Journal of Diabetes Mellitus, 2015, 5, 36-47
Published Online February 2015 in SciRes. http://www.scirp.org/journal/jdm
http://dx.doi.org/10.4236/jdm.2015.51005

Holistic Evaluation of the Morbidity Due to Diabetes Mellitus Type 2 and Its Main Risk Factors in the State of San Luis Potosi, Mexico

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Received 20 January 2015; accepted 9 February 2015; published 11 February 2015

Abstract

Objective: To evaluate the morbidity due to diabetes mellitus type 2 within the State of San Luis Potosí, México, through a strong methodology, through which the multivariate relations were identified of the main social and environmental determiners in the disease, thus managing to quantify their respective levels of responsibility. Material and Methods: This evaluation began as a hypothesis of a multicasual theoretical model on diabetes mellitus and its main determining factors, which was analyzed through the application of multivariate exploratory statistical methodologies and confirmed as it is the case of the principal components analysis and the structural equation models. Results: Three components were extracted that explain the 96% of the total variance of the indicators; the main risk factors which were identified in the first component were, the use of the car, age, homes with TV use, urban life and feminine population; the indicators from the second and third component have little influence in the impact of the disease. Conclusions: the study shows the usefulness of the model for the analysis and prioritization of the environmental and social determiners of the disease, information that could sustain the design of public guidelines for the prevention and control of the analyzed disease.

Keywords

Diabetes Mellitus, Risk Factors, Multivariate Analysis

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How to cite this paper: Darío, G.-H., Gabriela, D.-C., de Jesús, M.-S.J. and Ernesto, M.-M.L. (2015) Holistic Evaluation of the Morbidity Due to Diabetes Mellitus Type 2 and Its Main Risk Factors in the State of San Luis Potosi, Mexico. *Journal of Diabetes Mellitus*, **5**, 36-47. http://dx.doi.org/10.4236/jdm.2015.51005

1. Introduction

Diabetes Mellitus is a chronic illness that appears when the pancreas does not produce sufficient insulin or when the body does not use it effectively [1]. Diabetes mellitus type 2 represents a serious health problem in the world; there were 387 million people with diabetes in 2014 and 4.9 million died due to this [2]; in Mexico there were 6.4 million adults with diabetes [3].

There are multiple risk factors that have been associated with diabetes, such as obesity, age, gender, belonging to a certain ethnic race, level of education, income, life conditions, access to health services and urbanization [4]. Also it is associated with factors as family history of diabetes, overweight, unhealthy diet and physical inactivity among others [5].

Several factors associated to diabetes mellitus type 2 have been analyzed (MDMT2); such is the case of an ecological study in obese adults older than 20 from 183 countries in which a positive relation between diabetes prevalence and a low income was found ($p = 0.011$) [6]. This was also confirmed by another transversal study in which it was identified a prevalence in diabetes mellitus type 2, 4.11 times higher in the group with a low income than that of a high income [7]. At the same time, it was found a higher prevalence of diabetes in people with a lower educational level ($p < 0.001$) [8]; as well as in people who belong in a 65 to 74 years old range ($p < 0.001$) [9]. Deo and Col [10], found that the percentage of diabetics increased systematically with the age, finding a 1.69% of diabetics in the age group of 21 to 30 and a 20.9% in the 61 years and more group. Also, it is reported that obese people have a higher risk of suffering from diabetes than those at an average weight, basically women, (2.52 times) as for men (2.13) [11]. At the same time, it is described that some people with a family history of diabetes have a 2.9 times higher risk than those who do not have it and those with no physical activity have a 1.6 times higher risk than those that do some type of exercise [8]. On the other hand, it was identified that the residents of urban areas have more prevalence in diabetes than those on rural areas ($p < 0.002$) [6] [9].

Hu and Col [12] reported that spending two or more hours per week watching television represents a risk factor to acquire diabetes. They also estimated that the risk increases 1.23 times for five hours and two times more for 40 hours ($p = 0.000$).

The cited studies show an analysis of different risks factors and their relation with MDMT2 from a lineal perspective, without taking into account the possible multivariate relations, as a whole and simultaneously among them.

