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Effect of Human Development Index and other socioeconomic factors on mortality-to-incidence ratio of lips and oral cavity cancer in Mexican states: an ecological study

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ABSTRACT

Objectives To assess the association between the Human Development Index (HDI) and covariates on the mortality-to-incidence ratio (MIR) of lips and oral cavity cancer (LOCC) in Mexico.

Design Ecological study.

Setting Data from 32 Mexican states for year 2019.

Participants Data set of male and female populations from Mexico.

Exposures Socioeconomic conditions based on HDI and covariates related to healthcare system capacity (total health spending per capita, school dropout and ratio of medical personnel in direct contact with patients).

Primary and secondary outcome measures MIR of LOCC by state and sex was calculated from the Global Burden of Disease Study website for year 2019. Data for calculating HDI 2019 by state and covariates were obtained from the National Institute of Statistics and Geography. A multiple regression model was constructed to measure the effects of HDI and covariates on LOCC-MIR.

Results Among the states with the highest HDI (>0.780), Colima had the highest aged-standardised rates per 100.000 in men for incidence (5.026) and mortality (3.118). The greatest burden of the disease was found on men, with the highest Men:Women MIR in Colima (3.10) and Baja California Sur (2.73). The highest MIR (>0.65) was found among the states with the lowest HDI (Oaxaca and Chiapas). For each unit of increase of the HDI there was a decrease in the LOCC- MIR of −0.778, controlling for the covariates. The most suitable regression model explained the 57% (F (p): 0.000) of the variance.

Conclusions Men were most affected by LOCC in Mexican states. The highest MIRs of LOCC were found in the states with the highest HDI. But a worse prognosis of the disease, expressed as a higher MIR, is expected in contexts with lower HDI in the country, even with lower MIRs.

Strengths and limitations of this study

► It is necessary to make lip and oral cavity cancer (LOCC) should receive attention given its high mortality when receiving a diagnosis, the differences between sexes and between populations, even within the same country.

► This study uses the latest data set from the Global Burden of Disease Study and a simple search strategy, which can be applied to continue monitoring changes in the incidence and uptake of mortality in Mexico.

► Although an association between socioeconomic conditions and the ratio of mortality-to-incidence due to LOCC was demonstrated, it is necessary to deepen the relationship of other variables to develop more complex models.

► More research is needed to strengthen survival data records as an ideal indicator.

cause in developing countries.[1 2] Several factors, such as population ageing and growth, changes in lifestyles, economies and societies, are increasing the global burden of cancer, including those related to advances in human development.[3] Therefore, as the lives of populations become more economically prosperous, the incidence of cancer commonly found in high-income populations (ie, breast, prostate, colorectal) increases.[2]

Lips and oral cavity cancer (LOCC) is a malignant neoplasm that affects the anterior parts of the tongue, the floor of the mouth, the lips, the hard palate, the oral mucous membrane, the gums and the retromolar area (International Statistical Classification of Diseases and Related Health Problems (ICD)-11 2B60-2B69).[4] According to Global Cancer Observatory (GLOBOCAN), in 2020,

INTRODUCTION

Cancer, as a cause of death in developed countries, ranks first, while it is the secondmost

there were 377 713 new cases (age-standardised rate (ASR) 4.1) and 177 757 deaths from this type of cancer (ASR 1.9). Men accounted for 69.95% of the incidence and 70.33% of mortality worldwide.[5]

The risk increases between 20% and 30% with individual tobacco or alcohol consumption, but the risk can be three times higher with combined use.[6] There are other risk factors for specific subtypes: high-risk human papillomavirus (HPV) has been associated with cancers in the oropharyngeal regions (including the base of the tongue, the lingual tonsil and the soft palate) in subpopulations in selected countries, while lip cancers are strongly associated with ultraviolet radiation from exposure to sunlight.[7]

In the USA, LOCC accounts for approximately 5% of cancers, while in India, Brazil and Cuba it is among the five most common cancers, accounting for 25%–40% of all malignant neoplasms, and among the main causes of mortality among men.[8] LOCC has a mortality of more than 50% of cases, an aspect that is highly influenced by the living conditions of the population,[9] and access to quality and timely healthcare.[10] In this sense, the mortality-to-incidence ratio (MIR) is an indicator of the results that a population can expect from a cancer diagnosis. High MIR values for a population are an indicator of poor cancer outcomes relative to incidence.[11] Currently, the MIR can be calculated based on easily accessible and publicly used data on incidence and mortality according to the type of cancer in most countries, thanks to some initiatives such as the Global Burden of Disease Study,[12] while survival data (considered to be superior to MIR) is publicly available only for limited databases covering a minimum of populations. Some studies have shown the severity and impact of cancer according to geographical regions using MIR, such as the states of a country.[13–16]

