The burden of suboptimal breastfeeding in Mexico: Maternal health outcomes and costs

Mishel Unar-Munguía¹ | Dalia Stern² | Monica Arantxa Colchero³ |
Teresita González de Cosío⁴

¹Center for Research on Health and Nutrition, National Institute of Public Health, Cuernavaca, Morelos, Mexico

²CONACYT—Center for Research on Population Health, National Institute of Public Health, Cuernavaca, Morelos, Mexico

³Center for Health Systems Research, National Institute of Public Health, Cuernavaca, Morelos, Mexico

⁴Health Department, Universidad Iberoamericana, Mexico City, Mexico

Correspondence

Teresita González de Cosío, Health Department, Universidad Iberoamericana, Mexico City, Mexico, Prolongación Paseo de Reforma 880, Lomas de Santa Fe, Mexico City, 01219, Mexico.

Email: teresita.glezdecosio@ibero.mx

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Abstract

Longer duration of breastfeeding is associated with a lower risk of type 2 diabetes, breast and ovarian cancer, myocardial infarction, and hypertension diseases in women. Mexico has one of the lowest breastfeeding rates worldwide; therefore, estimating the disease and economic burden of such rates is needed to influence public policy. We considered suboptimal breastfeeding when fewer than 95% of parous women breastfeed for less than 24 months per child, according to the World Health Organization recommendations. We quantified the lifetime excess cases of maternal health outcomes, premature death, disability-adjusted life years, direct costs, and indirect costs attributable to suboptimal breastfeeding practices from Mexico in 2012. We used a static microsimulation model for a hypothetical cohort of 100,000 Mexican women to estimate the lifetime economic cost and disease burden of type 2 diabetes, breast and ovarian cancer, myocardial infarction, and hypertension in mothers, due to suboptimal breastfeeding, compared with an optimal scenario of 95% of parous women breastfeeding for 24 months. We expressed cost in 2016 USD. We used a 3% discount rate and tested in sensitivity analysis 0% and 5% discount rates. We found that the 2012 suboptimal scenario was associated with 5,344 more cases of all analysed diseases, 1,681 additional premature deaths, 66,873 disability-adjusted life years, and 561.94 million USD for direct and indirect costs over the lifetime of a cohort of 1,116 million Mexican women. Findings suggest that investments in strategies to enable more women to optimally breastfeed could result in important health and cost savings.

KEYWORDS

burden of disease, economic costs, maternal health, Mexico, microsimulation, suboptimal breastfeeding

1 | INTRODUCTION

Breastfeeding rates in Mexico are very low compared with the World Health Organization (WHO, 2008) recommendations of exclusively breastfeeding for the first 6 months of life and continue breastfeeding for 2 years or longer. In 2006, the prevalence of exclusive breastfeeding up to 6 months was 22.3% and decreased to 14.4% in 2012 (González de Cosío, Escobar-Zaragoza, González-Castell, & Rivera-Dommarco, 2013). Moreover, median breastfeeding duration among Mexican

women is 10.2 months and has not improved over the last 20 years (González de Cosío et al., 2013). Additionally, the prevalence of continued breastfeeding until at least 24 months of age was 14.1% in 2012 (González de Cosío et al., 2013).

Suboptimal breastfeeding is associated with higher infectious and chronic diseases among infants (Victora et al., 2016), but its adverse effects are not exclusive to infants. Recent evidence shows that women with shorter breastfeeding duration have an increased risk of breast and ovarian cancer, type 2 diabetes, hypertension, and myocardial

infarction (MI; Bartick et al., 2013; Chowdhury et al., 2015). This is of special concern because these diseases are the leading causes of morbidity and mortality in Mexican women (Gomez-Dantes et al., 2016) and represent a high economic burden for the health system (Figueroa-Lara, Gonzalez-Block, & Alarcon-Irigoyen, 2016; Gonzalez-Robledo, Wong, Ornelas, & Knaul, 2015) and society (Barraza-Lloréns et al., 2015).

Increasing breastfeeding duration may reduce the risk of the aforementioned maternal diseases, prevent premature deaths, and potentially reduce health care and productivity costs. There are estimations for several distinct scenarios, documenting these costs. A study from the United States shows that suboptimal breastfeeding cost 2.8 billion U.S. dollars annually on direct and indirect costs associated with breast and ovarian cancer, type 2 diabetes, hypertension, and MI among women (Bartick et al., 2017). In the United Kingdom, a 100% increase in the proportion of mothers' breastfeeding for 7–18 months would save 41 million USD only accounting on reducing breast cancer burden due to suboptimal breastfeeding (Pokhrel et al., 2015). In Mexico, only one study has documented the burden of suboptimal breastfeeding in mothers associated to breast cancer in 2012, which adds up to 245 million USD in direct and indirect costs (Unar-Munguia, Meza, Colchero, Torres-Mejia, & González de Cosío, 2017). However, no previous study has quantified the overall disease and economic burden of suboptimal breastfeeding in Mexican women.