The present work proposes a robust methodology from of which we can achieve the integration of two multivariate methodologies: the principal components analysis components (PCA) to explore and identify latent variables and reduce the dimension of indicators; and a structural equation model (SEM) to confirm the identified structure through PCA as well organizes hierarchically the load of the factors upon MDMT2; which can generate integral information to support more effectively decision making, that incite in the decrease of this illness. Successful analysis have been carried out using this methodological tool in different fields of study as the confirmation of an explicative model of stress and its relation with psychosomatic symptoms trough structural equations [13], as well as to predict the well-being and the functional dependence of elderly people [14].

In accordance with the previous paragraph, the objective of the present research consists in evaluating MDMT2 in the State of San Luis Potosi, Mexico, with a methodological approach that would allow identifying the main social and environmental determiners of the illness, as well as their multivariate relations for the generation of integral proposals for prevention and effective actions directed to the solution of this health problem.

The basis for this study is the design of a theoretical model, of the main factors that determine MDMT2 (**Figure 1**); this model reflects the observable factors diversity and/or measurable as well as latent variables that are not observable nor measurable directly, due to the nature of the problem; it is necessary the use of specific multivariate techniques that would allow carrying out the analysis as the PCA and SEM.

2. Material and Methods

The State of San Luis Potosí is located in the North central region of the Mexican republic, it has a territorial span of 60,933 km^2 and it is the Fifthteen State to its extension of the Mexican Republic. It has 58 counties with are distributed in four main geographical regions: Altiplano, Centre, Huasteca and Media [15].

A study was carried out to identify the main social and environmental determiners of the MDMT2 and their multivariate relations in the State. A theoretical multicasual model was designed of the MDMT2 and its main