Although Mexico has not been among the countries with the highest rates of LOCC in the world[17] or in the Latin American region,[18] the different presence of the main known risk factors between the sexes,[19] the latent influence of other factors of viral origin,[20] and the constant changes in social conditions that have been reflected in widely applied indicators such as the Human Development Index (HDI),[21–23] make it relevant to know how these associations have been according to the most recent data available. To our knowledge, LOCC has not been studied at the state level and by sex in Mexico.

The objective of this study was to construct and compare MIR at the state level to assess geographical disparities in survival of LOCC in Mexico. State MIRs were also stratified by sex, and indicators such as HDI, total health spending per capita, school dropouts and the proportion of medical personnel in direct contact with the patient per 1000 inhabitants were included to further explore the existing disparities.

MATERIALS AND METHODS

This ecological study used data from the Global Burden of Disease (GBD) for LOCC.[12] The GBD is a global initiative that records historical information on demographics and health of the different countries of the world; for some countries it has subnational information. Data were retrieved on ASRs per 100 000 inhabitants for the incidence and mortality of LOCC by sex and for each state of Mexico for the year 2019. The strategy for data extraction from the GBD results tool[12] included: incidence and deaths; age-standardised prevalence; year 2019; neoplasm of the oral cavity and lips; causality; each of the 32 Mexican states; men and women; and rates.

To obtain the HDI for each of the 32 states of Mexico, data from the National Institute of Statistics and Geography was used through the Index Calculation tool using Excel from the United Nations Development Programme.[24]

Patient and public involvement statement

Since it is an ecological study, the design is based on secondary data and no patients participated in the development of the investigation.

Ethics approval statement

As the study was considered risk-free, it was not submitted to any ethics committee. This study complies with the Guidelines for Accurate and Transparent Health Estimates Reporting recommendations.[25]

Outcome variable: MIR of LOCC

The MIR is an indirect measure of cancer survival and is calculated by dividing the age-standardised death rate by the age-standardised incidence rate. The MIR was estimated for each of the 32 states of Mexico. The continuous version of this measure was used as the dependent variable, as reported by Khazaei *et al*.[26–28]

Predictor variable: HDI

The HDI is a summary measure of achievement in three key dimensions of human development: health, education and standard of living. It is calculated from two steps: first, the minimum and maximum values are determined (considered as 'natural zeros' and 'possible goals', respectively), to generate the indices between 0 and 1. Second, the index of each dimension and then the geometric mean of the three indices is generated, the education dimension has two categories.[29] The established values and the formula are shown in table 1.

The HDI reports maintain the same cut-off points in the HDI for the grouping of countries that were introduced in 2014. Report: low (HDI <0.550); medium (0.550 <HDI <0.699); high (0.700 <HDI <0.799); very high (HDI >0.800). The HDI measures were calculated for each of the 32 states of Mexico for 2019 using the Excel tool of the United Nations Development Programme,[24] which has the mathematical formulas.

Table 1 Values and formula for calculating the Human Development Index

Dimension	Indicator	Minimum	Maximum
Health	Life expectancy (years)	20	85
Education	Expected years of schooling (years)	0	18
	Mean years of schooling (years)	0	15
Standard of living	GNI per capita (2017 PPP$)	100	75 000

$$HDI = (I_{Health} * I_{Education} * I_{Income})^{1/3}$$

Source: Human Development Indices and Indicators: 2020.[29]
The asterisk implies that the three indices are multiplied.
GNI, Gross National Income; HDI, Human Development Index; PPP, Purchasing Power Parity.