The objective of this study was to estimate the lifetime economic and disease burden in terms of incident cases, deaths, disability-adjusted life years (DALYs), direct medical costs, and indirect costs from premature morbidity and mortality (productivity losses) associated with suboptimal breastfeeding practices. We simulated a cohort of Mexican women aged 15 years in 2012 for which we modelled their age of death using survival functions that we estimated from age-specific survival rates obtained from epidemiological studies for each disease or the age-specific mortality rates from other causes in 2012. We modelled the baseline scenario using 2012 breastfeeding rates and compared it with an optimal scenario where 95% of parous women breastfed for 24 months. Quantifying the economic and disease burden associated with suboptimal breastfeeding provides information on the minimum amount the country should invest to achieve optimal breastfeeding duration. This is an initial step on constructing the public health agenda for breastfeeding practices in Mexico, as the federal health budget does not explicitly include breastfeeding promotion, protection, and support.

2 | METHODS

Our analyses rely on a previous simulation study that estimated the burden of suboptimal breastfeeding only on breast cancer in Mexican women (Unar-Munguia, Meza, et al., 2017). Our study adds estimations for other four diseases in women that were selected based on a review of its relation with breastfeeding in epidemiological studies and meta-analyses.

We used a cost of illness methodology (Jo, 2014) and implemented a static microsimulation model that allows estimating the

Key messages

- Suboptimal breastfeeding practices contributes to the increasing burden of diabetes, myocardial infarction, hypertension, and breast and ovarian cancer among Mexican women.
- In 2016, suboptimal breastfeeding among women represented 2.5% of the public health expenditure in the country.
- Indirect costs represented three quarters of the maternal burden of suboptimal breastfeeding.
- Investments in strategies to enable more women to optimally breastfeed could result in important health and cost savings.
- Future studies should estimate the cost-effectiveness of interventions aimed at improving breastfeeding practices in Mexico.

economic cost and disease burden of chronic diseases and cancer in mothers due to suboptimal breastfeeding. We assumed a societal perspective, which estimates the costs independently of who pays. We applied a prospective time horizon that accounts for all incident cases of selected diseases associated to 2012 breastfeeding rates in women over their life course. We estimated the lifetime number of children per woman and the proportion of women that were nulliparous using the most recent age-specific fertility rates (National Survey of Demographic Dynamics, 2009). Our estimations were extrapolated to 1.116 million Mexican young women with a baseline age of 15 years in 2012, the number of 15-year-old young women in Mexico on that date (CONAPO, 2013). To estimate the present value of economic cost and DALYs, we used a 3% annual discount rate and tested the sensitivity of the results using 0% and 5% discount rates that is more appropriate for developing countries based on recommendations for cost-effectiveness analyses (Arnold, 2016; Drummond, Sculpher, Torrance, O'Brien, & Stoddart, 2005; Rascati, 2009).

2.1 | Suboptimal and optimal breastfeeding scenarios

We simulated two breastfeeding conditions: the baseline or suboptimal scenario and the optimal scenario. For the baseline scenario, we used the breastfeeding prevalence observed in the National Health and Nutrition Survey (ENSANUT) 2012, the most recent national health and nutrition survey data on breastfeeding (González de Cosío et al., 2013). We estimated each woman's duration of breastfeeding, assuming a geometric distribution with a median of 10 months per child, where 6.3% of parous women never breastfed and only 14% breastfed each child for ≥ 24 months (González de Cosío et al., 2013). We assumed zero months of lifetime breastfeeding for nulliparous women. Under the optimal breastfeeding scenario, we assumed that 95% of parous women breastfed for 24 months per child,

following the WHO (2008) recommendation to continue breastfeeding their infants up to 2 years of age or beyond. We also assumed that 5% of women were not able to breastfeed because of adoption, maternal death, or serious diseases, all of which interfere with breastfeeding (Lawrence & Lawrence, 2005).