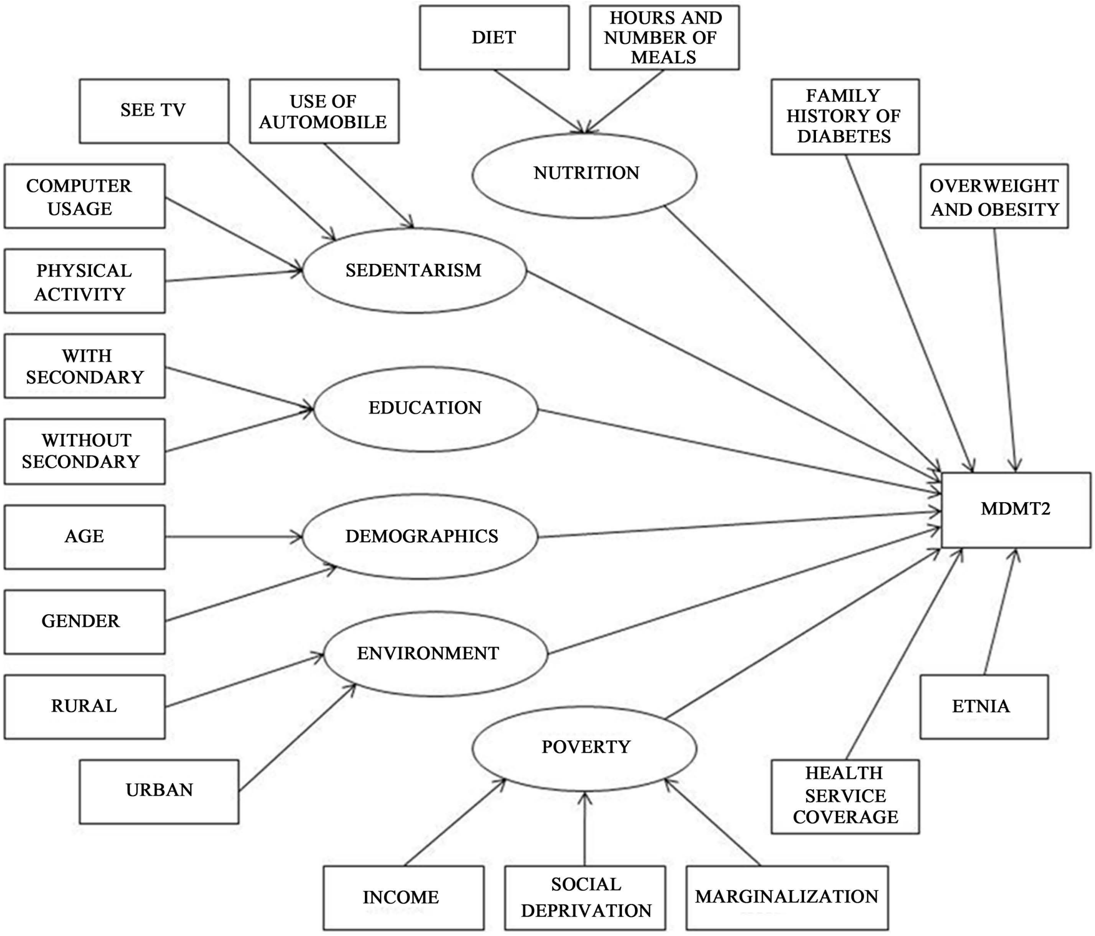

Figure 1. Theoretical model of determinants related to MDMT2.

determining factors based on the revision of the published studies that identify them as determinants of the illness (**Figure 1**), based on such scientific evidence and by availability of information, 17 indicators were selected (**Table 1**).

The population in the study was grouped in the following age ranges: 20 to 44, 45 to 49, 50 to 59, 60 to 64, 65 years and older; from the years 2005 and 2010, with data from the 58 counties that conform the State of San Luis Potosí.

Statistical Analysis

An outlook for the state was generated using the indicators signaled and the rates for MDMT2 by gender and age groups. An exploratory factorial analysis was used through the multivaried methodology for PCA in order to identify components or suppress variables (24).

The level of colineality among the indicators were evaluated through the determinant of the matrix of correlation, a value of the determinant nearing cero indicates the high existence of colineality. The Kaiser-Mayer-Olkin test was used to evaluate the adequacy of the sample, comparing the magnitudes of the observed correlation coefficients with magnitudes of partial correlation coefficients, this statistic takes values between 0 and 1, values higher than 0.70 indicate that sample is adequate for utilize PCA [24]. Barlett's sphericity test, was used to reject the hypothesis that the correlations matrix and the identity matrix are equal [25]. The explained total variation table was generated to identify the number of components with eigen-values higher than 1, as well as the percentage of the variance that they explain [24] [25]; and the sedimentation graph as a support to determine the optimum number of components to be included in the solution [24].

It was worked with a matrix of rotated components by the Varimax method in order to facilitate the interpreta-

Table 1. List of used indicators.

Code	Name	Description
MDMT2	Diabetes*	New cases in the year from diabetes mellitus type 2 [16].
IND1	Female population*	Number of people from the female gender [17] [18].
IND2	Male population*	Number of people from the male gender [17] [18].
IND3	Ages 20 to 44	Number of people from 20 to 44 years of age [17] [18].
IND4	Ages 45 to 49	Number of people from 45 to 49 years of age [17] [18].
IND5	Ages 50 to 59	Number of people from 50 to 59 years of age [17] [18].
IND6	Ages 60 to 64	Number of people from 60 to 64 years of age [17] [18].
IND7	Ages 65 and older	Number of people 65 and older [17] [18].
IND8	Urban population*	Number of people in localities ≥ 2500 habitants [17] [18].
IND9	Rural population*	Number of people in localities < 2500 habitants [17] [18].
IND10	Automobiles	Automobiles that are registered in circulation [19].
IND11	Homes with TV	Number of houses with TV [17] [18].
IND12	Without secondary*	Population without secondary school [17] [18].
IND13	Without health care*	Population without right to public health care [20].
IND14	Income**	Population % that earns up to 2 minimum wages [21] [22].
IND15	Indigineou population*	Population that speaks an indigenous tongue [17] [18].
IND16	Marginalization**	Marginalization index [21] [22].
IND17	Social deprivation**	Social deprivation index [23].

*Population ≥ 20 years of age; **Open population.

tion of the loads that the indicators have in the extracted components [24] [25]. For the processing and analysis the SPSS version 18 statistical program was used [26]. Subsequently, a confirmatory analysis with multivariate technique (SEM) was developed to evaluate the described model for the PCA results. The development of the model was carried out in the Amos software version 20.

A sequence diagram was constructed to facilitate the design of casual relations and the relation between the components and indicators, parting from this, the model was created. The three components extracted in the PCA, became non-observable latent variables and the MDMT2 became the endogenous variable, in the structural model. The measurement model was specified to indicate the indicators each component.