Covariates

Total expenditure on health per capita

The data collected integrate public and private health spending per capita in each Mexican state. Quantifying the relationship between health spending and outcomes provides important evidence on the efficiency of the health system. Additionally, this quantification provides an opportunity to take action with respect to national health policy to address health inequalities. In the long term, continuous evaluation of the dynamics of this relationship can also provide useful mechanisms for evaluating the degree of success of changes in national health policy and the overall performance of the health system.[30] The data were obtained from the Centre for Economic and Budgetary Research.[31]

School dropout

According to the 2016 HDI report,[32] it is recommended to complement the enrolment and schooling data with dropout rates. This is because multiple factors reduce school enrolment and attendance. Examples of such factors are nutritional deficiency, personal and social problems, and even the need to start work at an early age. Therefore, the situation becomes a relevant factor to consider and evaluate.[32] Dropout rates were used for all educational levels and states in 2019. Dropout rates are calculated by subtracting the number of students enrolled at each level from the projections made year by year from those who should enter each school year.[33] Data were obtained from the Institute for the Evaluation of Education.[34]

Primary care medical and dental practitioners

Since the survival of LOCC is largely based on the delay and stage of diagnosis of patients who are referred by primary care physicians and dentists, the effect of referral by one or the other has been studied. A recent systematic review found that the percentage of medical referrals ranged from 13% to 86% and the referrals of the dentists ranged between 15% and 80% without statistical significance between the remission of one or the other on the results in the patients.[35] The present study considered the number of graduated dentists and the ratio of medical personnel in direct contact with the patient per 1000 inhabitants for the year 2019 in each of the states. The data were obtained from the National Association of Universities and Institutions of Higher Education[36] and the Secretariat of Health of Mexico,[37] respectively.

Analysis

Apart from the study variables, the population of each Mexican state for the year 2019 was considered (table 2). Histograms and kernel density plots were used to analyse the outcome variable (LOCC MIR) and the main predictor (HDI). Both had an approximately normal distribution (online supplemental appendix 1).

Simple linear regression models were run to analyse the individual contribution of each predictor to LOCC MIR. The coefficient of determination ($r2$) was used to compare the models and it was assumed that an independent variable significantly predicted the MIR if its p value was <0.05 (F test). In this step, the number of graduated dentists in each of the states ($r2$: 0.006, p value=0.668) was eliminated (table 3).

Finally, a multiple regression model was used to evaluate the association between LOCC-MIR and a combination of the outcome variables. Eight models were analysed. All models included HDI as a minimal predictor, and the final model included MIR, HDI and three other covariates. All analysis was done in Stata V.15.1.

RESULTS

In general, the ASR of incidence in Mexico is 2247 for men and 1301 for women, while mortality is 1388 and 0.749, respectively. This resulted in a higher MIR in men (0.619) than in women (0.575). Table 2 shows the ASR by age of incidence and mortality, and the MIR of LOCC together with the HDI indicators, total health expenditure, school dropout and ratio of medical personnel in direct contact with the patient per 1000 inhabitants.

The states with the highest HDI are those with the highest incidence rates. The average HDI for Mexico is 0.772; with the highest value in Mexico City (very high HDI: 0.885) and the lowest in Chiapas (high HDI: 0.700). The highest MIR among men can be seen in the states of Chiapas (0.664) and Guerrero (0.659); the last two are the states with the lowest HDI in the country. Interestingly, Colima's incidence rates (ASR 50.26) and mortality (ASR 3.118) among men stand out compared with the rest of the country. It also has one of the highest incidence rates among women (ASR 1624); only surpassed by the Veracruz rate (ASR 1629).

Among the covariates, the highest health expenditure per capita is found in Mexico City (MXN11 251); which implies an important difference compared with the state with the lowest health expenditure (Chiapas: MXN3386). Michoacán de Ocampo has the highest dropout rate

Table 2 Epidemiological and socioeconomic indicators of lips and oral cavity cancer in Mexico according to the HDI in 2019

