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Maintaining rigor in research: flaws in a recent study and a reanalysis of the relationship between state abortion laws and maternal mortality in Mexico

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Abstract

Objective: A recent publication [Koch E, Chireau M, Pliego F, Stanford J, Haddad S, Calhoun B, Aracena P, Bravo M, Gatica S, Thorp J. Abortion legislation, maternal healthcare, fertility, female literacy, sanitation, violence against women and maternal deaths: a natural experiment in 32 Mexican states. BMJ Open 2015;5(2):e006013] claimed that Mexican states with more restrictive abortion laws had lower levels of maternal mortality. Our objectives are to replicate the analysis, reanalyze the data and offer a critique of the key flaws of the Koch study.

Study design: We used corrected maternal mortality data (2006–2013), live births, and state-level indicators of poverty. We replicate the published analysis. We then reclassified state-level exposure to abortion on demand based on actual availability of abortion (Mexico City versus the other 31 states) and test the association of abortion access and the maternal mortality ratio (MMR) using descriptives over time, pooled chi-square tests and regression models. We included 256 state-year observations.

Results: We did not find significant differences in MMR between Mexico City (MMR=49.1) and the 31 states (MMR=44.6; p=.44). Using Koch's classification of states, we replicated published differences of higher MMR where abortion is more available. We found a significant, negative association between MMR and availability of abortion in the same multivariable models as Koch, but using our state classification (beta=−22.49, 95% CI −38.9; −5.1). State-level poverty remains highly correlated with MMR.

Conclusion: Koch makes errors in methodology and interpretation, making false causal claims about abortion law and MMR. MMR is falling most rapidly in Mexico City, but our main study limitation is an inability to draw causal inference about abortion law or access and maternal mortality. We need rigorous evidence about the health impacts of increasing access to safe abortion worldwide.

Implications: Transparency and integrity in research is crucial, as well as perhaps even more in politically contested topics such as abortion. Rigorous evidence about health impacts of increasing access to safe abortion worldwide is needed.

Keywords: Abortion research; Abortion legislation; Abortion access; Maternal mortality; Mexico; Scientific integrity

1. Introduction

Reducing maternal mortality remains a top global health priority [1]. The large disparities in the maternal mortality ratio (MMR; number of maternal deaths per 100,000 live births) between countries [2] and populations suggest that much of the burden of maternal death is preventable. It is imperative that we have rigorous evidence about the correlates and causes of maternal death to inform policies, programs and services that contribute to reducing maternal mortality. Unsafe abortion is an important contributor to overall MMR — up to 13% of maternal deaths are due to complications from unsafe abortion [3]; however, where abortion is legal, the fraction of MMR due to abortion is very low [4].

A recent study by Koch et al. [5] focused on state-level MMR in Mexico concluded that states with more restrictive laws "exhibited consistently lower maternal mortality rates" [5]. A press release for the study goes further, stating that the study "confirm[s] that Mexican states with less permissive

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abortion laws exhibited 23% lower overall maternal mortality" [6].

The purpose of this study is to describe MMR and access to abortion over time and test the association of state-level abortion law, maternal mortality and socioeconomic factors in Mexico, using the same data as Koch et al. Our aim is to improve transparency, acknowledge the limitations of data, and contextualize results, as recommended in studies of abortion and abortion-related morbidity and mortality [7]. Our ultimate goal is to improve the evidence available to guide policies and services to reduce unsafe abortion.

We discuss three key flaws in the Koch et al. study: misuse of data sources and overreliance on International Classification of Diseases, 10th edition (ICD-10) codes for measurement of abortion-related morality; classification of Mexican states by access to abortion and of deaths by residence or place of occurrence; and misuse of the term natural experiment for the study design.

1.1. Abortion-related morbidity and mortality remain difficult to measure

Estimates of the incidence of maternal deaths have improved [2] but cause remains difficult to discern. Abortion incidence as a cause of maternal death is underrecognized, underreported [8] and therefore undercounted in civil registration and vital statistics data as well as in hospital discharge data that rely on ICD-10 codes. Even in countries such as Mexico with robust vital statistics systems [9], common causes of direct maternal deaths, e.g. postpartum hemorrhage and sepsis, may not be explicitly attributed to delivery or abortion.