The sample was of 116 and the model included 23 non-observable variables (three components and 20 estimated measuring errors), therefore, it was complied with what was recommended, at least five observations per estimated parameter [25].

As entry data, the correlations matrix was used, and for the estimate of the model the maximum likelihood technique was applied and the direct estimation process. The procedure was carried out 14 times to estimate the maximum likelihood and to find the best possible adjustment.

The infringing estimates were validated, identifying three with a negative variance in the measuring error, so three constraints were added and these variances were fixed with a value of 0.005 [27] [28]. The validity of the model was done through the degrees of freedom, that according to condition and order, these must be higher of equal to zero [25].

To evaluate the overall fit of the model, the likelihood ratio chi-square statistic was examined, to measure the correspondence between the correlations matrix actual input or observed with that it is predicted by the proposed model. This indicator resulted too high in comparison with the degrees of freedom, which indicates that among the observed matrixes and those, estimated there is a significant difference, therefore this evaluation was completed with other fit measures [29].

The validation for the integral model was carried out as a whole in order to identify the degree in which the specified indicators represent the assumptions constructs, for that absolute fit measures, increasing and parsimony were used (**Table 2**) [25].

Finally, to evaluate the fit, the values obtained from the indexes were catalogued in accordance to the scale: low grade (0.000 - 0.333), average (0.334 - 0667) and high (0.668 - 1.0); in accordance to results published by another study [33].

3. Results

As it is shown in **Table 3**, the rate for diabetes (MDMT2) showed a global decrease of 0.9 cases per 1000 habitants between 2005 and 2010, nevertheless, such decrease was higher in female population (0.6 cases/1000 hab.)

Table 2. Measures used to validate the integral model.

Fit measures	Indicator	Values show a good fit
Absolute	likelihood ratio chi-square statistic (X^2) [24] [25]	$p > 0.05$ [24]
	Goodness of fit index (GFI) [24] [25]	>0.90 [24]
Incremental	Trucker-Lewis index (TLI) [25]	>0.90 [25]
	Normed fit index (NFI) [24] [25]	>0.90 [24]
	Relative fit index (RFI) [24] [30]	>0.90 [24]
	Incremental fit index (IFI) [24] [31]	>0.90 [24]
	Comparative fit index (CFI) [24] [32]	>0.95 [24]
Parsimony	Parsimonious normed fit index (PNFI) [24] [25]	>0.50 [24]
	Parsimony goodness of fit index (PGFI) [25]	>0.90 [25]
	Parsimonious comparative fit index (PCFI) [24]	>0.50 [24]

Table 3. State scenario of the used indicators. San Luis Potosí, México.

Code	Indicator name	Year	
		2005	2010
MDMT2*	Diabetes rate[a]	8.7	7.8
IND1*	Female Population[b]	53.0	52.5
IND2*	Male population[b]	47.0	47.5
IND3	Ages 20 - 44[b]	62.5	60.9
IND4	Ages 45 - 49[b]	8.5	8.7
IND5	Ages 50 - 59[b]	12.4	13.3
IND6	Ages 60 - 64[b]	4.9	4.8
IND7	Age 65 and older[b]	11.7	12.3
IND8*	Urban population[b]	64.8	65.6
IND9*	Rural population[b]	35.2	34.4
IND10	Automobiles[c]	12.0	17.1
IND11	Homes with TV[b]	86.2	88.0
IND12*	Without secondary school[b]	2.7	2.9
IND13*	Without health care[b]	47.5	27.2
IND14**	Income[b]	56.1	46.7
IND15*	Indigenous population[b]	11.0	10.7
IND16**	Marginalization[d]	high	high
IND17**	Social deprivation[d]	high	high

*Population ≥ 20 years; **Open population; [a]Rate per every 1000 habitants; [b]Percentage; [c]for every 100 habitants; [d]Grade.

that in the male population (0.3 cases/1000 hab.). at the same time, in the age group of 50 to 59 (IND5) there was also a decrease in the incidence rate of the illness (**Table 3**). On the other hand, some indicators, such as, urban population (IND8), percentage of homes with TV (IND11) and number of automobiles that are registered in circulation per every 100 habitants (IND10), increased in 0.8%, 1.8% and 5.1% respectably.