State	Sex	Incidence	Mortality	MIR	Population	HDI	Health expenditure per capita (MXN)	School dropout	Ratio of medical personnel in direct contact with the patient per 1000 inhabitants
Mexico City	Men	1.804	1.107	0.614	8811266	0.885	11251.3	8.73	3.73
	Women	1.262	0.713	0.565					
Baja California Sur	Men	4.183	2.485	0.594	809833	0.830	6420.0	5.10	2.18
	Women	1.532	0.866	0.566					
Baja California	Men	2.085	1.259	0.604	3584605	0.809	4826.3	7.13	1.44
	Women	1.036	0.587	0.566					
Nuevo León	Men	2.373	1.395	0.588	5229492	0.807	4730.1	6.07	1.62
	Women	1.629	0.890	0.547					
Sinaloa	Men	2.890	1.634	0.565	3034942	0.804	4230.8	6.10	1.83
	Women	1.251	0.660	0.528					
Sonora	Men	2.773	1.709	0.616	3011810	0.804	5766.5	7.70	1.85
	Women	1.291	0.745	0.577					
Aguascalientes	Men	1.373	0.860	0.627	1321453	0.798	5560.0	7.57	1.94
	Women	1.084	0.637	0.588					
Tamaulipas	Men	3.077	1.790	0.582	3622605	0.792	5339.3	7.40	1.84
	Women	1.428	0.753	0.527					
Jalisco	Men	2.037	1.251	0.614	8110943	0.789	4511.4	7.13	1.78
	Women	1.110	0.639	0.575					
Colima	Men	5.026	3.118	0.620	747801	0.789	6086.6	7.90	2.16
	Women	1.624	0.962	0.592					
Querétaro	Men	2.278	1.436	0.630	2063148	0.788	4441.3	6.87	1.51
	Women	1.290	0.767	0.595					
Chihuahua	Men	2.266	1.418	0.626	3782018	0.786	4712.2	8.27	1.38
	Women	1.353	0.785	0.580					
Quintana Roo	Men	2.205	1.414	0.641	1664667	0.784	4441.3	5.27	1.48
	Women	1.521	0.933	0.613					
Mexico	Men	1.634	1.020	0.624	17363387	0.783	4203.7	6.57	1.19
	Women	1.081	0.628	0.581					
Nayarit	Men	2.166	1.307	0.604	1268460	0.779	4833.0	7.07	1.98
	Women	1.377	0.765	0.555					
Morelos	Men	1.912	1.195	0.625	1965487	0.776	4393.2	7.87	1.66
	Women	1.446	0.847	0.586					

Continued

Table 2 Continued

State	Sex	Incidence	Mortality	MIR	Population	HDI	Health expenditure per capita (MXN)	School dropout	Ratio of medical personnel in direct contact with the patient per 1000 inhabitants
Tabasco	Men	1.990	1.236	0.621	2431339	0.775	5312.2	5.90	2.00
	Women	1.608	0.927	0.577					
Yucatán	Men	2.532	1.624	0.641	2172839	0.774	5875.7	6.57	1.90
	Women	1.385	0.833	0.601					
Durango	Men	1.711	1.052	0.615	1799320	0.771	5182.3	8.57	1.91
	Women	1.159	0.644	0.556					
Campeche	Men	2.898	1.807	0.624	935047	0.770	5889.8	8.67	2.14
	Women	1.310	0.764	0.583					
Coahuila	Men	2.141	1.328	0.620	3029740	0.770	5100.9	6.73	1.70
	Women	1.279	0.724	0.566					
Tlaxcala	Men	1.311	0.827	0.631	1313067	0.770	4374.3	5.67	1.77
	Women	0.982	0.571	0.582					
Zacatecas	Men	1.530	0.953	0.623	1600412	0.764	4617.0	7.43	1.80
	Women	1.226	0.708	0.577					
San Luis Potosí	Men	1.917	1.193	0.622	1664667	0.760	3925.8	6.57	1.55
	Women	1.274	0.731	0.574					
Hidalgo	Men	2.161	1.317	0.610	2947206	0.760	4059.0	6.47	1.51
	Women	1.150	0.644	0.560					
Guanajuato	Men	1.780	1.107	0.622	5908845	0.757	4187.1	8.10	1.37
	Women	1.111	0.647	0.582					
Michoacán de Ocampo	Men	1.876	1.136	0.606	4658159	0.745	3727.7	10.03	1.51
	Women	1.050	0.595	0.567					
Veracruz de Ignacio de la Llave	Men	2.315	1.427	0.616	8163963	0.744	4511.0	6.07	1.45
	Women	1.496	0.850	0.568					
Puebla	Men	1.417	0.916	0.646	6313789	0.744	3756.4	5.13	1.48
	Women	1.185	0.595	0.595					
Oaxaca	Men	1.649	1.058	0.642	4061497	0.716	3904.6	10.70	1.54
	Women	1.383	0.823	0.595					
Guerrero	Men	2.889	1.903	0.659	3607210	0.708	4143.4	6.90	1.62
	Women	1.116	0.632	0.566					

Continued

Table 2 Continued

State	Sex	Incidence	Mortality	MIR	Population	HDI	Health expenditure per capita (MXN)	School dropout	Ratio of medical personnel in direct contact with the patient per 1000 inhabitants
Chiapas	Men	1.719	1.142	0.664	5382083	0.700	3386.2	6.83	1.25
	Women	1.622	0.992	0.611					
Estados Unidos Méxicanos	Men	2.247 (0.780*)	1.388 (0.469*)	0.619 (0.020*)	122381097	0.776 (0.035*)	4928.13 (1,375.81*)	7.158 (1.301*)	1.752 (0.444*)
	Women	1.301 (0.189*)	0.749 (0.116*)	0.575 (0.527*)					

Source: author's elaboration. *SD. The dotted lines separate the states with the highest and lowest HDI, respectively.
The dotted lines suggest the separation of the states with the first three and last three places of the epidemiological indicators.
HDI, Human Development Index; MIR, mortality-to-incidence ratio.

