0	0	3	2	1	1	4	4	1	1	17
Tlaxcala (*l*)	1	2	0	2	0	1	1	0	1	0	8
Veracruz (*m*)	9	6	7	11	4	7	6	5	9	4	68
Yucatán (*m*)	1	2	1	4	0	0	2	2	1	1	14
Zacatecas (*l*)	2	0	1	0	0	1	1	1	1	1	8
Less permissive states	**35**	**21**	**32**	**35**	**36**	**28**	**36**	**22**	**38**	**31**	**314**
More permissive states	**62**	**65**	**56**	**58**	**58**	**53**	**42**	**52**	**54**	**43**	**543**
United Mexican States	**97**	**86**	**88**	**93**	**94**	**81**	**78**	**74**	**92**	**74**	**857**

Official records of maternal deaths with abortive outcome (ICD-10 codes O00-O08) by place of occurrence were extracted from the General Directorate of Health Information (DGIS),[57] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of maternal deaths with abortive outcome by place of occurrence between 2002 and 2011.

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Table S9 Induced abortion-related deaths by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†
Aguascalientes (*l*)	0	1	0	0	1	2	1	0	0	0	5
Baja California (*l*)	0	1	3	0	0	0	0	0	1	0	5
Baja California Sur (*m*)	0	0	0	0	0	0	0	0	0	0	0
Campeche (*l*)	1	0	0	0	0	0	0	0	1	0	2
Coahuila (*m*)	1	0	0	0	0	1	0	0	1	0	3
Colima (*m*)	0	0	0	0	0	0	0	0	0	0	0
Chiapas (*m*)	7	8	3	1	4	2	3	2	1	0	31
Chihuahua (*l*)	2	2	0	2	0	0	1	1	2	1	11
Distrito Federal (*m*)	3	6	5	8	5	7	4	2	4	1	45
Durango (*l*)	1	0	0	0	0	0	3	0	1	0	5
Guanajuato (*l*)	1	0	1	2	0	0	0	1	1	1	7
Guerrero (*m*)	4	6	6	3	3	2	2	1	2	3	32
Hidalgo (*m*)	1	0	2	0	2	2	2	1	1	1	12
Jalisco (*l*)	1	0	0	1	2	4	1	0	1	0	10
México (*m*)	0	5	4	4	7	3	5	4	6	7	45
Michoacán (*l*)	1	1	1	3	0	1	0	0	2	3	12
Morelos (*m*)	1	2	1	0	0	0	0	2	1	0	7
Nayarit (*l*)	1	1	0	0	1	0	0	0	0	0	3
Nuevo León (*l*)	2	1	0	0	0	0	1	0	0	0	4
Oaxaca (*m*)	3	2	2	2	3	3	1	2	2	1	21
Puebla (*m*)	4	2	2	2	1	4	1	2	1	1	20
Querétaro (*l*)	0	0	0	1	0	1	0	0	0	1	3
Quintana Roo (*m*)	0	1	0	0	0	0	0	0	0	0	1
San Luis Potosí (*l*)	1	0	0	0	0	0	1	0	1	2	5
Sinaloa (*l*)	0	0	0	0	0	0	0	0	0	0	0
Sonora (*l*)	1	1	0	0	2	1	1	0	1	1	8
Tabasco (*l*)	0	0	4	0	3	2	0	0	0	1	10
Tamaulipas (*l*)	0	0	1	1	0	0	0	4	0	0	6
Tlaxcala (*l*)	1	1	0	2	0	1	0	0	1	0	6
Veracruz (*m*)	3	2	4	4	1	3	1	2	5	2	27
Yucatán (*m*)	0	0	1	2	0	0	2	0	0	1	6
Zacatecas (*l*)	0	0	0	0	0	0	0	1	0	0	1
Less permissive states	**13**	**9**	**10**	**12**	**9**	**12**	**9**	**7**	**12**	**10**	**103**
More permissive states	**27**	**34**	**30**	**26**	**26**	**27**	**21**	**18**	**24**	**17**	**250**
United Mexican States	**40**	**43**	**40**	**38**	**35**	**39**	**30**	**25**	**36**	**27**	**353**

Official records of induced abortion related deaths (ICD-10 codes O04-O07) by place of occurrence were extracted from the General Directorate of Health Information (DGIS),[57] excluding cases outside the United Mexican States.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Cumulative figures of induced abortion related deaths by place of occurrence between 2002 and 2011.