In **Figure 2** it is shown a State scenario for MDMT2 where it can be seen that the tendency of the global rates were higher in the year 2005 than in 2010 in all the age groups, women had a higher rates than men did in the two time lapses analyzed; and in all the analyzed series the age group from 60 to 64 years, resulted with the highest rates.

The results of the tests of viability of PCA were as follows: a) Beginning with the Barlett sphericity test and the determinant from the correlations matrix was identified a high level of colineality among the analyzed variables (determinant = 1.23E−35), presenting a significant difference in relation to the identity matrix (Chi^2 = 8722.03, df = 136, p = 0.000); b) with the Kaiser-Meyer-Olkin test (KMO = 0.82), it was determined that the correlations are adequate to apply the PCA.

The male population indicator was removed from the analysis since it was in perfect correlation (r = 1) with the female population index and it was worked with a matrix of 17 × 17. In **Table 4** shown the total variance explained by each component, achieving extract three components that explain the 96% of the accumulated variance the total data.

In **Figure 3** can be observed that as of the fourth component, the slope is almost nonexistent, therefore only the three first components should be taken into account to represent the indicators group.

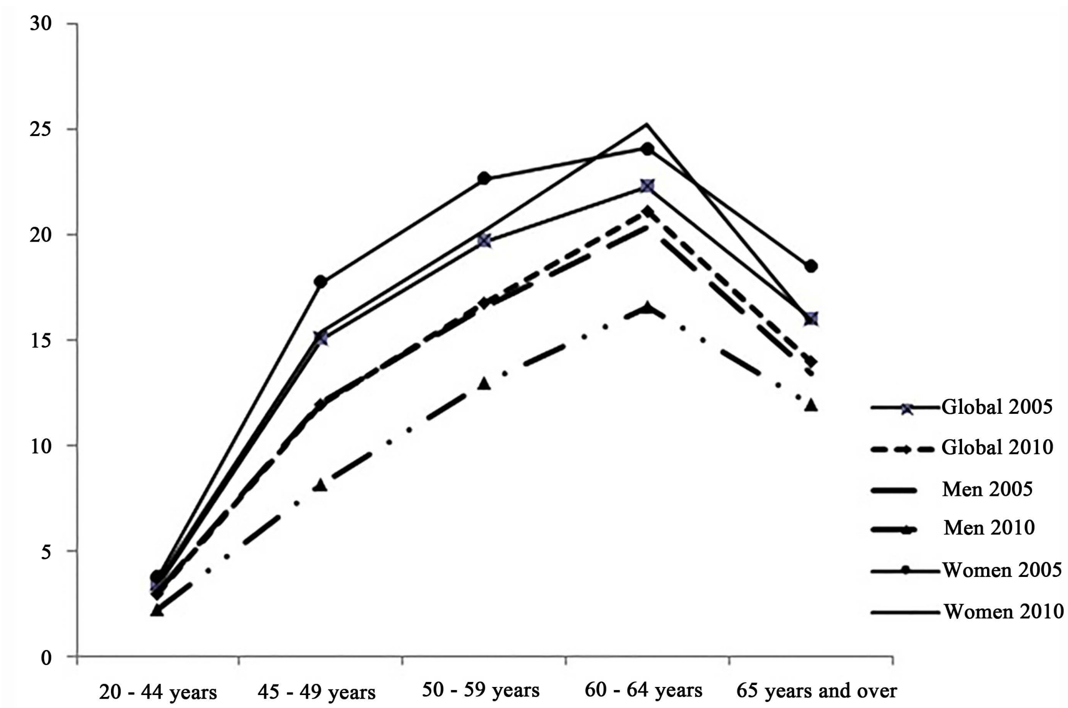

Figure 2. Rates of MDMT2 per every 1000 habitants ≥ 20 years in the State of San Luis Potosí, México.

Table 4. Total variance explained by each component, of the variance of the original indicators.