2.2 | Health outcomes

Evidence on increased risk of diseases among women associated with suboptimal breastfeeding practices was obtained from a comprehensive Lancet Breastfeeding Series, which reported the most recent meta-analyses summarizing the scientific evidence on the relationship between breastfeeding and different health outcomes in women (Victora et al., 2016). We reviewed all the meta-analysis reported in the Lancet Series and also reviewed recent meta-analyses for endometrial cancer (Zhan, Liu, Li, & Zhang, 2015) and breast cancer (Unar-Munguia, Torres-Mejia, Colchero, & Gonzalez de Cosio, 2017) not included in the Lancet Series. Additionally, we reviewed studies for hypertension (Stuebe et al., 2011) and MI (Stuebe et al., 2009) because there is biological plausibility of risk reduction by increasing the duration of breastfeeding. We included the health outcomes for whom there is evidence of an increased risk of suboptimal breastfeeding practices. We selected breast cancer (Unar-Munguia, Torres-Mejia, et al., 2017), ovarian cancer (Chowdhury et al., 2015), type 2 diabetes (Aune, Norat, Romundstad, & Vatten, 2014), hypertension (Stuebe et al., 2011), and MI (Stuebe et al., 2009) and retrieved the risk reductions expressed as risk ratios of disease per months of duration of any mode of breastfeeding compared with no breastfeeding among women (see Table S1). We concluded that there is insufficient evidence that breastfeeding protects mothers from endometrial cancer, postpartum depression, osteoporosis, and postpartum weight loss (Chowdhury et al., 2015; Victora et al., 2016); therefore, we did not model these diseases.

Because it is unclear how many years of protection breastfeeding confers to each maternal health outcome, we used the years of follow-up from the cohort studies that have estimated the associations between breastfeeding and maternal health outcomes. We assumed that the duration of breastfeeding protects from type 2 diabetes only for 15 years after the last child was born for each woman (Bartick et al., 2013), 30 years for MI (Stuebe et al., 2009), and 15 years for hypertension (Stuebe et al., 2011). After this period, we modelled the incidence of these diseases as the observed average incidence for all Mexican women regardless of their breastfeeding history. For breast and ovarian cancer, we assumed a lifetime protection from breastfeeding according to epidemiological evidence (Chowdhury et al., 2015).

We modelled each maternal health outcome independently of having the other selected diseases because information on comorbidity and competing risks was not available. Additionally, due to lack of information, we did not model the burden derived from complications and severity of type 2 diabetes and assumed that 3.4% of women with hypertension will develop moderate heart failure due to hypertensive heart disease (Stevens, Pezzullo, Verdian, Tomlinson, & Zegenhagen, 2016). For cancer, we modelled the distribution of disease stages at

first diagnosis (Angeles-Llerenas et al., 2016) and conservatively assumed no disease recurrence.

2.3 | Data on incidence and mortality for the selected maternal health outcomes

To estimate incident cases for each maternal health outcome in our model, we relied on age-specific incidence estimates for Mexican women in 2012 for type 2 diabetes (Meza et al., 2015) and breast and ovarian cancer (Ferlay et al., 2015). Data on incidence of MI and hypertension were not available for Mexico; therefore, we used data from the Epidemiological Surveillance System (2012; SINAVE), which reports new cases of ischemic heart disease (IHD), including MI, and separately reports hypertension new cases in Mexican women in 2012 (see Table S2). To approximate the incidence of MI, we multiplied the IHD incidence by 0.827, which is the estimated proportion of nonfatal MI cases from total IHD cases in a cohort of women (Chang et al., 2017). We assumed that the proportion of MI from IHD were the same across age groups. As incidences were aggregated into 5-year age groups, we extrapolated linearly to have specific incidences for ages 15 to 90 years.

Mortality estimates for type 2 diabetes, MI, and hypertension in women came from age-specific survival rates estimated for Mexican women aged 50 years or older (Gonzalez-Gonzalez, Palloni, & Wong, 2015) and followed for 12 years from 2001 to 2012. For breast and ovarian cancer, we obtained 5-year survival rates at different stages of disease (I–IV) from studies of Mexican women (Angeles-Llerenas et al., 2016; Novoa-Vargas, 2014). We estimated the probability of death from other causes than the selected maternal health outcome by subtracting women's deaths from each specific disease from total deaths by age in 2012, reported by the National Institute of Statistics and Geography (2012; INEGI). The remaining deaths from other causes were divided by the population of women by age in 2012 (CONAPO, 2013). For each specific death, the model randomly assigned an age at death from a distribution for age at death based on microdata on mortality for other causes of death and mortality estimates from the mentioned studies. Therefore, on average, life expectancy in the hypothetical cohort was 77.4 years. The sources of information and estimations for each outcome incidences and mortality are presented in Tables S2 and S3.

2.4 | Disability-adjusted life years

We estimated the number of years of life lost (YLL) and the number of years lived with disability (YLD) for each woman simulated in our study using the general formula proposed by Murray and colleagues for estimating the burden of disease (Murray, 1994) and described in the DALY calculator for R (Devleeschauwer, McDonald, Haagsma, & Nicolas Praet, 2014). We explain the formulae in the Supporting Information. For estimating YLD and YLL, we used information of incident cases, age of onset, duration of the disease, and premature death simulated for each woman in our hypothetical cohort for each maternal health outcome. We used disability weights for each disease from the Global Burden of Disease (GBD) study 2016, coordinated by the Institute for Health Metrics and Evaluation (Hay,

2017; Table S4). We estimated DALYs as the sum of YLD and YLL and applied the same time discount rate as for costs and assumed no age weighting.