(10.47) and Mexico City has the highest proportion of medical personnel in direct contact with the patient per 1000 inhabitants (3.73).

Linear regression models showed that four of the five study variables were statistically significant ($p<0.05$). A modest proportion of the total variability is explained by the HDI alone ($r2=0.346$). Other results of simple linear models are shown in table 3.

The final model was chosen using a combination of the coefficient of variability ($r2$) together with the Akaike and Bayesian information criteria (online supplemental appendix A). The model with greater parsimony was preferred to the others. The final multivariate model, which included the HDI and the other three covariates as exposure variables, showed that the proportion of variability in the LOCC MIR explained by the predictors was 57.01%. In addition, the variance inflation factor with a threshold of 10 was used to assess collinearity (online supplemental appendix A). The fit of the model appears strong with most of the points close to the prediction line (figure 1). Other tests applied to the final model are shown in online supplemental appendix A.

In general, whenever the HDI increases there is a corresponding decrease of −0.778 units in the LOCC MIR while controlling for total health spending per capita, school dropouts and the proportion of medical personnel; the behaviour of the HDI rates and MIR is statistically significant (table 4). Therefore, the total variability explained by the model was moderate with around 57.01%

DISCUSSION

This study highlights the utility of using incidence, mortality and MIR to describe variations in cancer distribution and survival between and within states for populations and sexes. Although the highest incidence and mortality rates of LOCC were observed in states with a high HDI, calculation and comparison of MIR at the state level for LOCC revealed that some states with a lower HDI have relatively low survival rates of LOCC compared with other central and northern states. Indicators such as the HDI and the covariates used gave a moderate explanation of the possible results of a diagnosis of LOCC. Despite the fact that Mexico is a country with low rates of LOCC, these type of data provide relevant information for various areas of society to explore in-depth the determinants of these differences in mortality versus incidence, and identify actions that allow a reduction of the cancer burden in high mortality settings. To our knowledge, this is the first research in Mexico that studies the relationship between socioeconomic factors and LOCC in the 32 states.

We found that men are more affected by LOCC than women, as observed in other Latin-American contexts, reaching a male/female ratio of >4.0 in Paraguay.[18] This fact has been related to the higher prevalence in men who present with the main traditional risk factors such as tobacco and alcohol consumption.[38]

Table 3 Regression models between mortality-to-incidence ratio and each predictor

Model	Predictor	R² (p)	P value	β (IC 95)	MSE
1	Human Development Index	0.346	0.000	−0.344 (−0.520 to −0.168)	0.017
2	Total health expenditure per capita.	0.410	0.026	−3.026 (−8.450 to −2.420)	0.024
3	School dropout	0.273	0.005	0.002 (0.001 to 0.003)	0.018
4	Number of graduated dentists	0.006	0.668	−5.411 (−0.000 to 0.000)	0.021
5	Ratio of medical personnel in direct contact with the patient per 1000 inhabitants.	0.562	0.019	−0.011 (−0.027 to −0.006)	0.020

Source: author's elaboration.
MSE, Mean Squared Error; p, p *value*; r2, r squared value.

In the study by Reynales-Shigematsu *et al*[39] evaluating the effects of tobacco control policies on smoking in Mexico, the authors found that smoking rates have been reduced by approximately 30% as a result of policies such as cigarette taxes, open air smoke laws, media campaigns, advertising, prohibitions, warning labels, treatment cessation and tobacco access policies for young people, implemented since 2002. However, the implementation of the recommendations to control tobacco use suggested by the MPOWER agreement has progressed unevenly in Mexican states, according to the 2016 National Survey on Drug, Alcohol and Tobacco Consumption Encuesta Nacional de Consumo de Drogas, Alcohol y Tabaco; in spanish (ENCODAT).[40]