Component	Initial eigen-values		
	Total from the variance	% from the variance	% accumulated
1	12.718	74.810	74.810
2	2.539	14.933	89.743
3	1.070	6.297	96.039

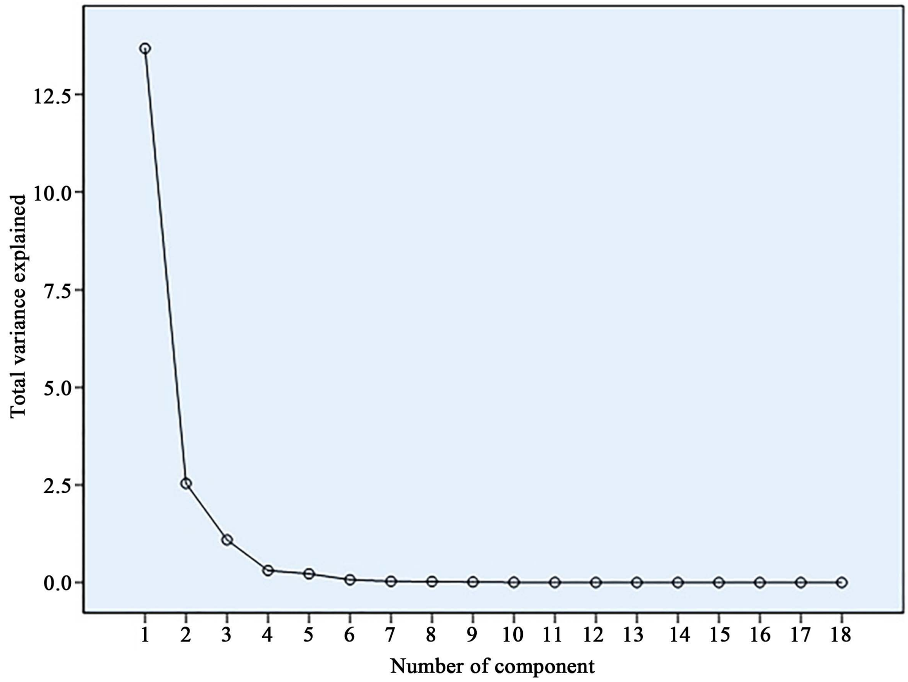

Figure 3. Sedimentation curve for the determination of the number of components extractable.

In **Table 5**, it is shown the matrix of rotated components by the varimax method which describes clearly the saturations of the indicators in each of the three components. According to this, the first component was formed by 11 indicators that on the whole explain 75% of the incidence rate evaluated in diabetes, being in order of importance in accordance to their multivariate correlations (attributed weights) the following: usage of automobiles (IND10 = 0.973), age groups 45 - 49 and 50 - 59 (IND4 = 0.968, IND5 = 0.965), urban population (IND8 = 0.965), female population (IND1 = 0.963) age group 60 - 64 (IND6 = 0.962), homes with TV (IND11 = 0.962), age groups 20 - 44 and 65 years or older (IND3=0.959, IND7 = 0.953 respectably), population without health care (IND13 = 0.929) and population without secondary school (IND12 = 0.923). In the second component, with a level of attribution to the illness of 15% the following indicators were identified: High marginalization (IND16 = 0.924), Social deprivation (IND17 = 0.918) and low income (IND14 = 0.857), whereas in the third component with a level of attribution of a barely 6%, the indicators included were: rural population (IND9 = 0.902) and indigenous population (IND15 = 0.847).

On the other hand, the confirmatory model was formed with 40 variables, 17 observable and 23 non-observable; 20 endogenous variables and 20 exogenous; and 133 degrees of freedom.

Figure 4 shows the integral model, the measuring errors (e1, … e20), the weights of the standardized regression coefficients for each indicator and the effects of the components on MDMT2.

According to the results of the structural model, the indicators of the first component represent a risk factor for MDMT2, since, for every increase of one unit in the first component; the diabetes increase rate will suffer an increase of 0.92 units, considering the synergy among the 11 indicators and their respective measuring error.

On the other hand, the indicators of the second and third component showed a very poor effect on MDMT2, showing for each unit increase in the second and third component, increased diabetes incidence rate of 0.02 and 0.01 units, respectively.

In **Table 6** it is shown the statistical values that were used to assess model fit.