2.5 | Direct and indirect costs

Direct costs included health care costs for each maternal health outcome associated with diagnosis and treatment in the public health care sector. We relied on estimations of annual healthcare cost per case for public institutions from published literature for type 2 diabetes, hypertension (Arredondo & Aviles, 2015) and breast cancer (Gonzalez-Robledo et al., 2015). For ovarian cancer and MI, we used costs provided by the Fund for the Protection against Catastrophic Expense (FPGC for its Spanish name) of the public insurance system known as “Seguro Popular” (Ministry of Health, 2015). When necessary, we converted costs from Mexican pesos into 2016 dollars (USD) using the appropriate exchange rate (Banco de Mexico, 2017) and the American inflation index (Consumer Price Index, US, 2017). We show cost per case for the selected maternal health outcomes and the methods used in Table S5.

We assumed that all incident cases received health care treatment at a public institution and excluded medical costs from private institutions due to lack of information. Nevertheless, only 0.4% of the Mexican population receives private medical attention (Gutierrez & Hernandez-Avila, 2013). We estimated direct costs from age at onset until death from type 2 diabetes, hypertension, and MI. For women with breast or ovarian cancer, we estimated direct costs only for a maximum of 5 years for cancer stages I to IV, and 3 years for cancer in situ (stage 0), which are the standard average treatment periods for these diseases (Gonzalez-Robledo et al., 2015; Hospital General de México. Oncología, 2013).

Indirect costs comprised productivity losses due to morbidity and premature mortality from the maternal health outcomes modelled. We assumed per capita gross domestic product (GDP) as a measure of productivity lost for all women, independently of having a remunerated employment, and considered that women also contribute to GDP through nonpaid work. We used estimations of the annual GDP at current prices in 2016 divided by the total population provided by the World Bank (2016). Morbidity costs included the cost of temporary absence from work associated with each disease. We assumed that morbidity days were those reported as annual average disability days by age group and disease in adult women by The Mexican Social Security Institute (IMSS for its Spanish name; Mexican Institute of Social Security, 2015), multiplied by the proportion of disease cases by age group. Premature mortality was defined as dying from any of the diseases modelled before life expectancy.

2.6 | Simulation model

We made conservative assumptions about the model and the main parameters that we describe in the Supporting Information; therefore, we are potentially underestimating the burden of suboptimal breastfeeding. We assumed steady-state rates of fertility, breastfeeding duration, disease incidence, mortality rates, health care costs, and per capita GDP. We simulated prospectively the lifetime number of

children and the duration of breastfeeding per child using 2012 breastfeeding rates and estimated the accumulated duration of breastfeeding per women. We also estimated the incident cases for each maternal health outcome, the age of onset and disease duration, specific disease deaths and deaths for other causes, premature deaths, DALYs associated to the disease, and direct and indirect costs. Details are described in the Supporting Information. The simulation algorithm is summarized in Figure S1.

For each of the five diseases modelled under each breastfeeding scenario (10 models), we used Monte Carlo simulations with 1,000 replications per scenario (baseline and optimal) of a hypothetical cohort of 100,000 women to obtain the epidemiological and economic outcomes. With this number of replications and sample size, we reached convergence to the population values. The difference in outcomes between baseline and the optimal breastfeeding scenarios is the estimated burden of suboptimal breastfeeding in mothers per 100,000 women. The authors programmed all codes and made the simulations with R statistical software version 3.2.3 (Vienna, Austria; R Core Team, 2017).

2.7 | Probabilistic sensitivity analysis

Uncertainty in parameters is considered in the simulation model through different distribution functions for the main parameters: median duration of breastfeeding, relative risks by breastfeeding duration, health care costs per case, and the disability weights for each disease (see Tables S1–S5 for details).

2.8 | Sensitivity analysis by scenarios

We estimated different scenarios for our one-by-one sensitivity analysis to explore what parameters made our estimations more sensitive. We selected the following changes in key parameters with uncertainty: (a) time discount rates of 0% and 5% in addition to the 3% baseline rate assumed in all models and (b) health care costs with two scenarios (costs per case reduced by 20% or increased 20% from the baseline assumed costs).

3 | RESULTS

3.1 | Model validation

The simulated lifetime risk for the baseline scenario was consistent with other risk estimates for type 2 diabetes (Meza et al., 2015), breast cancer (Ferlay et al., 2015), and ovarian cancer (Ferlay et al., 2015) for Mexico (Table S6). The proportion of deaths estimated for each specific disease, with the exception of hypertension, were lower than those reported by INEGI in 2012 (National Institute of Statistics and Geography, 2012; Table S7).