Relying on abortion-related ICD-10 codes to assess prevalence, safety, mortality or morbidity related to abortion is flawed [7]; ICD-10 codes may not represent the gold standard for causes of maternal death as Koch claims [10]. For these reasons, we focus our study on maternal deaths overall.

The denominator for MMR, live births, is often also captured in several data sources. In Mexico, births are counted via a birth registration system (called INEGI) [11], and the government (in an agency called CONAPO) also produces corrected birth estimates [12]. Koch et al. used birth registration data from INEGI and not the corrected estimates, and thus, they overestimate births due to population mobility for registering, double registration and time lags in registration. Low fertility can also inflate the MMR due to a smaller denominator; thus, researchers also use the ratio of deaths per 100,000 women of reproductive age (15–49 years) to account for this, called the maternal mortality rate [13].

1.2. Misclassification of access to abortion at the state level and classification of deaths by residence or place of occurrence

Mexico City changed its abortion law in 2007 [14], and abortion is available to all women (women younger than 18 years old must have an adult present) in the public, nongovernmental nonprofit, and private for-profit sectors. This is a watershed policy and service delivery advance in Latin America; however, abortion remains highly criminalized outside of Mexico City. Koch et al. classify states in Mexico as "more or less permissive" (i.e. abortion is less or more criminalized/restricted) based on exemption from prosecution of abortion in cases of congenital malformation (see Koch Table 1 and Supplementary Table A1). The congenital malformation exemption appears to have been selected because it was the only classification method that produced significant results. The most common legal indications across states in Mexico are rape, "imprudential conduct", and "risk to the life of the woman" [15]. However, accessing abortion services via these exemptions requires burdensome documentation, which varies by state [16]. The burden of proof (even of rape) to access services means that abortion is essentially not available to women outside of Mexico City, especially for poor women, who have less access to health services in general and to abortion in particular [17].

Koch presents results by place of residence of the woman and place of occurrence of the death. He uses pooled results of place of occurrence of the death to help argue that states with access to abortion have higher MMR; however, the sickest women are most likely to travel outside their state of residence for care and ultimately to die. Koch draws inference from data on place of occurrence of the death, which does not help us understand availability of abortion in the state where the woman resides and the pregnancy presumably occurred.

In sum, the classification of the main exposure variable, availability of abortion, is deeply flawed. Koch presents a complex justification for his selection of congenital malformation as the deciding factor in being classified as "permissive" or not, while ignoring the obvious classification: prior to mid-2007, all 32 Mexican states are restrictive, and from mid-2007 on, only Mexico City has abortion available on request; the other 31 states remain restrictive.

1.3. Study design

The title of the manuscript includes the words "a natural experiment." The exposure in a natural experiment must be independent of other factors that could affect the outcome [18]. It is part of a researcher's job to convince readers of the validity of the claim of independence of the "naturally occurring" phenomenon and other observable or nonobservable factors. Koch provides no such justification. Abortion laws are not randomly distributed in Mexico (or globally); there are statistical techniques to address the endogeneity of abortion legislation, but Koch et al. neither employ such techniques nor acknowledge this limitation.

Second, no change is under study here. Koch et al. present descriptive data by year, using ARIMA models to test for time trends [19], and pooled multivariable models. These

approaches test associations but are not natural experiment designs. Finally, if no intervention or before/after period is under study, ARIMA models are likely not the most appropriate approach [20]. None of these approaches involves examining the effect of a change in abortion law or other exposure. This is not a natural experiment.

2. Materials and methods

This is a retrospective observational study aimed at conducting a reanalysis of maternal mortality and availability of abortion; we draw on several sources of existing data in Mexico. We undertook three related analyses. We first replicated the Koch et al. analysis for the years where we have overlapping data (2006–2011). We then replicated Koch but using CONAPO [12], the corrected birth estimates, to allow for comparison with our third and final analysis using a different classification of states according to availability of abortion.

We used the Búsqueda Intencionada y Reclasificación de Muertes Materna (BIRMM) dataset for state-level maternal deaths by year (2006–2013) [21,22]. We used the corrected population/birth statistics from CONAPO [12] in the denominator of our MMR calculations. We calculated the state-level MMR, our dependent variable, by place of residence of the woman and place of occurrence of the death. We also calculated the maternal mortality rate (maternal deaths per 100,000 women age 15–49 years) [12] that can help account for differences in fertility reflected in MMR.