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Table S10 Maternal mortality ratio (MMR) by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total †	Trend‡	SE§	P¶
Aguascalientes (*l*)	21.80	45.86	18.85	27.32	47.18	15.49	33.95	50.39	37.62	18.23	31.51	0.340	1.531	0.830
Baja California (*l*)	29.14	37.97	54.16	45.28	35.43	33.28	36.89	47.09	37.76	32.00	38.85	0.233	0.895	0.801
Baja California Sur (*m*)	51.22	74.81	32.10	26.07	32.64	61.02	35.73	37.47	28.60	29.82	40.68	2.617	1.640	0.149
Campeche (*l*)	72.66	56.93	40.83	60.29	60.14	17.69	38.66	46.22	39.25	45.17	47.23	2.737	1.514	0.108
Coahuila (*m*)	38.30	37.23	26.14	42.89	24.80	22.07	32.44	25.80	42.13	37.36	32.89	0.060	0.898	0.948
Colima (*m*)	15.37	24.04	30.14	8.15	51.01	15.67	31.44	22.31	††	35.58	23.15	1.385	1.569	0.407
Chiapas (*m*)	50.18	73.40	71.65	59.64	62.02	50.04	59.84	48.94	39.34	35.66	54.12	2.994	1.011	0.018
Chihuahua (*l*)	59.46	42.20	45.05	73.23	59.12	60.40	46.19	72.08	52.66	66.31	57.54	1.153	1.220	0.373
Distrito Federal (*m*)	45.19	61.94	52.01	49.02	50.10	55.37	43.02	46.99	47.48	35.77	48.71	1.357	0.671	0.078
Durango (*l*)	31.02	42.76	60.73	35.43	67.67	34.75	58.54	32.72	35.28	31.01	42.60	0.946	1.590	0.568
Guanajuato (*l*)	47.03	47.63	42.98	33.00	36.36	31.43	31.15	47.90	33.14	33.87	38.45	1.247	0.702	0.114
Guerrero (*m*)	74.23	61.92	59.33	83.58	82.38	55.16	61.05	68.73	44.25	60.69	64.45	1.778	1.284	0.204
Hidalgo (*m*)	47.17	50.99	49.34	60.25	41.28	44.42	43.59	48.84	46.64	25.24	45.74	1.680	0.850	0.084
Jalisco (*l*)	31.22	35.53	41.58	33.53	50.12	29.24	33.17	52.35	29.71	22.07	35.72	0.553	1.093	0.627
México (*m*)	57.42	63.13	57.70	58.76	45.14	41.53	44.92	46.71	35.43	38.82	48.94	2.796	0.518	0.001
Michoacán (*l*)	34.03	38.64	34.68	44.13	53.25	37.30	41.07	38.22	42.15	47.59	40.95	0.844	0.629	0.217
Morelos (*m*)	64.58	76.98	39.27	64.23	49.89	37.44	39.17	62.57	24.87	32.31	48.65	3.796	1.477	0.033
Nayarit (*l*)	67.60	61.88	40.79	80.58	28.91	20.37	36.04	48.78	32.47	40.08	45.33	3.368	1.858	0.107
Nuevo León (*l*)	24.06	11.34	13.27	22.82	27.39	18.51	25.21	27.33	14.87	26.67	21.15	0.708	0.673	0.324
Oaxaca (*m*)	66.51	41.85	52.26	61.95	50.55	57.11	56.63	60.56	53.82	50.56	55.24	0.168	0.814	0.842
Puebla (*m*)	50.97	52.44	54.93	44.70	40.15	36.67	37.75	50.08	36.12	40.17	44.50	1.576	0.621	0.035
Querétaro (*l*)	51.45	44.60	44.92	35.80	50.63	39.12	37.68	29.08	31.81	38.36	40.12	1.772	0.606	0.019
Quintana Roo (*m*)	49.24	58.94	46.39	53.36	47.73	48.09	58.00	33.85	44.83	45.06	48.28	1.120	0.744	0.170
San Luis Potosí (*l*)	69.72	63.42	52.28	42.37	32.75	49.81	28.64	48.03	37.55	41.70	46.76	2.901	1.105	0.030
Sinaloa (*l*)	27.69	17.33	27.66	37.33	33.36	41.21	29.24	30.03	29.40	14.95	28.76	0.211	0.931	0.827
Sonora (*l*)	40.05	32.84	33.56	35.44	46.86	36.05	25.28	38.94	22.18	40.18	35.13	0.532	0.827	0.538
Tabasco (*l*)	28.73	43.01	37.69	39.81	39.97	41.83	53.87	41.51	28.09	42.36	39.72	0.493	0.840	0.573
Tamaulipas (*l*)	32.62	33.08	35.69	41.85	48.91	32.69	44.30	33.16	37.57	14.95	35.67	0.904	1.018	0.401
Tlaxcala (*l*)	67.03	57.36	41.06	52.33	50.90	24.13	21.80	40.33	51.71	25.12	43.09	3.265	1.385	0.046

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Table S10 Maternal mortality ratio (MMR) by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total †	Trend‡	SE§	P¶
Veracruz (*m*)	57.81	47.12	52.41	43.29	43.96	53.72	52.25	53.73	44.81	47.25	49.69	-1.412	0.562	0.485
Yucatán (*m*)	76.30	54.90	50.21	53.29	27.34	52.81	38.90	39.32	31.83	37.98	46.30	-1.506	1.106	0.013
Zacatecas (*l*)	43.32	62.50	25.64	23.44	41.49	27.99	34.02	48.15	33.36	32.76	37.29	-1.020	1.338	0.468
Less permissive states	**39.75**	**39.51**	**38.27**	**40.14**	**44.28**	**34.27**	**36.00**	**43.54**	**33.82**	**33.54**	**38.28**	**-0.563**	**0.405**	**0.202**
More permissive states	**55.28**	**57.21**	**54.14**	**54.76**	**48.34**	**46.82**	**47.63**	**49.61**	**40.56**	**40.95**	**49.57**	**-1.766**	**0.276**	**<0.001**
United Mexican States	**48.62**	**49.58**	**47.22**	**48.36**	**46.56**	**41.39**	**42.57**	**46.94**	**37.62**	**37.67**	**44.65**	**-1.258**	**0.286**	**0.002**