3.2 | Simulation results

Table 1 shows the disease burden associated with suboptimal breastfeeding practices simulated for a hypothetical cohort of 100,000 Mexican women and extrapolated to 1.116 million women,

TABLE 1 Lifetime disease burden of suboptimal breastfeeding, simulated for a cohort of Mexican women in 2012

Disease	Variable	Scenario	Mean ^b	95% CI lower limit	95% CI upper limit
Type 2 diabetes	Cases	Baseline	479,428	479,315	479,540
		Optimal	479,121	479,006	479,235
		Difference	307	148	466
	Premature deaths	Baseline	187,348	187,268	187,429
		Optimal	187,165	187,082	187,248
		Difference	184	65	302
	DALYs	Baseline	2,504,481	2,503,119	2,505,844
		Optimal	2,481,491	2,480,049	2,482,933
		Difference	22,990	20,959	25,021
Breast cancer	Cases	Baseline	44,436	44,393	44,479
		Optimal	40,122	40,053	40,190
		Difference	4,315	4,232	4,398
	Premature deaths	Baseline	9,913	9,893	9,933
		Optimal	8,944	8,921	8,968
		Difference	969	938	1,000
	DALYs	Baseline	196,031	195,440	196,622
		Optimal	176,463	175,855	177,071
		Difference	19,567	18,745	20,390
Ovarian cancer	Cases	Baseline	7,072	7,055	7,089
		Optimal	6,682	6,663	6,700
		Difference	390	365	415
	Premature deaths	Baseline	3,652	3,639	3,664
		Optimal	3,441	3,428	3,454
		Difference	211	193	229
	DALYs	Baseline	56,014	55,794	56,234
		Optimal	52,709	52,487	52,931
		Difference	3,305	2,998	3,612
Myocardial infarction	Cases	Baseline	78,002	77,938	78,067
		Optimal	77,707	77,644	77,770
		Difference	296	207	385
	Premature deaths	Baseline	47,705	47,656	47,753
		Optimal	47,415	47,368	47,461
		Difference	290	224	356
	DALYs	Baseline	584,342	583,494	585,191
		Optimal	563,188	562,153	564,223
		Difference	21,154	19,810	22,498
Hypertension	Cases ^a	Baseline	449,998	449,876	450,121
		Optimal	449,943	449,818	450,068
		Difference	56	-116	227
	Premature deaths ^a	Baseline	104 159	104 095	104 222
		Optimal	104,131	104,063	104,199
		Difference	28	-67	122
	DALYs ^a	Baseline	53,517	53,273	53,761
		Optimal	53,660	53,421	53,899
		Difference	-144	-477	190
All diseases	Total cases	Baseline	1,058,937	1,058 76,	1,059,114
		Optimal	1,053,574	1,053,371	1,053,776
		Difference	5,363	5,103	5,624
	Total premature deaths	Baseline	352,777	352,662	352,891
		Optimal	351,095	350,974	351,217
		Difference	1,681	1,515	1,848
	Total DALYs	Baseline	3,394,385	3,392 63,	3,396,135
		Optimal	3,327,512	3,325,616	3,329,408
		Difference	66,873	64,300	69,447

Note. Simulated for a cohort of 100,000 women, considering the uncertainty in parameters in the simulation model through different distribution functions through a probabilistic sensitivity analysis. Estimations were extrapolated to 1.116 million Mexican young women with a baseline age of 15 years in 2012, the number of 15-year-old young women in Mexico on that date. DALYs = disability-adjusted life years.

^aDifference between baseline and optimal scenarios not statistically significant at a *p* value <0.05.

^bTotals may not always round up because of rounding.

the size of the population of women aged 15. With the exception of hypertension, there were significantly more cases, premature deaths, and DALYs for type 2 diabetes, breast and ovarian cancer, and MI among parous women under the suboptimal breastfeeding conditions, compared with the optimal scenario. Our estimations show a lifetime excess of 5,363 disease cases (95% CI [5,103; 5,624]), 1,681 premature deaths (95% CI [1,515; 1,848]), and 66,873 DALYs

(95% CI [64,300; 69,447]) of all diseases under current suboptimal breastfeeding rates compared with the optimal scenario.