Among the 32 states, those with the highest MIRs among men were Colima, Baja California Sur, Tamaulipas, Guerrero and Campeche. Among these states, only Baja California Sur showed a higher prevalence of smoking in men
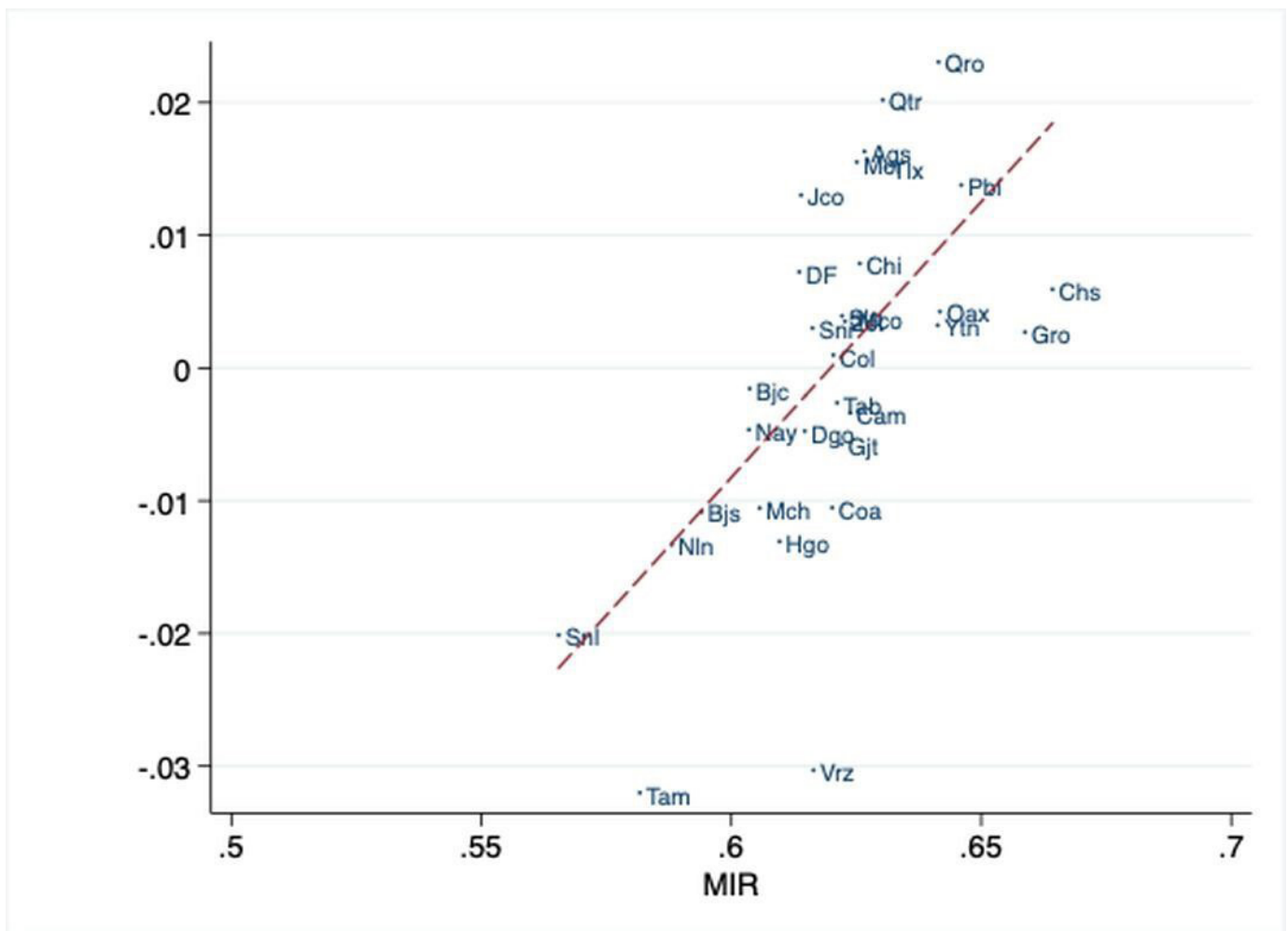
Figure 1 Mortality-to-incidence ratio: observed versus predicted values. Source: author's elaboration.

Table 4 Multiple regression analysis of mortality-to-incidence ratio of lips and oral cavity cancer and Human Development Index and covariates

p: 0.0001	R²: 0.5701	Adj R²: 0.5064
Variable	β (95% CI)	P value >|t|
Human Development Index	−0.778 (−1.159 to 0.396)	0.000
Total health expenditure per capita	0.000 (7.945 to 0.000)	0.003
School dropout	−0.001 (−0.003 to 0.001)	0.038
Ratio of medical personnel in direct contact with the patient per 1000 inhabitants	−0.032 (−0.067 to 0.002)	0.048

Source: author´s elaboration.
The bold refers only to style and the format defined by the magazine can be used
p, p *value*; r2, r squared value.