We classified the 32 Mexican states based on actual availability of first-trimester-induced abortion. In 2006, 31 states and Mexico City were in the "restricted access" category. 2007–2013, Mexico City became "wide access" and the 31 states remained in the "restricted access" category. Our classification of states, the key independent variable, differs from that of Koch (see Supplementary Table A1).

We extracted state-level variables used by Koch: total fertility rate, proportion of the population with access to clean water, female literacy [23], contraceptive prevalence, proportion of births attended by a skilled birth attendant [24], prevalence of low birth weight, proportion of women who report interpersonal violence [25] and all-abortion-related hospitalizations between 2000 and 2008 [26]. Data were extracted from publicly available data and we used the years of data closest to our study years (Table A2).

In addition, we included the number of hospital beds and operating rooms per 100,000 population [25] in an effort to account for supply of tertiary-level care services. Mexico City, for example, has a higher capacity to treat severely ill women and likely has more high-risk patients and thus deaths [27]. Regional specialty hospitals exist, but in 2011, an estimated 14% of hospital discharges in Mexico City were patients residing outside Mexico City, and deliveries were the most common reason for hospitalization [27].

We merged these data sources creating a state-level (n=32) and year-level (n=8) dataset (N=256) with values for live births, maternal deaths, MMR, maternal mortality rate and covariates for each of Mexico's 32 states by year.

We were able to replicate the Koch analysis exactly (data not shown). Next, we undertook our revised analysis and comparison with Koch. We first described MMR over time using the different data sources (INEGI, CONAPO) for the denominator of live births. We followed the flow of the original Koch analysis to be able to compare our results with Koch. We used descriptive analyses over time and using pooled data of MMR by place of residence of the woman and place of occurrence of the death to examine differences in the availability of abortion using Koch's classification of states and then our own (using CONAPO for both). We used chi-square tests to test for differences in MMR and maternal mortality ratio by availability of abortion. Finally, we replicated Koch's multivariable models to estimate the association of the availability of abortion and MMR controlling for state-level covariates (as above).

We performed several multivariable sensitivity analyses, including running the ARIMA models Koch presents using

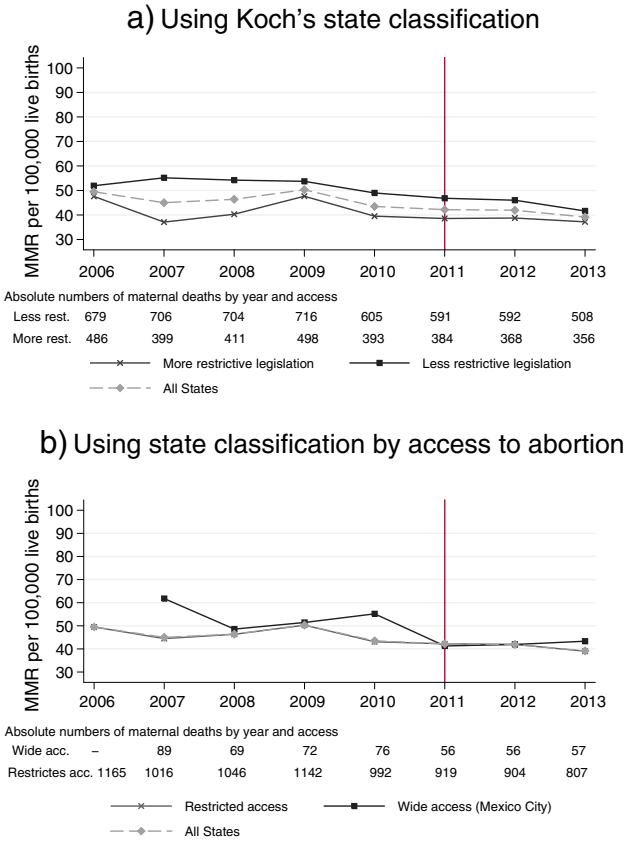

Fig. 1. MMR by place of residence, access to abortion and year. Footnote: Koch et al. study ends in 2011, at the red line. Denominator for MMR is birth estimates from CONAPO in both panels.

