UNIVERSIDAD DE COSTA RICA
CCP Centro Centroamericano de Población

Población y Salud en Mesoamérica. Doi: http://dx.doi.org/10.15517/psm.v14i2.27028
Volume 14, number 2, article 1, january-june 2017

Población y Salud en Mesoamérica

PSM

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Biannual electronic journal
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Centro Centroamericano de Población
Universidad de Costa Rica

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: http://dx.doi.org/10.15517/psm.v14i2.27028
Volume 14, number 2, article 1, january-june 2017

Type 2 diabetes mortality at Mexican borders

Mortalidad por Diabetes tipo 2 en las fronteras de México

José Luis Manzanares Rivera[1]

ABSTRACT: Objective: To analyze type II diabetes mortality rates geographic distribution and evolution in time across both Mexican border regions during the period 1998-2013. **Methods:** The work is based on exploratory and inferential data analysis conducted using death reports from the national health information system. The analysis considers social determinants of health as a theoretical paradigm and includes microdata on consumption patterns at household level for the US-Mexico and Mexico-Guatemala border states. **Results:** A convergence path for type II diabetes mortality rates is found during the last 15 years between the studied border regions. **Conclusions:** The evidence presented indicates that the southern border states had been experiencing an epidemiologic transition towards mortality causes such as type II diabetes in the last decade. A trajectory that reflects a convergence pattern towards mortality rates found in the northern border states.

Keywords: Diabetes Mellitus, Type 2; Diet, Diabetic; Population Groups; Mexico.

RESUMEN: Objetivo: Analizar la distribución geográfica y evolución temporal de las tasas de mortalidad por diabetes tipo II en el periodo 1998-2013 para las regiones frontera sur y norte de México. **Métodos:** el trabajo se basa en el análisis exploratorio e inferencial de datos a partir de los registros de mortalidad reportados por el sistema nacional de información en salud SINAIS. El análisis retoma el paradigma teórico sobre determinantes sociales de salud por lo que se consideran microdatos sobre los patrones de consumo a nivel hogar en el contexto de la frontera México-Estados Unidos y México-Guatemala. **Resultados:** Se encuentra una trayectoria de convergencia durante los últimos 15 años en las tasas de mortalidad por diabetes tipo II entre las dos regiones fronterizas estudiadas. **Conclusiones:** La evidencia presentada indica que los estados de la frontera sur han experimentado en la última década una transición epidemiológica hacia causas de mortalidad como la diabetes tipo II, una trayectoria que muestra un patrón de convergencia con la población en la frontera norte.

Keywords: Diabetes Mellitus Tipo 2; Dieta para Diabéticos; Grupos de Población; México.

Received: April 22, 2016 | **Corrected: Sept 14, 2016** | **Approved: Oct 03, 2016**

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ISSN-1659-0201 http://ccp.ucr.ac.cr/revista/

Doi: http://dx.doi.org/10.15517/psm.v14i2.27028
Volume 14, number 2, article 1, january-june 2017

1. Introduction

The evolution of type II diabetes as a death cause in Mexico increased by 76% during the period between 1998-2013, while the over all death causes experienced a 18,3% increase in same period. The exponential growth rate implicit by this trend reflects a public health concern of epidemic proportions.

Although diabetes is a major public health problem in Mexico previously thought to be related to population with relative higher income levels or affluent, recent studies had suggested an epidemiological transition impacting individuals in lower income regions. Studies conducted with a focus on the Mexican population suggest that this transition may be linked to nutritional changes (Seuring, Goryakin & Suhrcke, 2015). Argument that highlights the importance to consider social determinants of health such as consumption patterns as contextual factors to understand this growing public health treat.

Studies emphasizing behavioral determinants have established that inadequate diet is a key risk factor for the development of T2D (Sundquist, Eriksson, Mezuk & Ohlsson, 2015; Wali, Thomas & Sutherland, 2014). According to Ortiz-Hernández (2006), a link towards diabetes development through consumption practices finds a key path via the metabolic energy intake balance; the path identified can be traced back to life style habits further pressured by low price per calories processed foods available at the neighborhood scale.

As evidence suggest, diet follow trends tied to consumption practices that differ across demographic groups and regions (Gordon-Larsen, Guilkey and Popkin, 2011). Although it is recognized that T2D is a multifactorial public health issue and its determinants are not limited to consumption patterns, considering contextual factors may provide additional insights to improve its understanding at a regional scale.

Despite the importance of geographic location to explain this epidemic, in the past decades the study of biological risk factors has been the dominant paradigm (Graves and Kayal, 2008; Stolar 2010). While research on environmental correlates of physical activity such as obesity, a well-known risk factor for the development of diabetes (Day and Baily, 2011) has been well documented in the US Mexico border communities (Fisher-Hoch et al., 2010). There is a clear research gap relative to diabetes studies for the Mexican southern border states and its connections to population consumption patterns at a local level.

The contrasting demographic profiles found across regions in Mexico constitute a rich area for research to help explain and develop preventive measures to control this epidemic. Additionally, research to date has not extensively examined the geographic distribution and the evolution in time of T2D mortality in Mexico, in particular, the contrast between opposite regions in the country such as the northern and southern border states offer a unique research perspective. While the northern border states, a region with a relative high household income profile receives cultural influence that

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shapes population consumption patterns given its geographic proximity to the US; the southern border region, characterized by lower income levels, concentrate the highest proportion of indigenous population in the whole country, with reports as high as 97% of the total in some Chiapas Municipalities and similar proportions found at Campeche where at least one third of the populations is indigenous according to official census data (Comisión Nacional para el Desarrollo de los Pueblos Indígenas, 2010). Indigenous population represent a demographic group with dietary patterns often associated to a low intake of protein suppliers (Romano, Guerrero and García, 2014) and a high food poverty incidence.