Maternal mortality ratio per 100,000 live births directly calculated from data in tables S2 and S4.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Average MMR between 2002 and 2011.
‡β-coefficient representing the average change per year for MMR trend between 2002 and 2011 computed by autoregressive integrated moving average (ARIMA) model.
§Standard error for β-coefficient obtained between 2002 and 2011 with ARIMA.
¶P for trend between 2002 and 2011 calculated with ARIMA.
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Table S11 Maternal mortality ratio with abortive outcome (MMR_{AO}) by place of residence in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	SE§	P¶
Aguascalientes (l)	0.00	3.82	0.00	0.00	11.80	7.75	7.54	0.00	3.76	0.00	3.42	-0.110	0.498	0.831
Baja California (l)	5.14	1.73	11.49	1.62	3.08	1.51	0.00	3.14	6.29	4.57	3.82	-0.130	0.381	0.743
Baja California Sur (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	††	††	††
Campeche (l)	6.61	0.00	0.00	0.00	0.00	0.00	5.52	0.00	9.81	0.00	2.25	-0.156	0.427	0.724
Coahuila (m)	1.67	3.55	0.00	0.00	3.54	1.70	0.00	0.00	3.51	1.70	1.56	-0.011	0.180	0.952
Colima (m)	7.69	0.00	0.00	0.00	0.00	7.83	0.00	0.00	0.00	0.00	1.54	-0.372	0.359	0.330
Chiapas (m)	4.80	7.62	6.72	3.64	7.56	3.21	3.90	1.38	2.28	2.38	4.24	-0.542	0.181	0.017
Chihuahua (l)	2.38	3.84	1.33	6.42	2.75	0.00	3.65	2.62	8.10	4.32	3.52	-0.259	0.260	0.349
Distrito Federal (m)	5.28	5.63	4.18	4.90	5.14	8.09	3.74	3.26	5.00	3.19	4.85	-0.172	0.155	0.301
Durango (l)	2.22	0.00	0.00	0.00	2.60	0.00	17.82	0.00	2.35	2.39	2.68	-0.417	0.617	0.518
Guanajuato (l)	4.05	0.00	2.43	3.93	3.38	1.57	1.60	3.19	1.58	1.61	2.32	-0.096	0.147	0.530
Guerrero (m)	8.68	5.10	6.88	3.93	4.90	0.86	1.97	4.04	2.50	2.64	4.14	-0.586	0.182	0.012
Hidalgo (m)	4.57	3.19	4.35	1.63	4.76	7.40	3.11	4.88	1.61	0.00	3.59	-0.257	0.229	0.294
Jalisco (l)	1.87	1.27	1.89	2.58	3.91	3.18	3.19	3.88	3.71	1.23	2.66	-0.136	0.113	0.263
México (m)	2.39	4.21	4.08	4.47	6.36	2.31	3.79	4.22	5.36	4.58	4.17	-0.136	0.133	0.339
Michoacán (l)	2.62	1.64	4.45	4.80	5.02	3.83	1.87	0.93	2.58	5.39	3.28	-0.024	0.185	0.901
Morelos (m)	5.17	5.50	8.42	5.59	0.00	0.00	2.61	5.44	4.97	0.00	3.72	-0.449	0.305	0.179
Nayarit (l)	12.68	8.25	0.00	8.95	4.13	4.07	0.00	0.00	4.06	4.01	4.53	-0.814	0.404	0.079
Nuevo León (l)	2.19	2.27	1.11	3.42	2.28	4.35	2.19	0.00	1.06	3.20	2.20	-0.040	0.147	0.794
Oaxaca (m)	3.33	2.51	2.45	2.66	4.68	4.89	0.85	6.42	2.74	4.04	3.42	-0.137	0.178	0.464
Puebla (m)	4.63	2.95	2.53	3.62	1.27	3.16	1.22	3.21	1.87	2.72	2.73	-0.162	0.109	0.178
Querétaro (l)	0.00	0.00	0.00	4.77	5.06	2.30	0.00	0.00	2.45	4.79	1.97	-0.262	0.244	0.315
Quintana Roo (m)	0.00	8.42	4.22	8.21	0.00	6.87	3.41	6.77	0.00	0.00	3.71	-0.326	0.405	0.445
San Luis Potosí (l)	6.64	5.01	3.27	0.00	0.00	0.00	5.05	3.43	5.12	3.48	3.21	-0.071	0.282	0.808
Sinaloa (l)	1.46	1.58	1.54	1.62	0.00	0.00	0.00	0.00	1.63	0.00	0.80	-0.154	0.080	0.090
Sonora (l)	3.48	1.82	0.00	0.00	5.62	3.60	1.81	0.00	1.85	1.83	2.01	-0.068	0.212	0.756
Tabasco (l)	0.00	0.00	7.18	1.90	3.81	5.46	3.85	0.00	0.00	6.05	2.85	-0.158	0.323	0.639
Tamaulipas (l)	1.42	0.00	2.75	2.70	1.40	1.31	2.68	5.53	1.44	1.49	2.10	-0.148	0.164	0.394
Tlaxcala (l)	3.53	7.17	0.00	7.48	0.00	3.45	7.27	0.00	3.69	0.00	3.23	-0.323	0.355	0.390

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Table S11 Maternal mortality ratio with abortive outcome (MMR_{AO}) by place of residence in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	SE§	P¶
Veracruz (m)	4.09	3.01	3.14	5.28	2.23	3.26	3.73	2.89	5.74	3.50	3.69	0.054	0.126	0.678
Yucatán (m)	2.63	5.23	0.00	11.22	0.00	0.00	5.19	5.24	2.65	2.71	3.50	-0.056	0.403	0.893
Zacatecas (l)	5.41	0.00	0.00	0.00	0.00	2.80	2.83	2.83	5.56	2.73	2.26	0.244	0.238	0.336
Less permissive states	**2.94**	**1.75**	**2.54**	**2.94**	**3.10**	**2.44**	**3.06**	**1.95**	**3.22**	**2.72**	**2.67**	**0.030**	**0.057**	**0.615**
More permissive states	**4.10**	**4.32**	**3.93**	**4.16**	**4.27**	**3.52**	**2.90**	**3.61**	**3.69**	**2.99**	**3.75**	**-0.123**	**0.040**	**0.016**
United Mexican States	**3.61**	**3.21**	**3.32**	**3.62**	**3.76**	**3.06**	**2.97**	**2.88**	**3.49**	**2.87**	**3.28**	**-0.056**	**0.032**	**0.121**