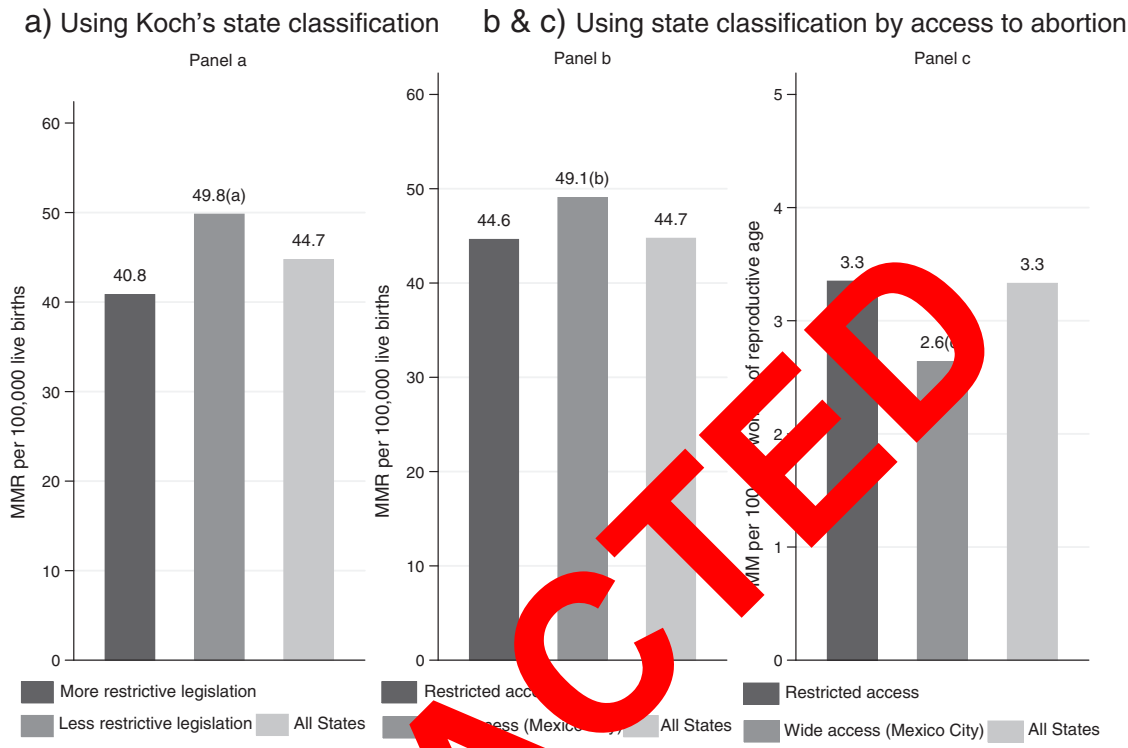

Fig. 2. Pooled 2006–2013 MMR (a and b) and maternal mort[illegible] women of reproductive age (c) by place of residence and access to abortion. Footnote: Difference test between states with restri[illegible]cess to a[illegible]n (more restrictive legislation) and states with wide access (less restrictive legislation). (a) p=.00, (b) p=.44 and (c) p=.16.

an array of parameter assumpti[illegible]s fo[illegible]q [19] but found no differences with our line[illegible] model w[illegible] fixed effects for year (data not shown). A[illegible]a[illegible]s was don[illegible]using stata v13 (StataCorp, College S[illegible]tion, TX). This study was deemed exempt by the ethi[illegible] committee of [illegible] National Institute of Public Health, C[illegible]rnava[illegible], Mexico.

3. Res[illegible]s

Our e[illegible]ates of MMR are higher due to the smaller denominator resulting from our use of population/birth estimates (CONAPO) instead of registered births (INEGI), which inflate actual births [21], but trends over time follow similar curves downward (Fig. A1). All results that follow use CONAPO for the denominator and compare Koch's state classification with ours. Fig. 1a shows Koch's MMR estimates by place of *residence* of the woman by year (compare with Koch Fig. 1); Fig. 1b shows the same estimates using our classification of states. There is no data point for "wide access" in 2006 in Fig. 1b since Mexico City liberalized its law in 2007, and Mexico City is thus the only state we classified as having abortion available on request. We did not find significant differences in MMR between Mexico City (49.1) and the 31 states (44.6; Fig. 2b), pooled across years; the higher MMR observed in the states Koch classified as being less restrictive (Fig. 2a) disappears in our reclassification of the states.