A question that emerges in this context is: how these locational features found at contrasting border communities are reflected in the population health status as measured by diabetes mortality rates? In this context, the aim of this study is to analyze type II diabetes mortality rates geographic distribution and its evolution in time across both Mexican border regions during the period 1998-2013.

To achieve this purpose, this work estimates a relative concentration measure, the location quotient LQ and determine age adjusted mortality rates over the last 15 years for population at the US-Mexico and Mexico-Guatemala border states. In addition, micro data to document expenditure patterns at the household level is analyzed to further investigate possible links to T2D mortality at the local scale. Given the marked demographic and cultural differences between border states (North *vs* South), incorporating a homogeneous time period to analyze both regions allows to contrast mortality trends and provide insight about possible causes associated to social or cultural context.

2. Methodology and Data

2.1. Sample size

Microdata covering fifteen years of death records from 1998 to 2013 is analyzed to determine the evolution in time of the outcome variable. The National Information System on Health (SINAIS; Dirección General de Información en Salud [DGIS], 2016) is the main source; this data base reports the cause of death obtained from the death certificate according to the international classification of decease codes (ICD-10) including socioeconomic attributes linked to a geographic reference.

The two international border regions are analyzed. The norther border region (US-Mexico border) is integrated by the following states: Chihuahua, Baja California, Sonora, Coahuila and Tamaulipas, with a total 10 966 diabetes death records during 2013; whereas the southern border region (Mexico-Guatemala-Belize border) is comprised by the states of Campeche, Chiapas, Tabasco and Quintana Roo, with a total of 5 825 recorder deaths due to diabetes in 2013.

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Microdata on consumption expenditures is obtained from the 2013 National Expenditure Household Survey (ENGASTO, Instituto Nacional de Estadística y Geografía [INEGI], 2013). This source complies with international standards; it is the leading source of information in Mexico to determine the national consumer price index, and since it is published yearly it allows to monitor expenditure trends and compare patterns across time.

ENGASTO sample design is probabilistic, stratified, multistage and by conglomerates; it contains sample weights linked to the household as the primary analysis unit and estimates are representative at a state scale (INEGI, 2013). The sample size for the northern border states contains 9,902 observations representing 4 554 722 households with a population of 16 010 893 individuals. The sample for the southern border states comprises 7 111 observations representing 2 399 657 households with a population of 9 666 129 individuals.

2.2. Outcome variable

Type II Diabetes mortality is consider as the outcome variable. This is defined according to the international classification of disease CIE-10 codes: E100-E149; the records are collected from the death certificated administered by the national health system via the epidemiologic and statistic subsystem of deaths. The information is public and made available annually at the national health information system web site.

2.3. Statistical methods

A first approach is based on exploratory data analysis (EDA). Here a relative concentration measure, the location quotient LQ, is estimated to evaluate the diabetes epidemic trend in time by state and border region.

Using this relative measure allows controlling the population size in every state, to determine diabetes deaths concentration among different geographic areas. This measure considers the principles developed in the context of regional analysis literature by Isard (1971).

The location quotient LQ for mortality data is build using the following specification:

- Where *i* corresponds to a particular death record for ICD-10 code rage E100 to E149, *j* represents a particular border state and *N* refers to the national death cases for a given time period *t*. In both geographic areas diabetes deaths proportion to total deaths is compared.

- The quotient may take two relevant values: LQ > 1, which indicates that diabetes deaths cases are higher in state *j* relative to the national level. Whereas values LQ <1 indicate a lower proportion in state *i*, relative to the national level.

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— Results from LQ estimation are contrasted with the traditional approach by estimating age adjusted mortality rates (AAMR) using the direct approach. In the inferential stage, a logistic regression model is proposed based on mortality records, the specification allows contrasting T2D odd ratios for population living in either border region controlling for personal characteristics such as sex and age group. Equation 1 and 2 show the proposed specification.

The dichotomous variable$T2D_{death}$ indicates whether or not diabetes was the patient's cause of death applying definitions given by the international classification of disease in codes: E100 through E149, taking value 1 in the affirmative case, 0 otherwise. The following independent variables from the SINAIS micro data base were considered:

— Sex with values: 1 Male, 2 female.

— Age group with five categories: 0-17:1, 18-44:2, 3:45-79 and 5:>79.

— Border, with values: 1 if the individual residence was located in a northern border state and 2 if the individual usual residence was located in a southern border state.

3. Results

3.1. Diabetes as a death cause at Mexican borders

During the last fifteen years, T2D mortality showed an explosive pattern at the border states. This growth rate pattern departs from the trend followed by all other death causes (see Figure 1).