Table 2 shows the economic costs associated with suboptimal breastfeeding practices. All costs were significantly higher under suboptimal breastfeeding practices compared with those under the optimal breastfeeding scenario, with the exception of hypertension. Our models estimated that the total costs incurred by failing to support

TABLE 2 Lifetime economic costs of suboptimal breastfeeding

Disease	Cost (million USD)	Scenario	Mean ^b	95% CI lower limit	95% CI upper limit
Type 2 diabetes	Direct costs	Baseline	1,620.65	1,610.35	1,630.95
		Optimal	1,583.40	1,573.39	1,593.42
		Difference	37.25	22.84	51.65
	Indirect costs	Baseline	30,425.81	30,411.34	30,440.28
		Optimal	29,759.28	29,739.55	29,779.01
		Difference	666.53	642.38	690.68
	Total costs	Baseline	32,046.46	32,028.65	32,064.27
		Optimal	31,342.68	31,320.38	31,364.99
		Difference	703.77	675.68	731.87
Breast cancer	Direct costs	Baseline	703.54	700.67	706.41
		Optimal	632.27	629.46	635.07
		Difference	71.27	67.32	75.22
	Indirect costs	Baseline	1,864.75	1,860.78	1,868.72
		Optimal	1,686.79	1,682.13	1,691.44
		Difference	177.96	171.86	184.06
	Total costs	Baseline	2,568.29	2,563.30	2,573.27
		Optimal	2,319.06	2,313.03	2,325.09
		Difference	249.23	241.47	257.00
Ovarian cancer	Direct costs	Baseline	48.02	47.80	48.25
		Optimal	45.41	45.18	45.64
		Difference	2.61	2.30	2.92
	Indirect costs	Baseline	582.26	579.70	584.83
		Optimal	550.26	547.51	553.01
		Difference	32.00	28.24	35.76
	Total costs	Baseline	630.28	627.64	632.93
		Optimal	595.67	592.81	598.53
		Difference	34.61	30.73	38.50
Myocardial infarction	Direct costs	Baseline	147.72	147.08	148.36
		Optimal	114.20	113.68	114.73
		Difference	33.52	32.67	34.37
	Indirect costs	Baseline	3,555.40	3,550.32	3,560.47
		Optimal	3,306.19	3,297.47	3,314.91
		Difference	249.21	238.87	259.55
	Total costs	Baseline	3,703.12	3,697.93	3,708.31
		Optimal	3,420.39	3,411.55	3,429.24
		Difference	282.72	272.22	293.22
Hypertension	Direct costs ^a	Baseline	1,238.82	1,231.14	1,246.50
		Optimal	1,227.17	1,219.51	1,234.83
		Difference	11.65	0.68	22.62
	Indirect costs	Baseline	12,618.88	12,609.14	12,628.62
		Optimal	12,530.50	12,520.35	12,540.64
		Difference	88.38	74.11	102.65
	Total costs	Baseline	13,857.70	13,845.22	13,870.18
		Optimal	13,757.67	13,744.66	13,770.67
		Difference	100.03	81.80	118.27
All diseases	Total direct costs	Baseline	3,758.76	3,745.53	3,771.98
		Optimal	3,602.46	3,589.41	3,615.51
		Difference	156.30	137.86	174.74
	Total indirect costs	Baseline	49,047.09	49,028.39	49,065.80
		Optimal	47,833.02	47,808.39	47,857.64
		Difference	1,214.08	1,183.84	1,244.32
	Total costs	Baseline	52,805.85	52,782.91	52,828.79
		Optimal	51,435.47	51,406.76	51,464.19
		Difference	1,370.37	1,334.80	1,405.95

Note. Simulated for a cohort of 100,000 women, considering the uncertainty in parameters in the simulation model through different distribution functions through a probabilistic sensitivity analysis. Estimations were extrapolated to 1.116 million Mexican young women with a baseline age of 15 years in 2012, the number of 15-year-old young women in Mexico on that date.

^aDifference between baseline and optimal scenarios not statistically significant at a *p* value <0.05.

^bTotals may not always round up because of rounding.

or promote breastfeeding as recommended by the WHO ranged from 14.94 to 255.85 million USD for each of the different maternal health outcomes, with a total cost for all diseases of 561.94 million USD (95% CI [539.99, 583.88]). Indirect costs contributed 75.0% to the total economic burden of all diseases, and direct costs accounted for 25.0%. The average lifetime cost per disease case was 104,781 USD (26,250 USD direct costs and 78,531 USD indirect costs).

3.3 | Sensitivity analyses

Suboptimal breastfeeding costs were 28 times higher when no discount rate was used compared with the baseline scenario where we used a 3% discount rate. Also, costs were 1.26 times lower when a 5% discount rate was used, compared with the baseline scenario (Figure 1). Total costs increased 1.05 times if health care costs per

FIGURE 1 Sensitivity analyses of lifetime economic costs of suboptimal breastfeeding, simulated for a cohort of 100,000 Mexican women in 2012 (million USD). Sensitivity analyses by scenarios were performed for 0% and 5% discount rates compared with 3% in baseline model, and a reduction or increase in 20% of health care costs per case compared with baseline costs. Estimations were extrapolated to 1.116 million Mexican young women with a baseline age of 15 years in 2012

case were 20% higher than baseline costs and decreased 1.05 times if health care costs were 20% lower compared with baseline (Figure 1).