Maternal mortality ratio with abortive outcome per 100,000 live births directly calculated from data in tables S2 and S5.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Average MMR_{AO} between 2002 and 2011.
‡β-coefficient representing the average change per year for MMR_{AO} trend between 2002 and 2011 computed by autoregressive integrated moving average (ARIMA) model.
§Standard error for β-coefficient obtained between 2002 and 2011 with ARIMA.
¶P for trend between 2002 and 2011 calculated with ARIMA.
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Table S12 Induced abortion mortality ratio (iAMR) by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Toral†	Trend‡	SE§	P¶
Aguascalientes (*l*)	0.00	3.82	0.00	0.00	7.86	7.75	3.77	0.00	0.00	0.00	2.28	0.094	0.382	0.811
Baja California (*l*)	0.00	1.73	4.92	0.00	0.00	0.00	0.00	0.00	1.57	0.00	0.80	0.156	0.178	0.407
Baja California Sur (*m*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	††	††	††
Campeche (*l*)	6.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.91	0.00	1.12	0.152	0.282	0.604
Coahuila (*m*)	1.67	1.77	0.00	0.00	0.00	1.70	0.00	0.00	1.76	0.00	0.69	0.081	0.100	0.440
Colima (*m*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	††	††	††
Chiapas (*m*)	3.74	4.85	2.24	0.73	3.78	1.28	1.95	1.38	0.57	0.00	2.02	0.405	0.119	0.010
Chihuahua (*l*)	2.38	2.56	0.00	2.57	0.00	0.00	1.22	1.31	2.70	1.44	1.44	0.030	0.130	0.823
Distrito Federal (*m*)	1.76	1.88	1.20	3.68	1.28	4.35	0.62	1.31	1.87	0.64	1.87	0.095	0.140	0.515
Durango (*l*)	2.22	0.00	0.00	0.00	0.00	0.00	7.64	0.00	2.35	0.00	1.22	0.118	0.283	0.689
Guanajuato (*l*)	0.81	0.00	0.81	1.57	0.00	0.00	0.00	0.00	0.79	0.81	0.48	0.020	0.064	0.769
Guerrero (*m*)	4.82	4.37	5.16	2.95	3.92	0.86	1.97	1.01	1.67	2.64	2.97	0.396	0.118	0.010
Hidalgo (*m*)	1.52	0.00	4.35	0.00	3.18	4.44	1.56	1.63	1.61	0.00	1.87	0.061	0.195	0.762
Jalisco (*l*)	0.00	0.00	0.00	0.64	1.30	1.91	0.64	0.65	0.62	0.00	0.57	0.050	0.072	0.511
México (*m*)	0.00	2.71	1.75	1.79	2.73	0.87	2.33	1.13	2.08	2.14	1.74	0.070	0.098	0.496
Michoacán (*l*)	1.75	0.82	0.89	2.88	0.00	0.96	0.00	0.00	0.86	2.69	1.09	0.021	0.123	0.871
Morelos (*m*)	0.00	5.50	5.61	0.00	0.00	0.00	0.00	5.44	2.49	0.00	1.86	0.133	0.301	0.671
Nayarit (*l*)	4.23	4.13	0.00	0.00	4.13	4.07	0.00	0.00	0.00	0.00	1.65	0.406	0.204	0.082
Nuevo León (*l*)	1.09	0.00	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.22	0.039	0.052	0.470
Oaxaca (*m*)	3.33	1.67	1.63	0.89	2.81	3.26	0.85	1.84	1.82	1.01	1.93	0.112	0.101	0.301
Puebla (*m*)	2.32	0.59	1.26	1.81	0.00	2.53	0.61	1.28	0.62	0.68	1.18	0.094	0.091	0.330
Querétaro (*l*)	0.00	0.00	0.00	2.39	0.00	2.30	0.00	0.00	0.00	2.40	0.74	0.101	0.128	0.453
Quintana Roo (*m*)	0.00	4.21	4.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.306	0.177	0.122
San Luis Potosí (*l*)	1.66	0.00	0.00	0.00	0.00	0.00	1.68	0.00	1.71	3.48	0.84	0.202	0.123	0.138
Sinaloa (*l*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	††	††	††
Sonora (*l*)	1.74	1.82	0.00	0.00	3.75	1.80	1.81	0.00	1.85	1.83	1.46	0.027	0.137	0.847
Tabasco (*l*)	0.00	0.00	7.18	0.00	3.81	3.64	0.00	0.00	0.00	2.02	1.71	0.108	0.288	0.716
Tamaulipas (*l*)	1.42	0.00	1.37	1.35	0.00	0.00	0.00	5.53	0.00	0.00	0.98	0.024	0.202	0.908
Tlaxcala (*l*)	3.53	3.58	0.00	7.48	0.00	3.45	3.63	0.00	3.69	0.00	2.51	0.237	0.278	0.419

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Table S12 Induced abortion mortality ratio (iAMR) by place of residence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	SE§	P¶
Veracruz (*m*)	1.02	1.00	1.57	2.11	0.56	1.09	0.53	1.16	2.87	1.75	1.35	0.081	0.080	0.337
Yucatán (*m*)	0.00	0.00	0.00	5.61	0.00	0.00	5.19	0.00	0.00	2.71	1.35	0.140	0.264	0.609
Zacatecas (*l*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.83	2.78	0.00	0.56	0.204	0.118	0.122
Less permissive states	**1.13**	**0.70**	**0.88**	**1.07**	**0.82**	**1.05**	**0.87**	**0.62**	**1.05**	**0.88**	**0.91**	**-0.010**	**0.019**	**0.619**
More permissive states	**1.76**	**2.26**	**2.03**	**1.80**	**1.85**	**1.80**	**1.35**	**1.25**	**1.61**	**1.18**	**1.69**	**-0.096**	**0.025**	**0.005**
United Mexican States	**1.49**	**1.59**	**1.53**	**1.48**	**1.40**	**1.47**	**1.14**	**0.97**	**1.37**	**1.05**	**1.35**	**-0.058**	**0.017**	**0.010**

Induced abortion mortality ratio per 100,000 live births directly calculated from data in tables S2 and S6.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Average iAMR between 2002 and 2011.
‡β-coefficient representing the average change per year for iAMR trend between 2002 and 2011 computed by autoregressive integrated moving average (ARIMA) model.
§Standard error for β-coefficient obtained between 2002 and 2011 with ARIMA.
¶P for trend between 2002 and 2011 calculated with ARIMA.
††Not applicable.