ISSN-1659-0201 http://ccp.ucr.ac.cr/revista/

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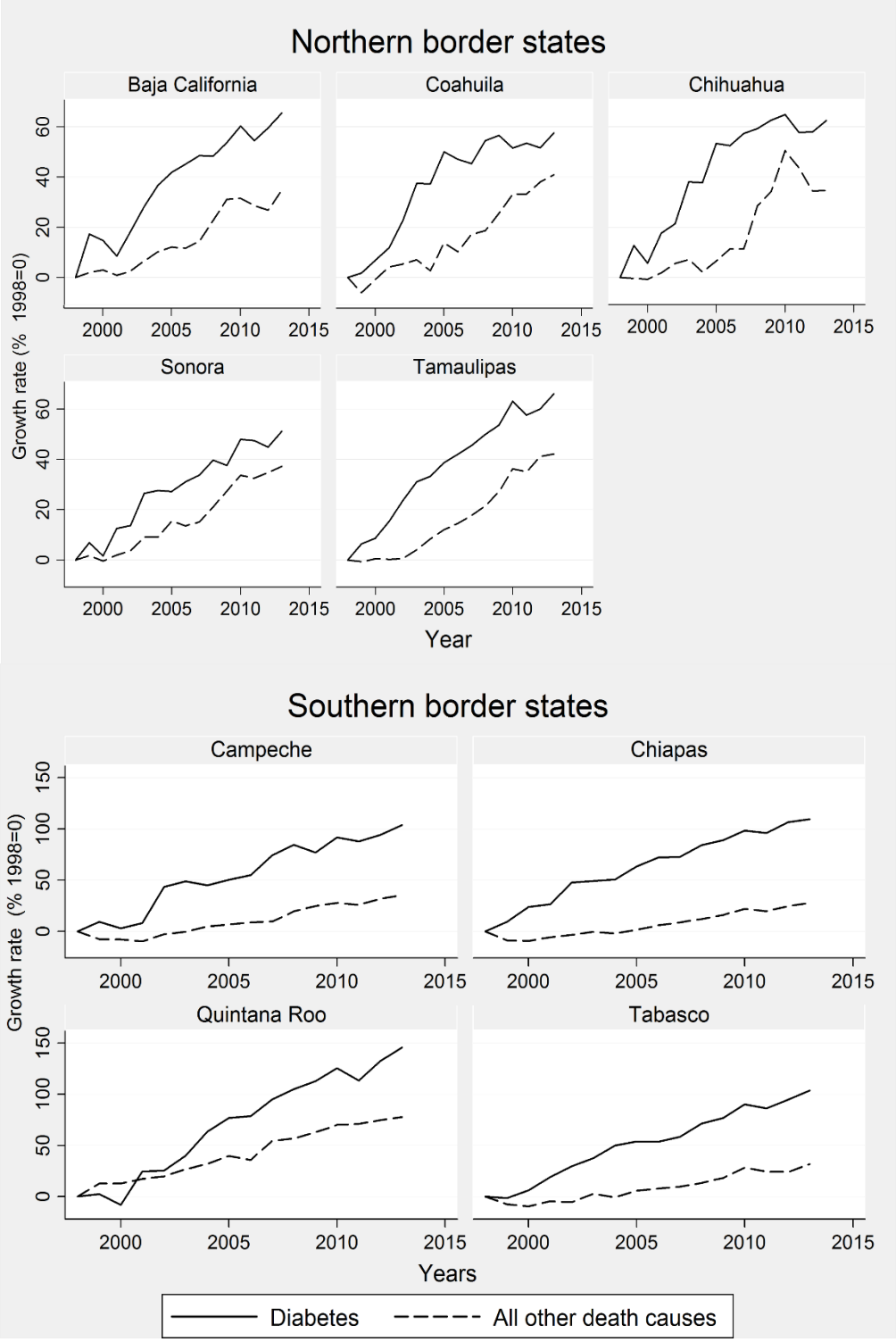
Figure 1

T2D deaths growth rate *vs* All other causes. Mexico-US border states, Mexico-Guatemala-Belize border states, 1998-2013.



Source: Own estimation. National Information System on Health (DGIS, 2016). E100-149. Note: Log normalized rate. 1998=0.

ISSN-1659-0201 http://ccp.ucr.ac.cr/revista/

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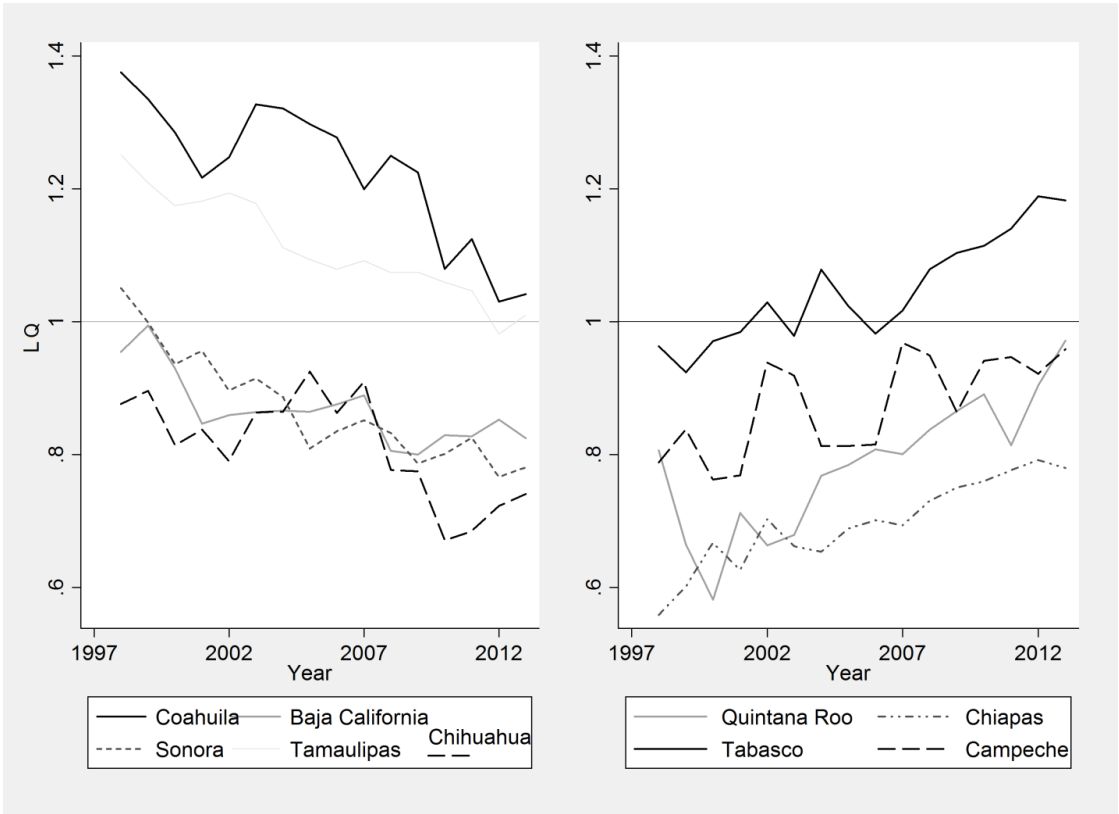
In particular, a rapid growth trajectory at the southern border is evident, with a widening gap by the end of the study period. This trend reaches a 146% increase in Quintana Roo by 2013 relative to the base year 1998, with an annual 9,11% average growth rate.