Place of *occurrence* of the death is presented next, using Koch's (Fig. 3a and Fig. 4a and see Koch, Fig. 2) and our (Fig. 3b and Fig. 4b) state classifications. The MMR in Mexico City, where national reference hospitals are located, is significantly higher than the 31 states where abortion is restricted (Fig. 3b; p<.001). Here, the estimates using maternal deaths per 100,000 women of reproductive age are helpful. Mexico City exhibits lower ratio of deaths per 100,000 women of reproductive age looking at place of *residence* (Fig. 2c) but slightly higher by place of *occurrence* (Fig. 4c).

In regression models that include access to abortion and year, our reclassification of states by access to abortion (Table 1, bottom panel) produced similar results to Koch (Table 1, top panel) but stronger relationships (coefficients for both "wide access" and "restricted access" are larger and "restricted access" became significant in our classification). Our reclassification also produced stronger relationships for the estimate of change in MMR for each unit change in year examining place of occurrence of the death.

In multivariable models that include state-level indicators of poverty (compare with Koch Tables 7 and 8 and Fig. 8), we find, as did Koch, that indicators of poverty are associated with MMR (Table 2). We also see further evidence of a decline in MMR in Mexico City, the only state classified as having wide access to abortion (beta=−22.5; 95% CI=−38.9; −5.99) (Table 2).

4. Discussion

We find declining maternal mortality across Mexican states during 2006–2013, with faster decline in the one state

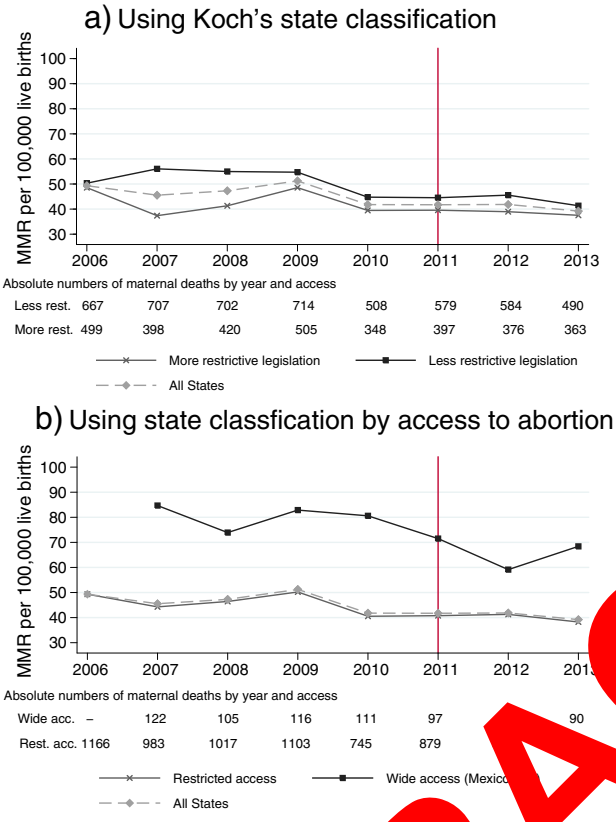

Fig. 3. MMR by place of occurrence, acces abortio nd year. otnote: Koch et al. study ends in 2011, at the red lin nor R is birth estimates from CONAPO in both pa .

with access to abortion, lex City. Our bivariate results differ from Koch; on we use a ification of states based on actual availabi of abortion, w id not find significant differences in R be en Mexico City (MMR=49.1) and the 31 states (M 4.6; p 4). Using Koch's classification, we ted p lish differences (MMR=41 versus 50; p 01). e foun significant, negative association betw M bortion legislation in multivariable models g our state classification (beta=−22.49, 95% CI=−38.9 .99). State-level poverty remains highly correlated with MMR.

The first major difference between our results and those of Koch is due to different classifications of the exposure: availability of abortion or restrictiveness of abortion law at the state level. Koch does not present a transparent justification for which of the indications translate into "more permissive laws" [5].