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Table S13 Maternal mortality ratio (MMR) by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	SE§	P¶
Aguascalientes (*l*)	23.49	49.33	17.61	28.57	43.30	17.93	31.72	69.07	35.52	17.68	33.27	-1.560	1.932	0.779
Baja California (*l*)	28.65	34.46	56.88	44.45	38.93	36.81	38.06	53.60	42.57	35.49	41.00	-0.489	1.001	0.639
Baja California Sur (*m*)	52.84	78.18	33.68	35.73	33.85	62.83	36.66	35.61	21.94	22.55	40.75	-3.787	1.604	0.046
Campeche (*l*)	69.15	53.24	49.70	52.80	63.87	18.63	40.36	48.24	43.00	53.07	48.86	-1.856	1.470	0.242
Coahuila (*m*)	41.17	29.84	27.78	38.96	29.78	23.66	32.33	30.85	35.05	33.86	32.35	-0.242	0.600	0.697
Colima (*m*)	15.26	31.39	15.16	7.86	31.57	21.76	37.02	21.31	6.89	20.01	20.70	-1.123	1.178	0.919
Chiapas (*m*)	48.69	71.23	68.63	56.85	57.63	47.09	54.46	43.50	37.07	32.64	50.94	-2.194	0.930	0.009
Chihuahua (*l*)	58.95	42.19	46.99	71.60	58.39	56.02	47.02	72.83	52.26	67.35	57.24	-1.207	1.166	0.331
Distrito Federal (*m*)	60.33	74.67	68.30	64.69	64.05	59.84	52.75	60.33	57.48	53.97	61.91	-1.560	0.537	0.020
Durango (*l*)	25.01	43.88	51.49	38.78	53.24	33.14	57.10	28.44	34.23	22.54	38.54	-1.031	1.380	0.476
Guanajuato (*l*)	46.92	46.61	38.99	29.15	36.98	26.77	31.09	50.03	31.14	33.44	37.05	-1.084	0.884	0.255
Guerrero (*m*)	76.19	62.68	58.51	78.89	79.97	53.55	58.37	69.49	43.55	55.75	63.08	-1.127	1.194	0.113
Hidalgo (*m*)	41.62	49.24	40.65	52.86	37.28	42.08	39.77	46.08	41.24	20.46	41.15	-1.538	0.851	0.108
Jalisco (*l*)	32.67	37.02	42.60	32.94	49.56	30.52	32.51	47.62	31.53	24.42	36.03	-0.654	0.909	0.492
México (*m*)	51.16	56.59	49.34	51.31	38.21	39.08	42.09	40.69	30.29	32.55	42.91	-1.555	0.455	0.001
Michoacán (*l*)	31.34	35.59	33.89	44.70	50.78	32.83	41.20	39.22	41.64	49.57	39.84	-0.240	0.664	0.099
Morelos (*m*)	61.76	69.15	33.55	63.29	40.05	39.57	38.54	66.50	22.12	32.40	46.34	-2.051	1.639	0.100
Nayarit (*l*)	63.15	62.36	48.76	77.97	31.49	18.03	44.89	48.58	26.31	48.75	46.76	-3.003	1.839	0.141
Nuevo León (*l*)	28.46	19.27	15.46	28.29	29.26	23.61	25.93	29.04	24.12	34.79	25.86	-0.885	0.563	0.154
Oaxaca (*m*)	62.73	40.04	49.02	63.30	50.13	54.71	57.00	58.89	54.26	50.67	54.06	-0.158	0.816	0.852
Puebla (*m*)	51.92	51.78	56.65	43.39	37.41	38.57	37.92	52.37	38.02	40.80	45.00	-2.412	0.715	0.084
Querétaro (*l*)	48.24	44.30	52.38	53.30	53.58	46.78	36.61	25.76	32.73	34.44	42.70	-4.395	0.771	0.015
Quintana Roo (*m*)	37.21	63.84	38.15	37.05	37.15	41.94	52.72	30.71	38.19	41.64	41.65	-0.758	1.082	0.503
San Luis Potosí (*l*)	71.90	63.81	48.25	39.45	35.08	49.12	27.68	48.33	40.29	38.53	46.42	-2.944	1.154	0.034
Sinaloa (*l*)	27.86	20.54	26.32	38.97	38.37	44.49	27.71	30.33	29.49	16.54	29.98	-0.284	0.991	0.782
Sonora (*l*)	40.03	32.92	33.49	35.32	42.92	37.81	25.36	31.59	20.32	40.20	34.02	-0.795	0.766	0.330
Tabasco (*l*)	32.25	52.56	42.84	48.98	43.44	47.05	60.84	52.98	36.57	43.93	46.17	-0.504	0.953	0.612
Tamaulipas (*l*)	33.57	38.45	48.70	46.71	65.05	28.77	50.91	39.68	32.68	16.05	40.23	-1.617	1.481	0.307
Tlaxcala (*l*)	63.14	48.74	39.76	51.33	49.99	22.15	15.24	30.27	45.21	29.25	39.44	-0.111	1.353	0.051

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Table S13 Maternal mortality ratio (MMR) by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	SE§	P¶
Veracruz (*m*)	58.69	44.89	51.62	43.68	43.11	54.91	51.96	53.68	46.12	47.12	49.61	-0.294	0.612	0.644
Yucatán (*m*)	85.10	53.83	54.54	65.44	34.43	56.52	42.96	38.40	33.78	37.23	50.17	-4.226	1.185	0.007
Zacatecas (*l*)	38.98	61.23	32.29	21.15	49.03	31.80	40.82	46.29	33.88	36.80	39.22	-0.602	1.272	0.649
Less permissive states	**39.52**	**40.44**	**39.47**	**41.05**	**45.60**	**34.39**	**36.81**	**44.35**	**34.61**	**34.96**	**39.09**	**-0.487**	**0.428**	**0.288**
More permissive states	**55.58**	**56.72**	**53.60**	**54.34**	**47.62**	**47.04**	**47.42**	**49.66**	**40.47**	**40.42**	**49.34**	**-1.764**	**0.275**	**<0.001**
United Mexican States	**48.69**	**49.69**	**47.43**	**48.52**	**46.74**	**41.57**	**42.80**	**47.33**	**37.92**	**38.01**	**44.88**	**-1.258**	**0.286**	**0.002**

Maternal mortality ratio per 100,000 live births directly calculated from data in tables S3 and S7.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Average MMR between 2002 and 2011.
‡β-coefficient representing the average change per year for MMR trend between 2002 and 2011 computed by autoregressive integrated moving average (ARIMA) model.
§Standard error for β-coefficient obtained between 2002 and 2011 with ARIMA.
¶P for trend between 2002 and 2011 calculated with ARIMA.