Nevertheless, the biggest gap between the overall mortality levels and diabetes mortality is observed in Chiapas, with a gap equivalent to 82% between diabetes mortality, which register a 110% accumulated growth during the period 1998-2013 compared to a moderate 27% mortality growth for all other causes. Nonetheless, among the northern border states there is an accelerated growth trend as well. This evolution was slower in relation to the southern border region, the biggest gap between diabetes and all other causes of death in that region is found in Baja California state, representing a 32% difference by the year 2013.

LQ evolution in time, depicted in Figure 2, reveals a clearer pattern, an opposite path between the two border regions. While the observed trend suggest an important epidemiological transition towards improved public health at the US-Mexico border, the opposite holds true for the Mexico-Guatemala-Belize border. What social determinants influence this relocation of disease at a regional level?

Figure 2

Location Quotient. Diabetes deaths, northern and southern border.



Source: Own estimation. National Information System on Health (DGIS, 2016). E100-149.

ISSN-1659-0201 http://ccp.ucr.ac.cr/revista/

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Despite the sustained increase found at the southern border by 2013, diabetes mortality concertation levels for the region still remained below the national proportion with a clear exception, Tabasco. The last mentioned is a relatively affluent state in the region[2] that register a proportion 20% higher than the national incidence. In addition, it is worth noting the path followed by Chiapas, the state with the lowest household income profile among the entire sample[3], showing the lowest relative diabetes death concentration.

Furthermore, an analysis string that has gain strength among other behavioral correlates in developing countries, such as Mexico, points towards changing consumption patterns as a key determinant. Arguably, social process, such as rural to urban migration that had previously posed major puzzles for public health (Harpham, 2009), represent forces that may supplant traditional dietary practices (Leatherman and Goodman, 2005). This happens even in regions such as the Mexico-Guatemala-Belize border, where the largest segment of indigenous population in the country lives.

3.2. Food items expenditure patterns

Both clinical randomized trials and studies considering a social determinants of health approach indicate the significance of lifestyle attributes, such as diet to prevent T2D or manage its complications (Deer, Kozka, Ozias and Reaven, 2015). In response to this awareness, several dietary models have been developed to improve T2D control. Some the dietary models are targeting products known to promote insulin resistance mechanisms such as flavored soft drinks (Deer *et al.*, 2015) or those associated with the formation of adipose tissue (which may induce a negative impact on cardio metabolic health such as fast food; Rummo, Meyer, Howard, Shikany, Guilkey and Gordon-Larsen, 2015).

It has been documented that a proper diet may reduce vascular complications (Chen, Sloan and Yashkin, 2015). This complications are common and, without a proper treatment, result in substantial human and economic burdens (Maiorino et al., 2016).

Considering household expenditures in products known to promote insulin resistance mechanisms such as flavored soft drinks, ENGASTO 2013 reveals that 80.5% and 78.1% of the households in the northern and southern border respectively are allocating part of their budget to consume these products. In addition, 39% of the households reported expenditures on fast food such as hot dogs, hamburgers, tacos, burritos, etc., sold by ambulatory vendors at the southern border, while a corresponding 36% did it at the US-Mexico border region (INEGI, 2013).

[2] Tabasco has the second higher household income in the region just below Campeche and both states are main oil producers for the country, given their location at the Golf of Mexico, one of the most important regions for energy resources in the world.

[3] Household income being a relevant correlate that remains a topic of active study in the diabetes determinants literature.

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This expenditure structure sharply contrast to the proportion of the population reporting expenditures in fruits items[4], such as: Guava 2% and 5% Orange 18% and 22% Apples 21% and 29% or vegetables such as Carrots 25% and 34%, Lentils 9,9% and 4,0%, or Broccoli 3,7% and 6,8%. If we further analyze expenditure shares, it is found that unhealthy products tend to absorb a higher share of resources in the budget allocation process. Considering the average amount of money per household dedicated annually to consume products such as beer, cola and flavored soft drinks, sugar and food prepared by ambulatory vendors was 73% higher compared to the combined amount dedicated to a basket of fruits and vegetables[5].

Research efforts by Myers, Denstel, & Broyles (2016) provide additional elements to understand this pattern. This fact can be traced to the neighborhood environment where the proliferation of unhealthy neighborhood features such as convenience store, fast food restaurants and gracery store location apparently are linked to health outcomes (Myers, Denstel, & Broyles, 2016), through their influence on access to healthy diet items (Ball, Timperio, & Crawford, 2009). Thus, the willingness to pay shown by the previous data may be a reflection of a more complex social estructure, where T2D is not an isolated result.