Focusing on place of residence of the woman versus place of occurrence of the death is the second major reason why our results are different. The bias introduced by focusing on Mexico City as a place of occurrence of death and confounding that with legality or availability of abortion, as Koch does in his conclusions and press release, is notable in our results. We show that MMR is much higher in Mexico City in the pooled analysis (Fig. 4b; MMR=74.4 versus 43.9 in other states; p<.001). Our estimates examining maternal deaths per 100,000 women of reproductive age instead of per 100,000 live births show that when we account for the lower fertility in Mexico City than the rest of Mexico [12], this results in lower ratio of deaths per women by residence (Fig. 2c) in Mexico City, the only state we classify as having access to abortion on request, while ratio of deaths by occurrence remains elevated in Mexico City (Fig. 4c), where high risk and sick women are referred for treatment [27].

However, even Koch n findings as published and as replicated here do t sup t the conclusions of the published article. is Koch interpretation of his own findings that mo flawed Given Koch's published findings an urs, a plau terpretation is that MMR is falling f r in tes wit access to abortion. This goes again his conclu n in the article and the associated pr release, ich the most misleading [6] and drawn e result ile ignoring the most robust finding: matern ortality is linked with poverty. The association of poverty a aternal mortality is well-documented [28]. Our group has found that women residing in poorer regions of M co experience more direct maternal death, which in des abortion-related death, than women in wealthier as, for example [29].

Our study has limitations, although we feel that we have carefully considered the limitations of our data and our ability to draw inference, unlike Koch et al. Our limitations lie mostly in our inability to draw causal inference. While Koch et al. conclude that their study "confirm[s] that Mexican states with less permissive abortion laws exhibited 23% lower overall maternal mortality", we cannot conclude that our results confirm that access to abortion on request is the cause of reductions in MMR. First, our maternal mortality data, due to limitations in the quality of the BIRMM data, only go back to 2006, which does not permit a good time series of before and after the change in the law. Koch et al. use BIRMM from 2003, but the data quality of the early years is known to be poor (personal communication, R. Lozano). Second, we examine associations but cannot be sure that we have controlled unmeasured confounders. For example, our multivariable regression (Table 2) suggests that, accounting for time trends and common state-level sociodemographic and health systems factors, Mexico City (the only state with access to abortion on demand) is associated with a 22.5-unit decrease in MMR compared with the 31 states with restricted access. This could be due to the abortion law, but it could be due to things that we did not measure, such as other health system access changes or social programs. In middle to low maternal mortality environments such as Mexico and much of Latin America, changes in abortion law may not produce the drastic changes in maternal mortality documented in other countries and other eras [4].

The relationship of changing legal status and access to abortion with maternal morbidity and mortality remains a highly relevant question in Mexico and worldwide [30]. Correlates of maternal death are clear; we have strong