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Table S14 Maternal mortality ratio with abortive outcome (MMR_{AO}) by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	P§	P¶
Aguascalientes (*l*)	0.00	3.52	0.00	0.00	7.22	7.17	7.05	0.00	3.55	0.00	2.83	0.129	0.381	0.743
Baja California (*l*)	5.06	1.72	11.71	1.65	3.24	1.60	0.00	3.25	8.19	4.84	4.10	0.034	0.412	0.937
Baja California Sur (*m*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	††	††	††
Campeche (*l*)	6.91	0.00	0.00	0.00	0.00	0.00	5.77	0.00	16.13	0.00	3.02	0.412	0.608	0.517
Coahuila (*m*)	1.65	1.76	0.00	0.00	3.50	1.69	0.00	0.00	3.50	1.69	1.38	0.065	0.159	0.693
Colima (*m*)	7.63	0.00	0.00	0.00	0.00	7.25	0.00	0.00	0.00	0.00	1.48	0.372	0.342	0.308
Chiapas (*m*)	4.23	8.22	6.64	2.88	6.74	3.14	3.80	1.38	2.28	2.37	4.07	0.518	0.192	0.027
Chihuahua (*l*)	2.41	3.84	1.34	6.39	2.72	0.00	4.82	2.60	6.70	4.30	3.51	0.218	0.236	0.383
Distrito Federal (*m*)	5.85	6.57	4.49	5.55	6.95	6.38	5.02	3.15	5.70	3.34	5.34	0.228	0.129	0.115
Durango (*l*)	2.27	0.00	0.00	0.00	2.66	0.00	15.57	0.00	2.44	2.50	2.50	0.383	0.537	0.496
Guanajuato (*l*)	4.85	0.00	2.29	3.84	3.29	1.53	1.55	3.23	1.60	1.63	2.37	0.132	0.159	0.431
Guerrero (*m*)	7.81	5.16	6.11	3.99	3.00	1.76	2.01	3.11	2.56	2.70	3.85	0.523	0.134	0.005
Hidalgo (*m*)	4.46	3.08	2.80	0.00	4.66	7.26	3.06	4.77	1.59	1.57	3.35	0.090	0.238	0.716
Jalisco (*l*)	1.88	1.28	2.54	2.58	3.91	4.45	3.19	3.86	4.33	1.22	2.92	0.148	0.131	0.293
México (*m*)	1.76	3.20	3.82	3.89	4.56	2.30	2.96	4.73	4.99	4.60	3.69	0.228	0.100	0.052
Michoacán (*l*)	1.74	1.66	5.50	4.97	5.18	2.98	1.96	0.98	3.62	5.72	3.39	0.095	0.208	0.660
Morelos (*m*)	7.72	5.53	5.59	5.50	2.86	0.00	2.57	5.32	4.92	0.00	3.95	0.526	0.234	0.055
Nayarit (*l*)	13.53	8.91	4.43	9.75	4.50	0.00	0.00	0.00	0.00	4.43	4.50	1.213	0.365	0.011
Nuevo León (*l*)	3.28	3.40	1.10	3.39	2.25	4.29	2.16	0.00	1.05	3.16	2.40	0.150	0.148	0.341
Oaxaca (*m*)	2.48	2.50	2.45	2.67	5.67	4.14	0.86	6.54	2.76	4.05	3.36	0.178	0.188	0.370
Puebla (*m*)	4.08	2.98	2.55	3.06	1.93	3.21	1.24	3.31	1.93	3.52	2.79	0.077	0.097	0.448
Querétaro (*l*)	0.00	0.00	0.00	6.95	9.74	2.23	0.00	0.00	2.34	4.59	2.60	0.178	0.399	0.668
Quintana Roo (*m*)	0.00	8.51	0.00	8.23	0.00	6.99	3.51	6.82	0.00	0.00	3.38	0.198	0.441	0.666
San Luis Potosí (*l*)	6.69	5.04	1.66	0.00	0.00	0.00	5.19	3.58	5.26	3.50	3.09	0.012	0.294	0.968
Sinaloa (*l*)	1.47	1.58	0.00	1.62	0.00	0.00	0.00	0.00	1.64	0.00	0.64	0.107	0.087	0.255
Sonora (*l*)	3.48	1.83	0.00	0.00	5.60	3.60	1.81	0.00	1.85	1.83	2.01	0.068	0.211	0.754
Tabasco (*l*)	1.90	0.00	7.14	3.77	5.67	5.43	3.80	0.00	0.00	5.73	3.36	0.008	0.316	0.980
Tamaulipas (*l*)	0.00	0.00	4.06	2.67	1.38	1.31	5.36	5.47	1.42	1.46	2.35	0.231	0.221	0.326
Tlaxcala (*l*)	3.71	7.50	0.00	7.90	0.00	3.69	3.81	0.00	3.77	0.00	3.00	0.413	0.322	0.236

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Table S14 Maternal mortality ratio with abortive outcome (MMR_{AO}) by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	SE§	P¶
Veracruz (*m*)	4.76	3.10	3.80	6.01	2.30	3.92	3.32	2.98	5.32	2.42	3.81	-0.097	0.140	0.506
Yucatán (*m*)	2.58	5.13	2.87	10.91	0.00	0.00	5.05	5.12	2.60	2.66	3.68	-0.141	0.365	0.709
Zacatecas (*l*)	5.57	0.00	2.94	0.00	0.00	2.89	2.92	2.89	2.82	2.83	2.32	0.039	0.208	0.855
Less permissive states	**3.03**	**1.84**	**2.81**	**3.12**	**3.29**	**2.46**	**3.16**	**1.96**	**3.34**	**2.75**	**2.78**	**0.025**	**0.061**	**0.688**
More permissive states	**4.04**	**4.33**	**3.80**	**4.03**	**4.14**	**3.54**	**2.85**	**3.64**	**3.66**	**3.01**	**3.71**	**-0.112**	**0.040**	**0.022**
United Mexican States	**3.61**	**3.25**	**3.37**	**3.63**	**3.77**	**3.07**	**2.98**	**2.90**	**3.52**	**2.90**	**3.30**	**-0.056**	**0.032**	**0.121**

Maternal mortality ratio with abortive outcome per 100,000 live births directly calculated from data in tables S3 and S8.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Average MMR_{AO} between 2002 and 2011.
‡β-coefficient representing the average change per year for MMR_{AO} trend between 2002 and 2011 computed by autoregressive integrated moving average (ARIMA) model.
§Standard error for β-coefficient obtained between 2002 and 2011 with ARIMA.
¶P for trend between 2002 and 2011 calculated with ARIMA.
††Not applicable.