The geographic distribution of mean annual household expenditures on cola and flavored soft drinks shows that the highest mean expenditures in either border took place in Tabasco a state on the Mexico-Guatemala border. In addition, expenditures on this product appears to be dominant among the state's population with a share of 74% of the total households according to 2013 ENGASTO survey data[6] (INEGI, 2013).

Table 1 depicts selected items of annual expenditure for Tabasco state along with the corresponding percentage of households. This information reveals a pattern consistent with an insulin resistance model (Koska et al., 2016) towards a diet in which fructose containing products and adipose tissue stimulants are represented as regular consumer preferences.

[4] Percent data reported for the southern border followed by northern border figures.

[5] The vegetable basket is composed by guava, bananas, oranges, mango, papaya, apple, lentils, broccoli, zucchinni, chayote, carrots, beans, potatoes and chickpeas. The former basket (unhealthy) reaching $739,18 for the southern border and $744,6 at the US Mexico border whilst the latter amount (the vegetable basket) being $428,03 and 416,565 respectively.

[6] While, weather in this border state is on average warmer than most of the country, with an average daily high temperature above 34°C during six months of the year, the consumption of drinking bottled water figures indicate that 70% of the households acquired drinking bottled water with a mean expenditure of $203 a year, both figures below the corresponding for cola and flavored drinks, suggesting that other than weather factors may be determining this observed consumption pattern.

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Table 1

Tabasco annual mean household expenditures 2012 (Selected items).

Concept	Code	$ Expenditure	Households	%
Beans	11771	$ 66,1	362.381	62%
Potatoes	11781	$ 33,9	330.053	57%
Bananas	11621	$ 40,3	226.718	39%
Carrots	11742	$ 21,8	173.935	30%
Chayote	11738	$ 20,1	136.497	24%
Oranges	11615	$ 57,6	111.804	19%
Lentils	11774	$ 23,7	103.389	18%
Apple	11631	$ 84,3	91.248	16%
Zucchini	11733	$ 25,6	86.435	15%
Papaya	11663	$ 60,0	51.117	9%
Mango	11642	$ 49,5	45.616	8%
Chickpeas	11773	$ 18,1	27.170	5%
Broccoli	11722	$ 23,8	13.545	2%
Cola & Flavored sd.	12221	$ 223,9	431.536	74%
Sugar	11811	$ 49,7	361.061	62%
Food amb. vend.	111123	$ 168,1	163.096	28%

Source: Estimations using micro data from ENGASTO 2013 (INEGI, 2013).
Note: Codes based on the Classification of Individual Consumption According to Purpose, COICOP, recommended by ONU.

Considering recent evidence by clinical studies, adipose tissue found under obesity conditions has been suggested to play an important role in the development of insulin resistance and β-cell dysfunction, which are key metabolic processes involve in the pathogenesis of T2D. According to Meshkani & Vakili (2016): “obesity seems to be the major contributor to insulin resistance and T2D, as almost 80% of subjects with T2D are classified as overweight or obese.” (p.78)

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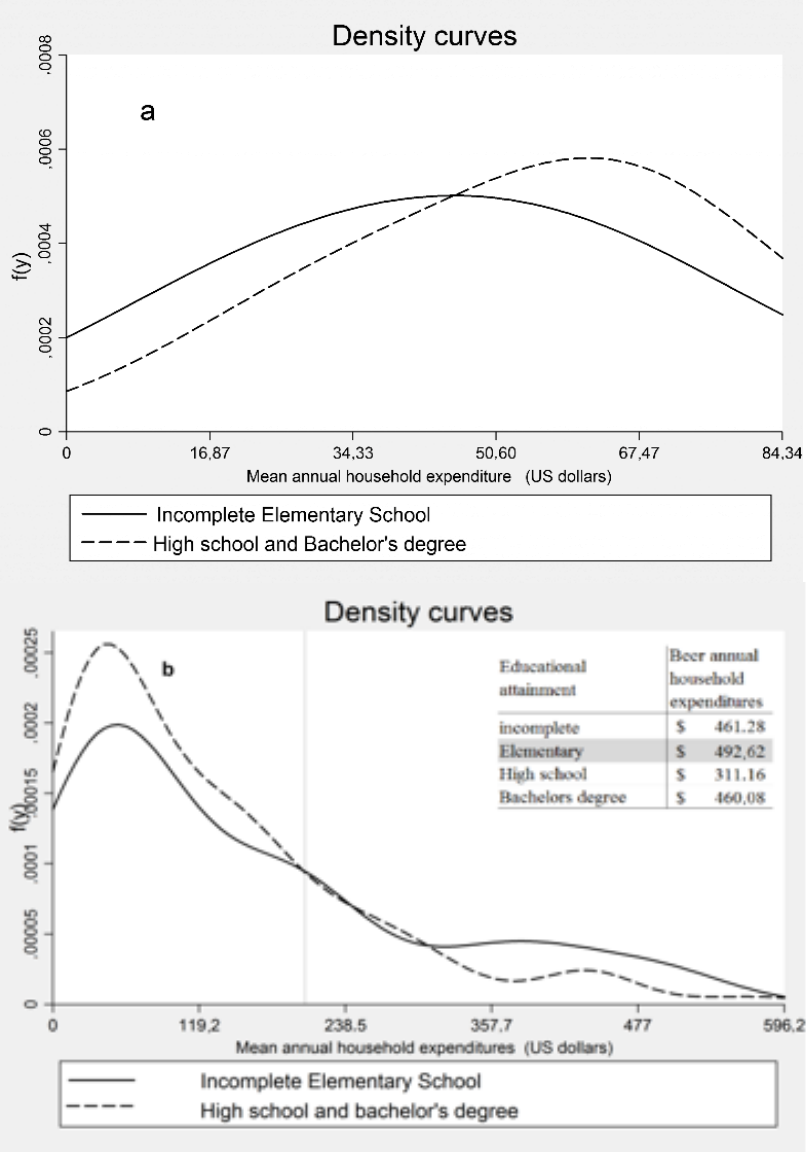
Furthermore, education has been referred as a determinant influence on consumption patterns[7] and health outcomes. To inquire into household expenditures distribution by population's educational attainment, density curves are constructed for two distinctive items on the diet from a healthy point of view: a) apples and b) food sold by street vendors. Figure 3 depicts this relationship.