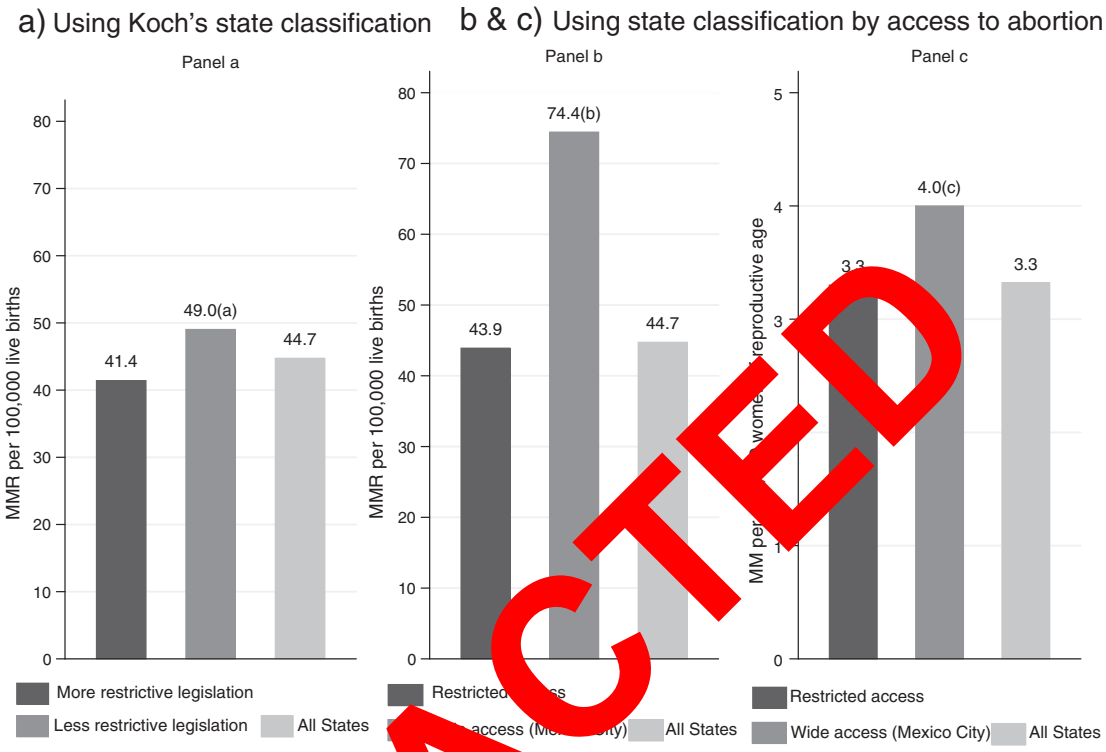

Fig. 4. Pooled 2006–2013 MMR (a and b) and maternal mortality ratio per 100,000 women of reproductive age (c) by place of occurrence and access to abortion. Footnote: Difference test between states with restricted access to abortion (more restrictive legislation) and states with wide access (less restrictive legislation). (a) p=.00, (b) p=.00 and (c) p=.17.

evidence [28] that demonstrates the relationship between poverty, low levels of female education, high fertility and maternal death. Koch et al.'s analysis supports previous work without adding anything new. Preventing undesired births via contraception and safe abortion are among key strategies to reduce maternal mortality, along with improving socioeconomic conditions for women, emergency obstetric care and access to high-quality antenatal, delivery and postpartum care [31,32]. We support a recent call to improve abortion data and research by adhering to three criteria: transparency, acknowledging the limitations of data and contextualizing results [7]. Koch and colleagues fail at all three and do not help us understand the relationship between decriminalization of or access to safe abortion and women's health.

Table 1
Average change per year in MMR by place of residence and occurrence and access to abortion

	Coefficient	SE	p Value
Using Koch's state classification			
By place of residence			
More restrictive legislation	−0.92	0.45	.051
Less restrictive legislation	−1.72	0.65	**.010**
All states	−1.27	0.40	**.002**
By place of occurrence			
More restrictive legislation	−0.99	0.46	**.034**
Less restrictive legislation	−1.86	0.73	**.013**
All states	−1.37	0.42	**.001**
Using state classification by access to abortion			
By place of residence			
Restricted access	−1.25	0.41	**.003**
Wide access (Mexico City)	−2.81	0.95	**.032**
All states	−1.27	0.40	**.002**
By place of occurrence			
Restricted access	−1.41	0.41	**.001**
Wide access (Mexico City)	−3.20	1.21	**.046**
All states	−1.37	0.42	**.001**

Table 2
Linear regression model for state-level MMR by place of residence, 2006–2013 (using state classification by access to abortion and place of residence of the woman)

MMR		
N=256, state-years	Coeff.	CI 95%
Abortion legislation (=1 restricted access)	**−22.49**	[−38.9; −5.99]
Year	**−0.88**	[−1.64; −0.13]
Clean water	**−0.45**	[−0.83; −0.80]
Female literacy	−0.10	[−0.83; 0.62]
Low birth weight	−0.88	[−2.12; 0.34]
Skilled attendance at birth	**−0.60**	[−1.06; −0.14]
TFR	1.36	[−1.23; 25.01]
Contraceptive use	−0.21	[−0.66; 0.24]
Physical violence	**1.94**	[0.89; 3.00]
All-abortion hospitalization ratio	**−1.05**	[−1.96; −0.13]
Hospital beds	−0.02	[−0.15; 0.11]
Operating room	1.72	[−1.45; 4.89]
p<.05		

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.contraception.2016.08.004.

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