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Table S15 Induced abortion mortality ratio (iAMR) by place of occurrence in 32 Mexican states exhibiting a more (m) or less (l) permissive abortion legislation, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	SE§	P¶
Aguascalientes (l)	0.00	3.52	0.00	0.00	3.61	7.17	3.52	0.00	0.00	0.00	1.77	0.064	0.294	0.834
Baja California (l)	0.00	1.72	5.02	0.00	0.00	0.00	0.00	0.00	1.64	0.00	0.82	0.156	0.182	0.417
Baja California Sur (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	††	††	††
Campeche (l)	6.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.38	0.00	1.21	0.149	0.301	0.635
Coahuila (m)	1.65	0.00	0.00	0.00	0.00	1.69	0.00	0.00	1.75	0.00	0.52	0.006	0.096	0.955
Colima (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	††	††	††
Chiapas (m)	3.71	5.48	2.21	0.72	2.99	1.26	1.90	1.38	0.57	0.00	2.00	0.425	0.122	0.008
Chihuahua (l)	2.41	2.56	0.00	2.56	0.00	0.00	1.21	1.30	2.68	1.43	1.43	0.034	0.130	0.803
Distrito Federal (m)	1.35	2.82	2.25	3.70	2.48	3.43	2.01	1.05	2.07	0.56	2.20	0.136	0.106	0.236
Durango (l)	2.27	0.00	0.00	0.00	0.00	0.00	7.79	0.00	2.44	0.00	1.25	0.121	0.289	0.685
Guanajuato (l)	0.81	0.00	0.76	1.53	0.00	0.00	0.00	0.81	0.80	0.82	0.55	0.008	0.061	0.897
Guerrero (m)	3.91	4.42	5.24	3.00	3.00	1.76	2.01	1.04	1.71	2.70	2.93	0.334	0.100	0.010
Hidalgo (m)	1.49	0.00	2.80	0.00	3.11	2.90	3.06	1.59	1.59	1.57	1.83	0.090	0.132	0.518
Jalisco (l)	0.63	0.00	0.00	0.65	1.30	2.54	0.64	0.00	0.62	0.00	0.63	0.001	0.093	0.994
México (m)	0.00	1.78	1.39	1.42	2.45	0.99	1.64	1.26	2.00	2.30	1.53	0.126	0.069	0.106
Michoacán (l)	0.87	0.83	0.92	2.98	0.00	0.99	0.00	0.00	1.81	2.86	1.13	0.074	0.126	0.573
Morelos (m)	2.57	5.53	2.80	0.00	0.00	0.00	0.00	5.32	2.46	0.00	1.84	0.194	0.250	0.461
Nayarit (l)	4.51	4.45	0.00	0.00	4.50	0.00	0.00	0.00	0.00	0.00	1.35	0.462	0.193	0.044
Nuevo León (l)	2.19	1.13	0.00	0.00	0.00	0.00	1.08	0.00	0.00	0.00	0.44	0.148	0.073	0.077
Oaxaca (m)	2.48	1.67	1.63	1.78	2.84	2.49	0.86	1.87	1.84	1.01	1.85	0.085	0.067	0.243
Puebla (m)	2.33	1.19	1.27	1.22	0.64	2.57	0.62	1.33	0.64	0.70	1.27	0.110	0.071	0.164
Querétaro (l)	0.00	0.00	0.00	2.32	0.00	2.23	0.00	0.00	0.00	2.30	0.71	0.097	0.124	0.458
Quintana Roo (m)	0.00	4.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.181	0.144	0.244
San Luis Potosí (l)	1.67	0.00	0.00	0.00	0.00	0.00	1.73	0.00	1.75	3.50	0.86	0.206	0.124	0.136
Sinaloa (l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	††	††	††
Sonora (l)	1.74	1.83	0.00	0.00	3.73	1.80	1.81	0.00	1.85	1.83	1.46	0.027	0.136	0.848
Tabasco (l)	0.00	0.00	7.14	0.00	5.67	3.62	0.00	0.00	0.00	1.91	1.87	0.125	0.314	0.702
Tamaulipas (l)	0.00	0.00	1.35	1.33	0.00	0.00	0.00	5.47	0.00	0.00	0.83	0.101	0.199	0.626
Tlaxcala (l)	3.71	3.75	0.00	7.90	0.00	3.69	0.00	0.00	3.77	0.00	2.25	0.323	0.295	0.306

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Table S15 Induced abortion mortality ratio (iAMR) by place of occurrence in 32 Mexican states exhibiting a more (*m*) or less (*l*) permissive abortion legislation, 2002-2011 (Continued)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total†	Trend‡	SE§	P¶
Veracruz (*m*)	1.59	1.03	2.17	2.18	0.57	1.68	0.55	1.19	2.96	1.21	1.51	0.009	0.089	0.926
Yucatán (*m*)	0.00	0.00	2.87	5.45	0.00	0.00	5.05	0.00	0.00	2.66	1.58	0.051	0.260	0.850
Zacatecas (*l*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.89	0.00	0.00	0.29	0.088	0.102	0.416
Less permissive states	**1.13**	**0.79**	**0.88**	**1.07**	**0.82**	**1.05**	**0.79**	**0.62**	**1.05**	**0.89**	**0.91**	**-0.011**	**0.020**	**0.602**
More permissive states	**1.76**	**2.26**	**2.04**	**1.81**	**1.86**	**1.80**	**1.42**	**1.26**	**1.63**	**1.19**	**1.71**	**-0.092**	**0.023**	**0.004**
United Mexican States	**1.49**	**1.63**	**1.53**	**1.48**	**1.40**	**1.48**	**1.15**	**0.98**	**1.38**	**1.06**	**1.36**	**-0.058**	**0.017**	**0.010**

Induced abortion mortality ratio per 100,000 live births directly calculated from data in tables S3 and S9.
Operational definition of more or less permissive according to criminal exemption from prosecution of abortion in case of genetic or congenital malformation.
†Average iAMR between 2002 and 2011.
‡β-coefficient representing the average change per year for iAMR trend between 2002 and 2011 computed by autoregressive integrated moving average (ARIMA) model.
§Standard error for β-coefficient obtained between 2002 and 2011 with ARIMA.
¶P for trend between 2002 and 2011 calculated with ARIMA.
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Table S16 Explanatory models for trends on maternal mortality ratio (MMR), maternal mortality ratio with an abortive outcome (MMR_{AO}), and induced abortion mortality ratio (iAMR) in 32 Mexican states before refinement, 2002-2011

	MMR*						MMR_{AO}**						iAMR***					
	β	SE	95% CI		P value	R^2	β	SE	95% CI		P value	R^2	β	SE	95% CI		P value	R^2
			Lower	Upper					Lower	Upper					Lower	Upper		
Female literacy (%)	-1.051	0.235	-1.532	-0.570	<0.001	0.512	-0.061	0.028	-0.118	-0.003	0.039	0.485	-0.062	0.022	-0.108	-0.017	0.009	0.292
Low birth weight (%)	1.585	0.690	0.171	2.998	0.029		0.299	0.082	0.131	0.467	0.001		0.149	0.066	0.014	0.283	0.031	
Skilled attendance at birth (%)	-0.427	0.196	-0.827	-0.026	0.038		-0.072	0.023	-0.120	-0.024	0.004		-0.023	0.018	-0.061	0.015	0.226	
Intimate-partner violence (%)	0.697	0.499	-0.326	1.720	0.173		0.045	0.061	-0.079	0.170	0.462		0.024	0.048	-0.075	0.123	0.626	
All-abortion hospitalisation ratio (per 100 live births)	-0.302	0.557	-1.444	0.840	0.591		0.046	0.066	-0.089	0.181	0.492		-0.029	0.050	-0.131	0.073	0.562	
Constitutional amendment (yes)	1.352	2.385	-3.542	6.246	0.576		0.222	0.282	-0.357	0.802	0.438		-0.198	0.224	-0.658	0.261	0.384	
Abortion legislation (less permissive)	-1.960	2.721	-7.543	3.623	0.478		0.052	0.327	-0.618	0.723	0.874		0.144	0.258	-0.385	0.672	0.583	
Contraceptive use (%)	0.300	0.308	-0.331	0.931	0.337		0.035	0.037	-0.040	0.110	0.351		-0.015	0.030	-0.075	0.046	0.623	