Figure 3

Mean household expenditures a) Apples b) Food sold by street vendors.



Source: Own estimation using data from ENGASTO 2013 (INEGI, 2013).

[7] The recognition in México about the link between consumption patterns and T2D has resulted in further regulations by the Federal Commission for Protection Against Health Risks (COFEPRIS), oriented towards information availability, advertisement and labeling protocols for specific products. It´s effects however are yet to be evaluated.

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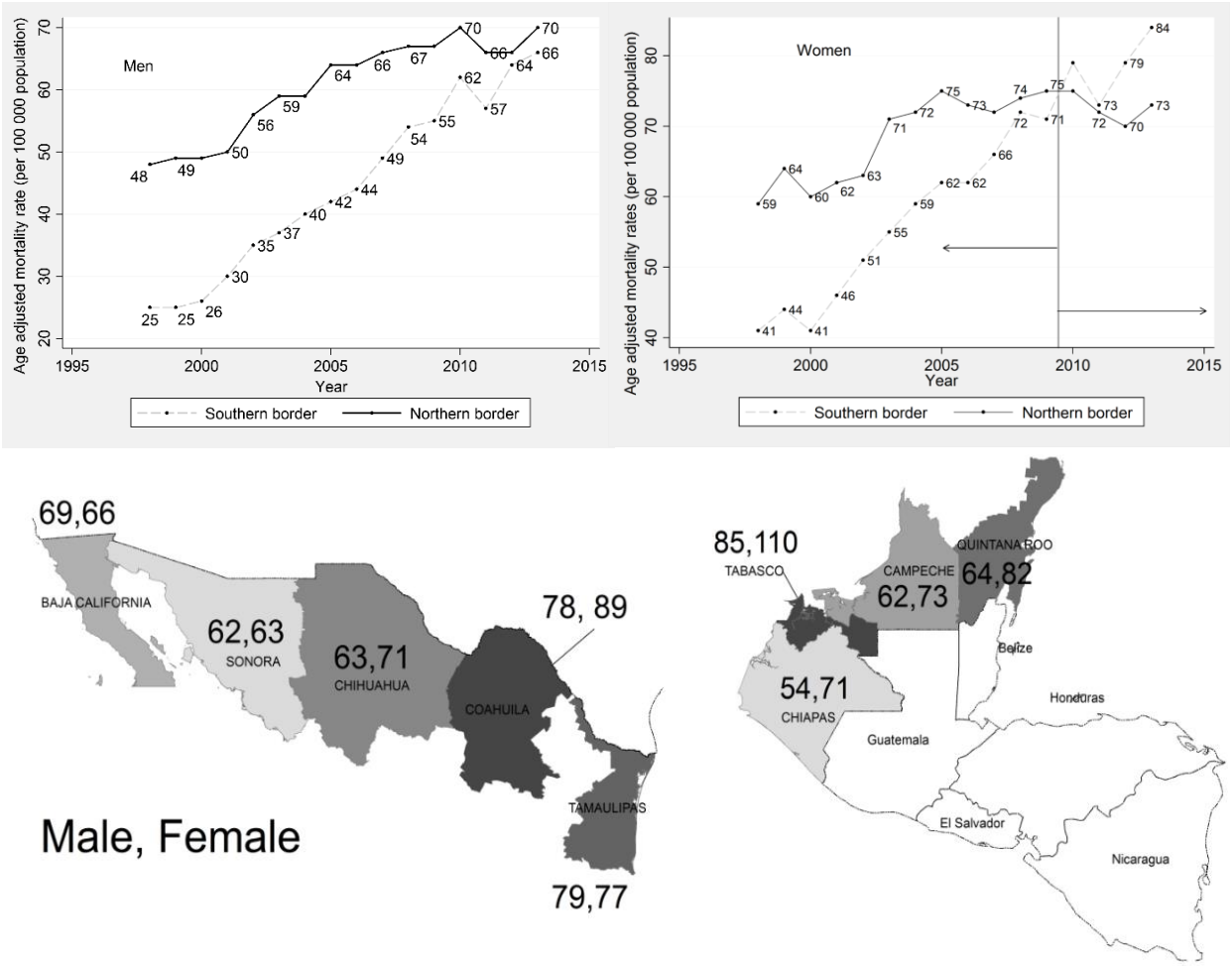
Economic theory suggest that there is a positive relationship between educational attainment levels and income (expenditures) though empirical evidence form this particular data indicate that this rationality varies depending on whether the item is consider healthy or not. The argument is further emphasized for products, such as beer in which a negative relation appears to be the case. Expenditures in food items for the case of Tabasco allow to place in perspective the upward trend found by the local Mortality Index at the southern border states and indicate the burden posed by T2D, certainly a growing challenge for this region in the coming decade.

3.3. Diabetes mortality

To evaluate diabetes mortality evolution in time in a spatial context, age adjusted mortality (AAMR) rates were estimated by sex applying the direct method. This information will be useful to determine the epidemic burden that both regions face. Results are shown in Figure 4.