4 | DISCUSSION

We estimated the lifetime economic and disease burden of type 2 diabetes, breast and ovarian cancer, MI, and hypertension in women and all diseases combined associated with suboptimal breastfeeding practices in Mexico in 2012. We found that there were 5,363 more cases of all analysed diseases, 1,681 additional premature deaths, 66,873 DALYs, and 561.94 million USD associated with suboptimal breastfeeding practices over the lifetime for the cohort of 1.116 million Mexican women aged 15 in 2012, if 95% of parous women breastfed for 24 months per child.

Our estimations are valid for several reasons. Our simulation model used the WHO recommendations for breastfeeding at least 2 years as the optimal scenario, which are the international standards to which we must adhere. We estimated the burden of suboptimal breastfeeding in a similar way to the GBD study, considering an ideal scenario where the population exposure to the risk factor had been modified to a theoretical minimum level (Forouzanfar et al., 2016), which in our study is defined as only 5% of parous women breastfeed suboptimally.

Moreover, our results only modelled maternal health outcomes in which there was biological plausibility and strong evidence of an association with breastfeeding duration among women and used risk ratios from the published literature that controlled for multiple confounders. Additionally, we accounted for the uncertainty of main parameters such as risk ratios, health care costs, and breastfeeding through a probabilistic sensitivity analyses, which improves the accuracy of estimations. Furthermore, our estimated projections of the lifetime risk of type 2 diabetes and cancer are similar to published studies for Mexico (Ferlay et al., 2015; Meza et al., 2015). Our estimations showing a high burden associated with suboptimal breastfeeding are consistent with those from other studies (Ferlay et al., 2015). The

amounts are not comparable as countries differ in the prevalence of breastfeeding, incidence rates, the diseases modelled, health care costs, and indirect costs, which are usually higher in developed countries where most of the literature comes from; and the outcomes included and methods used in the studies are different.

In the absence of population interventions that may revert the current disease burden, our estimates are conservative because we projected stationary parameters from 2012 into the future, even if the incidence of breast cancer is estimated to increase by 3% annually (Ferlay et al., 2015) and the incidence of type 2 diabetes is expected to double every 10 years (Meza et al., 2015). The estimated DALYs and costs are also likely to be underestimated because we did not model disease complications due to lack of information, which have higher related disability weights (Hay, 2017) and higher costs (Figueroa-Lara et al., 2016). Medical health costs were also underestimated, as they did not include any fixed costs of hospital equipment or infrastructure, or private medical costs (Arredondo & Aviles, 2015; Gonzalez-Robledo et al., 2015). Despite the biological plausibility that exclusive breastfeeding could exert a greater effect on the risk reduction of breast cancer due to intensity of breastfeeding (Unar-Munguia, Torres-Mejia, et al., 2017), we did not model its burden mainly due to the lack of studies that analysed exclusive breastfeeding and the risk of ovarian cancer, type 2 diabetes, hypertension, and MI. However, one study shows that the burden of breast cancer in Mexican women that do not breastfeed exclusively is twice compared with the burden when only the duration of any mode of breastfeeding is considered (Unar-Munguia, Meza, et al., 2017). Therefore, we consider that our estimations of the burden of suboptimal breastfeeding in Mexican women are conservative.

This study has some limitations. Like most modelling estimations, we made assumptions that were conservative related to disease incidence, mortality, survival, and costs. If any of these assumptions are incorrect, our analysis could either underestimate or overestimate cases averted and cost savings. Moreover, because the Epidemiological Surveillance System does not report cases of MI, we had to estimate them as a fraction of IHD cases, which may bias the estimates.

Our cost could be overestimated because we did not model the potential loss of earnings from dropping out of the labor market or working part time for mothers who breastfeed, due to lack of information for Mexico. Furthermore, we did not estimate the cost of extra food that women have to eat in order to produce milk. Additionally, overestimation of the number of cases is possible if some of the observed associations in the literature could still be confounded and if mothers who breastfeed are different in unmeasured characteristics and behaviours associated with the probability of having any of the diseases modelled (Bartick, 2013). Also, due to lack of data for Mexico, maternal health outcomes were modelled independently, even if some of the diseases may co-occur (Ward, Schiller, & Goodman, 2014), so the burden of incident cases could be overestimated. Another limitation of the study is that we do not have historical breastfeeding rates in Mexico for the years in which the incidence and relative risks of diseases were estimated in the epidemiological studies on which we rely. We assumed that the relative risks do not change from one population to another one and over time, assuming that modifiers of the association between breastfeeding and diseases were equally

distributed. However, by using 2012 breastfeeding rates, we could be overestimating the cases and costs in our model because historic breastfeeding rates would be higher in the years in which the incidence was collected in these studies.