(29.8% for men and 10.1% for women) than the national prevalence (27.1% for men and 8.7% for women). This contrasts with the states with the highest prevalence of smoking such as Mexico City (42.3% in men; 20.0% in women) and other northern states,[40] which are also the states with the greatest economic development.[41] Worldwide in 2015, the age-standardised prevalence of daily smoking was 25.0% (95% uncertainty interval (UI) 24.2% to 25.7%) in men and 5.4% (95% CI 5.1% to 5.7%) in women. Among men, the prevalence of smoking was highest in countries with a medium Sociodemographic Index (SDI), while for women, countries with a high SDI had the highest prevalence of smokers.[42]

ENCODAT[40] showed that excessive alcohol consumption occurred in 19.8% of the population; 10.9% men and 8.9% women. The regions that presented excessive alcohol consumption, above the national average (19.8%) were the north-west and west,[40] to which Baja California Sur and Colima belong, respectively. Alcohol consumption has increased in Mexico among women (mainly among the youngest), mainly in border regions.[43] Globally, in 2016, 25% (95% UI 23% to 27%) of women were current drinkers, as were 39%[36–43] of men. The prevalence was highest for high SDI settings, where 72% (95% IU 69% to 75%) of women and 83% (80% to 85%) of men were current drinkers. The prevalence of alcohol consumption was lower in places with low to medium SDI, where 8.9% (95% UI 6.6% to 9.7%) of women and 20%[17–22] of men were current drinkers. Across all SDI quintiles, women consumed less alcohol than men, and the size of this disparity decreased with higher SDI levels.[44]

The epidemiological behaviour of LOCC has shown changes. Although it still occurs in populations with the presence of known risk factors such as tobacco and alcohol consumption, this is no longer sufficient to explain its higher prevalence in countries such as India, France or Brazil.[45] The prevalence of tobacco and alcohol use in the world as a whole has decreased, especially in men.[42 44] But not so the prevalence of LOCC accompanied by a decrease in the ages of onset and an increase in the prevalence of oral cancer in the youngest population (<45 years) worldwide, particularly in Western populations.[46] Thus, it has been sensitised to study other aetiological factors such as the role of HPV,[47] immunodeficiency[48] and predisposition to genetic instability.[49]

Although the evidence supporting that HPV is a causative agent of LOCC is controversial, a positive association has been observed between HPV and potentially malignant lesions that develop squamous cell carcinoma in the oral cavity, reaching an OR of 3.97.[50] Subtype 16 has been associated with >90% of HPV-LOCC cases.[6] The profile of patients who develop LOCC associated with HPV is predominantly men, between 40 years and 55 years old, especially white, with a high educational and socioeconomic level, with sexual behaviours considered high risk, not necessarily smokers or drinkers. Globally, the prevalence of HPV is between 9% and 13%, with geographical differences and a greater participation in developing countries. A study in Mexico showed a prevalence of oral HPV infection of 12.1%.[51] Unfortunately, the absence of data by state makes it difficult to incorporate this variable in this type of study at this time. However, prophylactic vaccines may be useful in the prevention of squamous cell carcinoma of the oral cavity associated with HPV, but prospective studies on this topic are lacking.[52]

Baja California and Colima share other characteristics: as tourist sites close to the USA, they have high national immigration (>9% of the national population, most of them under 5 years of age) above the national average of 2.9%; high international migration (>6% of the national population, the majority under 5 years of age) above the national average of 3.5%;[53] changes in demographic composition with a thickening in the middle of the pyramid;[53] an apparent increase in the incidence and mortality from cancers in men who are severely affected by the so-called 'Western lifestyle' (ie, colorectal, lung and prostate cancers);[12] and high development according to our findings (HDI >0.785). Some studies have shown a positive relationship between the incidence of breast[54] and prostate[55] cancers and the HDI, while the relationship with mortality has been negative.[54 55] This has been associated with greater possibilities for proper registration, diagnosis and treatment, as well as changes in the regular patterns of presentation of the disease in relation to socioeconomic conditions.