Figure 4

Age adjusted mortality rate. Northern and southern border 2013



Source: Own estimation. National Information System on Health (DGIS, 2016). E100-149.T2D deaths by 100.000 population.

ISSN-1659-0201 http://ccp.ucr.ac.cr/revista/

Doi: http://dx.doi.org/10.15517/psm.v14i2.27028
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A higher T2D mortality in the norther border is found; however, the increase in the AAMR for the southern border is clear. For males the gap systematically closes between both regions, while among females, in the Mexico-Guatemala-Belize border, the upward trend indeed advanced beyond the level observed in the US-Mexico border. This significant event occurred around 2009[8]; from that year on female population show a greater T2D mortality rate, reaching 84 per 100.000 inhabitants in 2013, a stark 105% increase between the initial and final year. At the spatial level previous trends are confirmed and the higher rates within both regions in the study are found in Tabasco, in the southern border. While Coahuila state, in the limits with Texas, face the greatest burden at the northern border.

Results from the logistic model estimation presented in Table 2 suggest that southern border residents face a greater burden, with an OR= 1,14, CI (1,10-1,2), as well as female population with an OR= 1,55 CI(1,5-1,6). The age range 65-79 being the most affected. To further distinguish the regional effect and its evolution in time, T2D death probabilities are estimated by age using logistic regression model parameters for 1998 vs 2013. Figure 5 presents the estimated results.

Table 2

Logistic regression T2D deaths, regional effect.

N= 131,296	*OR*	*SE*	*CI*	
Age group				
>79	**Ref.**			
0-17	0,02*	0,0036	0,01	0,02
18-44	0,39*	0,0153	0,36	0,42
45-64	1,99*	0,0443	1,91	2,08
65-79	2,02*	0,0450	1,93	2,11
Sex				
Male	**Ref.**			
Female	1,55*	0,0264	1,50	1,6
Border				
North	**Ref.**			
South	1,14*	0,0203	1,10	1,2
*p <,001				

Source: Own estimation based on the National Information System on Health (DGIS, 2016).

[8] In 2013, the federal government launched a program called National Strategy for Overweight, Obesity and Diabetes Prevention and Control, to address this health policy challenge; however the long run impact of this program is yet to be evaluated (Secretaría de Salud, 2014).

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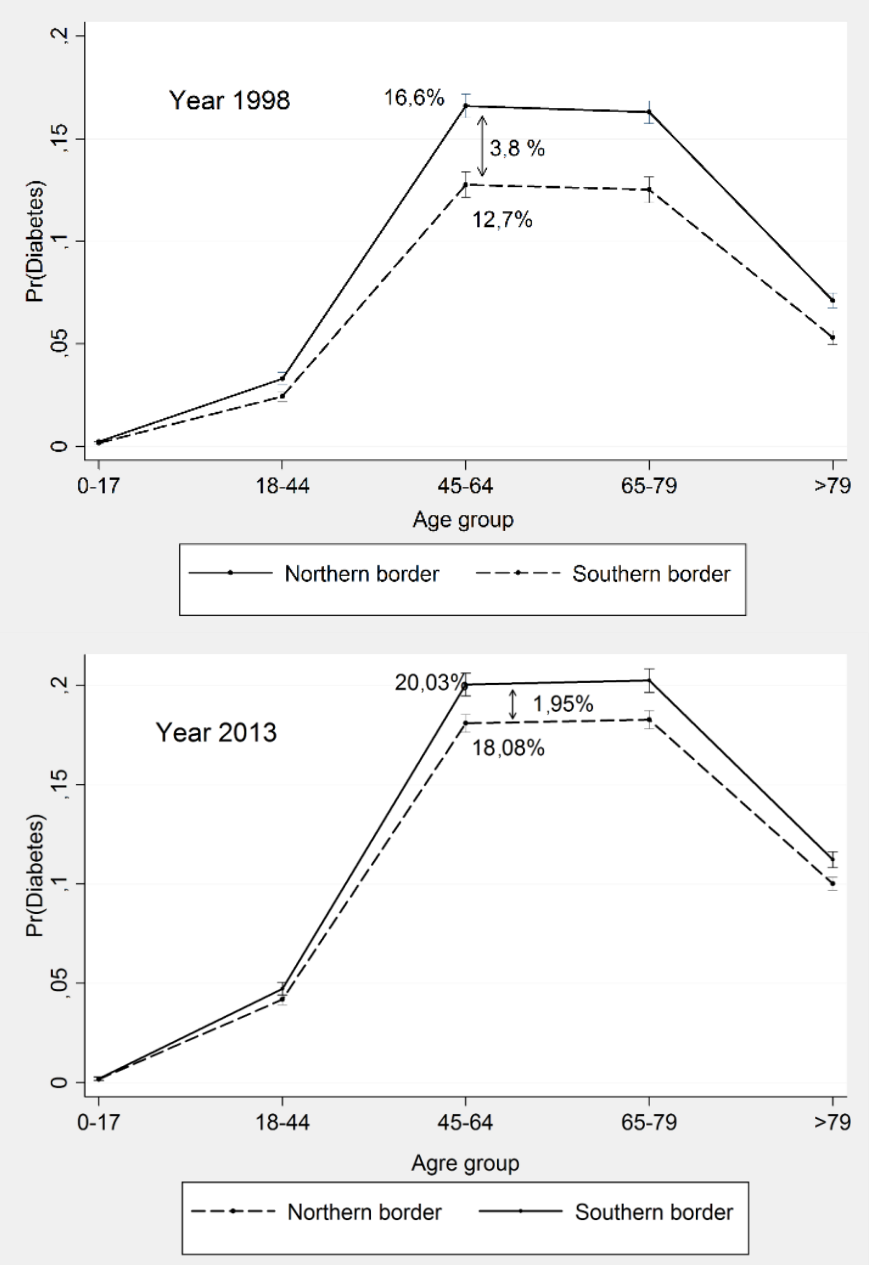
Figure 5

Estimated probabilities T2D deaths. Logistic model contrast 1998 vs. 2013.