On the other hand, our results could be underestimated for several reasons. Due to lack of data, we relied on estimations of age-specific incidences for type 2 diabetes based on the reported prevalence in the country and cancer incidence estimations from GLOBOCAN, a cancer surveillance database from the International Agency for Research on Cancer (IARC), based on mortality data that may be underreported. Moreover, our results could be underestimated because we did not consider the cost of formula for women who did not breastfeed or partially breastfeed in 2012 in Mexican infants (Colchero, Contreras-Loya, Lopez-Gatell, & González de Cosío, 2015), nor did we include the opportunity cost of breastfeeding mothers and caregivers of sick women. The latter represents up to 5% of the total economic costs of breast cancer due to suboptimal breastfeeding in Mexico (Unar-Munguia, Meza, et al., 2017). Although we are not able to estimate the range of overestimations or underestimations of our results due to lack of data, we consider that the sources of underestimation potentially compensate those of overestimation because we made conservative assumptions about the model and the main parameters.

We show that suboptimal breastfeeding in Mexico represents a heavy burden for the country in terms of the cost that it represents to the health system. In 2016, total costs represented 15% of the public insurance system Seguro Popular budget, 3.8% of The Mexican Social Security Institute budget for health care and 2.5% of the public health expenditure in the (Centro de Investigación Económica y Presupuestaria AC, 2017). Our findings also illustrate the severity in terms of disease burden and health costs of having suboptimal breastfeeding practices in Mexico.

Our estimations have several strengths. To the best of our knowledge, this is the only study in Mexico and Latin America that has estimated the economic and disease burden of suboptimal breastfeeding for maternal health outcomes. Related to some previous studies (Bartick et al., 2013; Pokhrel et al., 2015), our study considered the uncertainty of the main parameters through a probabilistic sensitivity analysis. Furthermore, our estimations include the burden of suboptimal breastfeeding in women in terms of DALYs, which has not been estimated in similar studies. Currently, the GBD study does not consider suboptimal breastfeeding practices as a risk factor for disease in women, despite the growing evidence of a protective association between breastfeeding and chronic diseases and cancer. Additionally, we included estimations for indirect costs, considering per capita GDP as productivity losses from morbidity and premature death, instead of women's salary, which is an underestimation of productivity loss, as another important source of income in Mexico comes from informal employment, which represented 58% of the economically active population of women in 2013 (National Survey of Occupation and Employment, 2013).

The promotion and sale of infant formula in Latin America, including Mexico, increased 37% between 2012 and 2014, the largest increase compared with that in other regions of the world (Nielsen, 2015). Increasing sales of breast milk substitutes worldwide, (Lampe, 2016; Rollins et al., 2016) and Mexico in particular (Escobar Zaragoza

& González de Cosío Martínez, 2016), coupled by a widespread violation of the International Code of Marketing of Breastmilk Substitutes (Code) in the country, accompanied by an absence of awareness of the existence of the Code by health care providers in Mexico (Hernández-Cordero et al., 2018) may explain the drastic drop in breastfeeding rates. Although by no means we imply a causal relationship between these determinants and the observed decline in breastfeeding practices, there is a strong body of evidence linking these variables (Rollins et al., 2016).

To improve breastfeeding practices among women, the National Academy of Medicine from Mexico (ANM) recommends limiting the marketing and sale of formula milk and monitor the International Code of Marketing of Breast-milk Substitutes (González de Cosío, Hernández-Cordero, Rivera-Dommarco, & Hernández-Ávila, 2017). Also, the ANM endorses legislating in favour of extending the duration of paid maternity leave for working mothers (González de Cosío et al., 2017). In developed countries, an extended period of maternity leave is associated with higher exclusive breastfeeding and longer breastfeeding duration (Andres, Baird, Bingenheimer, & Markus, 2016; Baker & Milligan, 2008). Since 1952, the period of paid maternity leave in the country covers 12 weeks, but only 32% of women have an employment with social protection.

5 | CONCLUSIONS

Our study estimates provide the minimum amount of resources that the government should invest to improve breastfeeding rates in the country. Findings suggest that investments in strategies to enable more women to optimally breastfeed could result in important health and cost savings. We recommend that future epidemiological studies in women should measure exclusive, predominant, or partial breastfeeding according to WHO definitions, along with effect modifiers so that future estimations of the burden of suboptimal breastfeeding could be more robust. Future studies should focus on the estimation of implementation costs and cost-effectiveness of interventions aimed at improving breastfeeding practices in the Mexican context.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

MAC and TGdC are responsible for the project conception, development of overall research plan, and study oversight. MUM and DS conducted research. MUM wrote the statistical program and DS helped in adapting it to model the different maternal health outcomes. MUM, DS, MAC, and TGdC wrote the manuscript. TGdC had primary responsibility for final content. All of the authors read and approved the final manuscript as submitted.

ORCID

Mishel Unar-Munguía <http://orcid.org/0000-0002-1156-9337>

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SUPPORTING INFORMATION

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