4. Discussion

Being diabetes a multifactorial illness, it is of great importance to study it and analyze it through multivariate models that allow us to know the load of the factors that determine it, since the methods that have been used do not allow us to face it adequately [34]. The PCA placed the official available indicators considered in the study, in three components in accordance to the multiple correlations among them, it also identified that the indicators

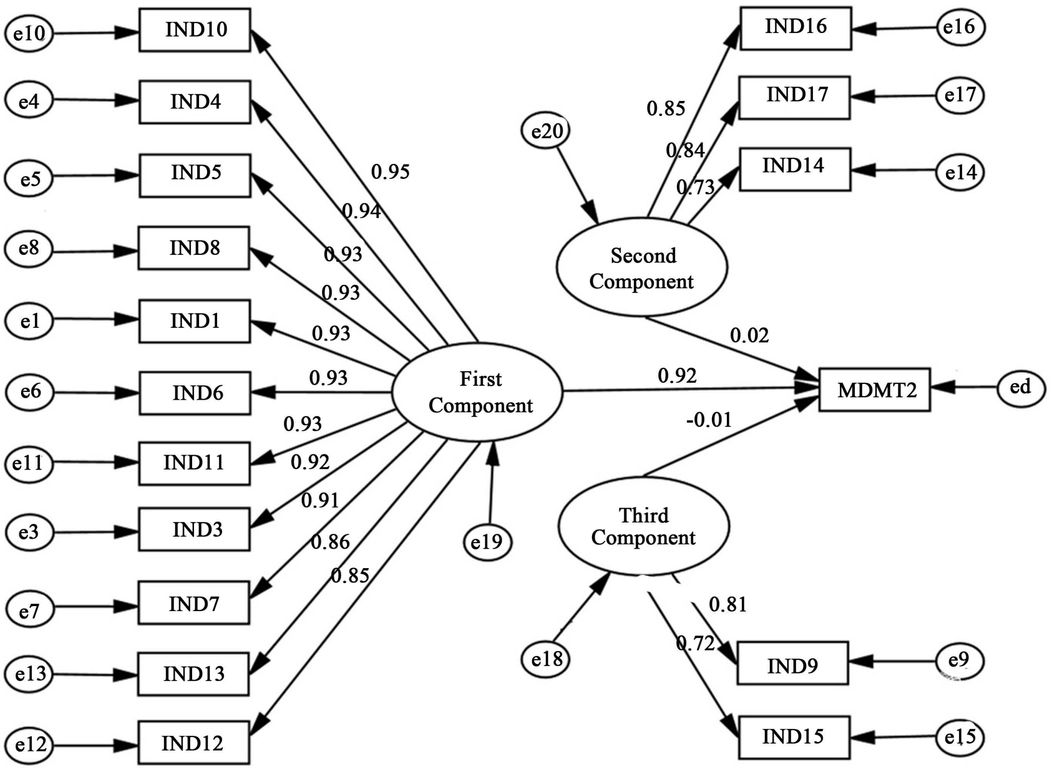

Figure 4. Structural model of the multivariate relations between MDMT2 and its social and environmental determinants obtained from SEM.

Table 5. Rotated component matrix by the Varimax method from PCA that shows the saturations (correlations) for each evaluated indicator in the different components extracted.

Code	Name of the indicator	Component		
		1	2	3
IND10	Automobiles	0.973		
IND4	Age 45 - 49	0.968		
IND5	Age 50 - 59	0.965		
IND8	Urban population	0.965		
IND1	Female population	0.963		
IND6	Age 60 - 64	0.962		
IND11	Homes with TV	0.962	−0.258	
IND3	Age 20 - 44	0.959		
IND7	Age 65 and older	0.953		
IND13	Without health care	0.929		0.280
IND12	Without secondary school	0.923	−0.259	
IND16	Marginalization	−0.298	0.924	
IND17	Social deprivation		0.918	
IND14	Income	−0.338	0.857	
IND9	Rural population	0.257		0.902
IND15	Indigenous population		0.327	0.847

Table 6. Validation indicators of integral model fit.

Fit measures	Indicator	Value	Grade		
			Low	Average	High
absolute	Chi-square authenticity ratio	3367.6 (133 df)	X		
	GFI	0.298	X		
incremental	TLI	0.637		X	
	NFI	0.636		X	
	RFI	0.628		X	
	IFI	0.645		X	
	CFI	0.645		X	
parsimony	PNFI	0.622		X	
	PGFI	0.259	X		
	PCFI	0.631		X	

GFI: Goodness of fit index; TLI: Trucker-Lewis index; NFI: Normed fit index; RFI: Relative fit index; IFI: Incremental fit index; CFI: Comparative fit index; PNFI: Parsimonious normed fit index; PGFI: Parsimony goodness of fit index; PCFI: Parsimonious comparative fit index.

of the first component have a high correlation with diabetes, whereas the second and third have little.