*Multivariate model before refinement identified three predictors after six steps of backward elimination (Female literacy, Low birth weight, and Skilled attendance at birth), accounting for 51% (R^2) of the differences in MMR between states.
**Multivariate model before refinement identified three predictors after six steps of backward elimination (Female literacy, Low birth weight, and Skilled attendance at birth), accounting for 49% (R^2) of the differences in MMR_{AO} between states.
*Multivariate model before refinement identified two predictors after seven steps of backward elimination (Female literacy, and Low birth weight), accounting for 29% (R^2) of the differences in iAMR between states.
R^2 refers to the goodness-of-fit for each model.
CI, confidence interval; ME, model in which the variable was excluded during the backward elimination; MMR, maternal mortality ratio; SE, standard error; VIF, variance inflation factor.

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Alternative explanatory models

Alternative multivariate regression models considering the variables excluded by collinearity were conducted (Table 8). First, female literacy was interchanged with clean water. After regression refinement (adjusted R^2=0.886, P for model<0.001), four factors were identified as independent explanatory variables for the MMR: clean water (β=-0.730, P<0.001, VIF=1.928), low birth weight (β=1.938, P<0.001, VIF=1.086), all-abortion hospitalisation ratio (β=-0.566, P=0.049, VIF=2.288), and intimate-partner violence (β=0.554, P=0.015, VIF=1.570). These variables explained (cumulative multivariate R^2) 64.7%, 22.0%, 1.9%, and 1.7% of the differences observed on the MMR among states, respectively. Second, female literacy was interchanged with sanitation (adjusted R^2=0.640, P for model<0.001). Variables showing significant effects were the latter (β=-0.758, P<0.001, VIF=1.001) and low birth weight (β=2.166, P<0.001, VIF=1.001), explaining 45.6% and 20.9% of the variance on MMR, respectively. Finally, cumulative TFR between 2002 and 2011 was interchanged with contraceptive use. Four explanatory factors were identified in the final model (adjusted R^2=0.714, P for model<0.001): female literacy (β=-1.013, P<0.001, VIF=1.876), low birth weight (β=1.260, P=0.009; VIF=1.127), all-abortion hospitalisation ratio (β=-0.962, P=0.012, VIF=1.779) and TFR (β=-14.329, P=0.002, VIF=1.728). These variables accounted for 41.3%, 18.8%, 7.6%, and 7.7% of the variance of observed MMR among states, respectively. No statistically significant effect was present for abortion legislation, constitutional amendment, or additional covariates other than those already mentioned.

For MMR_{AO}, when female literacy was replaced by clean water in multivariate regression models (adjusted R^2=0.420, P for model<0.001), only two variables appeared independently associated to this mortality outcome: skilled attendance at birth (β=-0.076, P=0.004, VIF=1.002) and low birth weight (β=0.321, P=0.001, VIF=1.002). These variables explained 17.8% and 27.9% of the variance on the MMR_{AO} among states, respectively. In the refined model when female literacy rate was replaced by sanitation (adjusted R^2=0.420, P for model<0.001), variables exhibiting significant effect sizes were low birth weight (β=0.321, P=0.001, VIF=1.002) and skilled attendance at birth (β=-0.076, P=0.004, VIF=1.002) explaining 27.9% and 17.8% of the variance on MMR_{AO}, respectively. Finally, when contraceptive use was replaced by TFR in the refined explanatory modeling (adjusted R^2=0.666, P for model<0.001), female literacy (β=-0.125, P<0.001, VIF=2.043), low birth weight (β=0.271, P<0.001, VIF=1.096), skilled attendance at birth (β=-0.064, P=0.002, VIF=1.031), and TFR (β=-1.750, P=0.008, VIF=2.143) were identified as explanatory factors. These variables accounted for 14.0%, 35.9%, 11.5%, and 10.0% of the variance of observed MMR_{AO} among states, respectively. No statistically significant effects were obtained for abortion legislation, constitutional amendment, or additional covariates other than those mentioned.

Lastly, in the case of iAMR, when clean water replaced female literacy in regression modeling, three factors (adjusted R^2=0.700, P for model<0.001) were identified as independent explanatory variables: clean water (β=-0.048, P<0.001, VIF=1.041), low birth weight (β=0.210, P<0.001, VIF=1.006), and skilled attendance at birth (β=-0.032, P=0.014, VIF=1.039). These variables explained 39.2%, 26.6%, and 7.4% of the differences observed in iAMR among states, respectively. When female literacy rate was replaced by sanitation, the model (adjusted R^2=0.593, P for model<0.001) identified sanitation (β=-0.052, P<0.001, VIF=1.000), low birth weight (β=0.169, P=0.002, VIF=1.003), and skilled attendance at birth (β=-0.044, P=0.004, VIF=1.003) explaining 29.8%, 19.2%, and 14.5% of the variance on iAMR, respectively. Finally, when contraceptive use was replaced by TFR, the model (adjusted R^2=0.335, P for model<0.001) identified low birth weight (β=0.197, P=0.004, VIF=1.015) and TFR (β=1.383, P=0.003, VIF=1.015) as explanatory factors. These variables accounted for 20.6% and 17.2% of the variance observed on iAMR among states, respectively. No statistically significant effects were obtained for abortion legislation, constitutional amendment, or additional covariates other than those mentioned.

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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
		(*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
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
		(*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
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
Study size	10✔	Explain how the study size was arrived at
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
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

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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
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14✔	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15✔	*Cohort study*—Report numbers of outcome events or summary measures over time
		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
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
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

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