It has been assumed that people can migrate from less developed to more industrialised places, as an example of the theory of a 'rapid epidemiological transition', so

that they move between contexts that are at different stages of the epidemiological transition.[56] This type of transit is common between Mexico and the USA, especially in the northern states of Mexico. Therefore, although at the place of birth the causes of mortality are related to infections, at the place of destination mortality may be lower and related to lifestyle. Examples of the latter are diabetes, cardiovascular disease and some cancers, which become increasingly common with longer stays and among migrant children.[57] In fact, countries with very high and high HDI account for 41% of cancer cases in the world.[2] Among the most common types of cancer are those of the lung, stomach, colorectal, prostate and breast; all have shown a negative relationship between their MIR and the HDI.[58] In agreement, mortality from LOCC has been associated with the HDI in Asia (r^2: −0.66, $p<0.001$)[21] and in the world (r^2: −0.29, $p<0.05$).[59]

The MIR is a relatively crude measure of cancer outcomes. A more robust measure might include survival; however, survival data are only available in some specialised centres in the country, which do not collect the national population,[60] and exclude the territories where the most significant deficiencies in socioeconomic conditions were identified in relation to the indicators studied. As such, we feel that this loss of granularity would result in an underpowered data set to support regression analyses. Mexico's MIRs for LOCC (0.619 for men and 0.575 for women) are higher than those of Asia (0.533 for men and 0.548 for women), Latin America and the Caribbean (0.444 for men and 0.374 for women) and North America (0.178 for men and 0.198 for women).[5] The Mexican states with the highest MIR in men were Chiapas (0.664) and Guerrero (0.659), which is similar to Sri Lanka (0.667) as a country with a high HDI.[5] Although the incidence and mortality were higher in other states, with higher HDI and higher prevalence of some risk factors, as has been explained, a relatively high MIR reflects poorer chances of survival, even in the presence of lower incidence. In essence, less developed states may have less access to quality health care. A relatively high MIR in some contexts reflects health-system limitations, especially in the diagnosis and management of cancer, such as an unavailability of adequate treatment that includes primary and specialised health personnel, sophisticated surgeries and chemotherapy regimens.[10] This can be seen in the fact that Chiapas and Guerrero are the states with the lowest health expenditure per capita (<MXN3900) and both have a ratio of medical personnel in direct contact with the patient per 1000 inhabitants under the national mean (<1.50 vs 1.75 national). In many settings, MIRs have been increasingly used to assess the efficacy of cancer control programmes within,[61] and between, countries.[62] It can highlight disparities in access and acceptance of treatment, as well as in detection and prevention practices, reflecting the need to strengthen timely access to health services within states to generate effective prevention of LOCC, early diagnosis and avoiding the poor prognosis associated with the disease, limited quality of services and delays in care.

For its part, the study of socioeconomic indicators has shown that economic growth does not reach the entire population in an equitable manner and that it does not necessarily lead to human development. This is especially true when evaluating HDI,[63] which showed minimal differences between Mexican states. In general, among the states of Mexico and the world, the main advances in HDI have been due to the increase in life expectancy at birth, especially as a result of important policies sustained over time that fight against maternal and infant mortality.[63] Worldwide, in 2019, life expectancy for women was 83.9 years and 78.3 years for men; while in Mexico it was 78.5 years for women and 76.2 years for men.[12] This reflects the possibility of suffering from diseases such as LOCC with cumulative exposure to multiple risk factors, beginning at a younger age.

Our study has several limitations in addition to those inherent to ecological designs, which do not allow us to speak of causality but of association. Many low-income and middle-income countries have cancer registries and vital registry data with limitations for analysis. Estimates in Mexico depend on multiple sources of information in the absence of country-specific epidemiological data on cancer incidence and mortality. Additionally, the quality of data from vital registration systems and cancer registries may vary from state to state, with under-reporting or miscoding of cancer cases or deaths. In this sense, through the redistribution of undefined codes and other estimation analyses, the GBD methodology[64 65] tries to correct the problems of quality and comparability of the data, at the national and subnational levels. Some registry efforts, such as the National Cancer Registry Network,[60] allow data from populations with limitations to continue to be considered in their registries given their proximity to places with more robust data. Our findings allow us to know the national needs for LOCC according to the observed rates.

The data analysed suggest that LOCC-MIR is inversely related to the HDI, total health spending per capita, school dropouts and the proportion of medical personnel, by up to 57%. Hence, the increase in HDI, and the other indicators, triggers the possibility of reducing mortality due to LOCC compared with cases of incidence.

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