The first component explains almost 75% of the total variance, the order of the indicators that make it up in accordance to the correlations coefficient multivariate is: automobiles in circulation, the different age groups, urban population, female population, homes with TV, population without health care and without secondary school studies; these indicators can be attributed them the greatest percentage of weight in the incidence rates for diabetes mellitus type 2, while the ones in the second component (marginalization, social depravation, income) and third component (rural population and indigenous population) can be attributed little weight.

This is confirmed by the structural model, that shows the hierarchy of the components in accordance to the effect that they have on MDMT2 and on that of the indicators, based on the weight that it represents over their respective component, thus, the ones in the first component (effect = 0.92) are the most important ones. The second and third components have an effect of 0.02 and −0.01 respectably over MDMT2 which it is not significant, therefore the indicators that conform it are not very relevant for the illness, nevertheless, Kuhmbou [6] and Dinca-Panaitescu and col [7] reported that a low income was in relation with high levels of diabetes, non the less this authors used lineal regression methods and logistics that may only evaluate casual lineal relations, whereas in the present study multivariate relations were analyzed of the different factors simultaneously, considering the measuring error.

Different studies confirm the associations that the model identified, but on a lineal manner, the results of this study are in accordance in an indirect way with those of Bener and Col [8] and Escolar [11], who reported that obesity is a risk factor for the development of the illness; on the other hand, the time that the population spends in the car is an indicator of obesity [35], in this study it was estimated in an indirect way, through the number of automobiles that are registered in circulation, this indicator resulted as a risk factor as well. Also, a relation was found between diabetes and the age; in other studies this relation was also identified [6] [8]-[10]. Another finding was that living in an urban area is also a risk factor, which also coincides with other reported results [6] [9].

Also, it was identified that being a female is a risk factor to suffer diabetes, which also coincides with other studies [7] [10]. It was also identified as a risk factor the time that the population watches television; this was estimated through the number of habited houses that have a TV, this coincides indirectly with other studies [12].

Bener and Col [8] published that a low educational level is a risk factor, in this study a similar result was obtained, and it was also found that not having health care in public institutions is a risk factor, this coincides with what was published by the PAHO [4].

In the analysis, some indicators were not considered which are relevant, as determinants of MDMT2, since official sources do not have a register on these. According to the theoretical model taken as a base for this study (**Figure 1**), the following risk factors were not included: overweight and obesity [4] [5] [11] [35] family diabetes background [5] [8], nutritional aspects such as diet type, number of meal per day and their schedules [4] [5], time spent in: physical activities [4] [5] [8], watching television [12] and the use of computers [4] [5] [36].

In future investigations it would be important to consider all of these indicators in order to achieve a more complete analysis and improve decision making, it is possible that when included in the analysis, some of the ones placed in the first component would be moved to another component of lesser importance.

According to the 2012 ENSANUT, in the State of San Luis Potosi, from 2006 to 2012 there was an increase of 3.8% in diabetes mellitus prevalence in adults ≥ 20 years [37], which demonstrates that the prevention and control strategies for the illness must improve. At the same time, the program for prevention and control for diabetes that is currently at work in the state [38], focuses its actions in adults ≥ 20 in general, therefore the integral results obtained in the study may be used to sustain strategies that would improve the different national programs for the prevention and control of DMT2 [38] [39].

5. Conclusions

The structural model shows its utility for the evaluation and hierarchy of the social and environmental determinants for MDMT2; this information may sustain the design of strategies and public policies for the prevention and control of the illness, which have to be directed mainly to the factors which integrate the first component, considering as well the order of importance of such factors to the interior of the same component according to their level of attribution with such illness, besides being planned and carried out taking into account in a holistic way all of these factors. On the other hand, the health system should have a database of all the indicators related to diabetes in order to carry out complete integrals analysis and improve decision making.

Finally, we consider it important to emphasize in the necessity of to work, in the design of indicators that allow us to incorporate aspects related to nutritional habits of the population at risk, to achieve assess their levels of attribution in the high rates of diabetes. Currently it does not have this information.

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