Source: Own estimation with data from National Information System on Health (SINAIS) 1998, 2013 (DGIS, 2016).

The previous estimation confirms that T2D at the southern border has become a public health issue of concern over the last 15 years and although the model probabilities are still higher; at the northern border, there has been a clear reduction in the probabilities gap between both regions. Nevertheless, it is worth nothing that between 1998 and 2013 there has been a significant increase in the probabilities of a T2D death in either border,

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from 16,6% to 20,03% in the northern border and 12,7% to 18,08% at the southern border for individuals in the age group most affected: 45-64 years.

4. Discussion

Location matters for T2D mortality? In this case study, a clear difference is documented in the evolution of this chronic degenerative disease between the US-Mexico border and the southern Mexican border. Although, traditionally, food preferences of indigenous people at the southern border states have acted as a protector factor against common health problems found elsewhere in the country. Including chronic diseases such as diabetes (Flores *et al.* 2010), consumption patterns and diet has been steadily changing across the country reaching even relatively isolated geographic areas where indigenous people constitute an important segment of the population such as Chiapas or Quintana Roo in the Mexico-Guatemala-Belize border.

At the same time, a similar trend in T2D among indigenous people linked to the changing lifestyle has been documented for other geographic areas around the world, where indigenous populations live. Young, Reading, Elias & O'Neil (2000) documented this trend for Canada's first nations (aboriginal peoples in Canada); in addition, Mann *et al.* (2006) make the case for New Zealand's Maori population. In the three cases a common determinant appears to be related to the changing consumption patterns away from the traditional diet. According to Brooking, Williams & Mann (2012) "rapid acculturation of these populations groups has been associated with adoption of many attributes of western eating patterns." (p. 40)

Further research, in the case of indigenous population in the Mexico-Guatemala-Belize border, document that an accelerated migration from rural areas to urban centers has been taking place (Reyes Posadas, Nazar Beutelspacher, Estrada Lugo & Mundo Rosas, 2007), perhaps contributing to the so called acculturation process and the resulting change in consumption patterns. The evolution in time of the local concentration index proposed in this study suggest a clear convergence path between mortality rates in both Mexican geographic locations. This evidence is further reinforced by the historic evolution of age adjusted mortality rates which indicate that the population at the southern border states faces a public health challenge of epidemic proportions regarding diabetes.

In the present case, an important limitation to measure the evolution in time of consumption patterns is that detailed expenditure patterns available through official sources, such as the national expenditure survey ENGASTO start to be conducted in 2012; this data source provide a detailed account to follow food consumption forward in time, but not before 2012. Despite this limitation, cross sectional sample data for 2013 provide evidence of a particularly risky set of items are being integrated in the die by border residents. The information presented in this study for southern border states such as Tabasco allows to corroborate such a trend.

ISSN-1659-0201 http://ccp.ucr.ac.cr/revista/

Doi: http://dx.doi.org/10.15517/psm.v14i2.27028
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5. Conclusions

The evidence presented indicate that at the beginning of the study period there were important differences in T2D mortality at border regions in Mexico; nevertheless, the southern border states has experienced an epidemiological transition towards diabetes mortality as a relevant cause of death during the last 15 years. In this regard, a convergence process at the spatial level is found between Mexico's border regions.

Border residents consumption patterns, as documented by expenditures in products known to promote insulin resistance mechanisms, appear to be relevant determinants to understand T2D epidemic growth even in places where demographic composition is markedly different. In addition, social determinants of health related to migration flows remains a topic of active study as possible causes that have contributed to shape the consumption patterns observed in communities at the southern Mexican border states where the majority of indigenous population in the country lives; nonetheless, how food expenditure patterns had changed on the southern Mexican border as a result of external influences related to migration is a topic that deserves further investigation.

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Volume 14, number 2, article 1, january-june 2017

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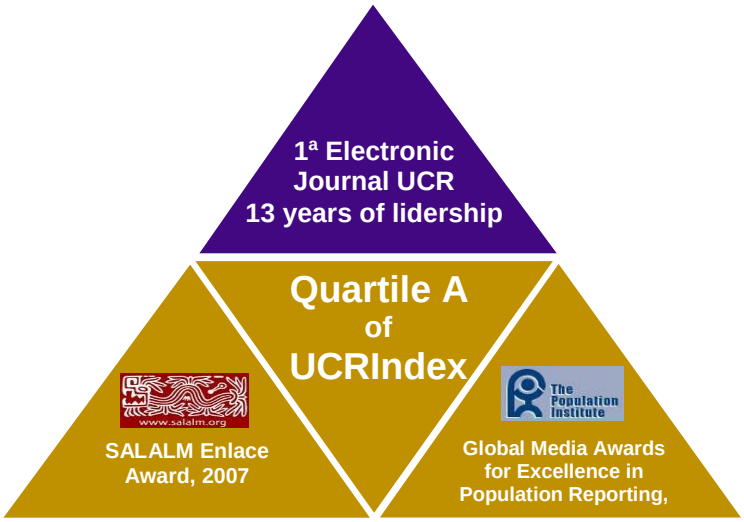

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