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Estimating the geographical distribution of the prevalence of the metabolic syndrome in young Mexicans

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Abstract. The geographical distribution of the metabolic syndrome (MetS) prevalence in young Mexicans (aged 17-24 years) was estimated stepwise starting from its prevalence based on the body mass index (BMI) in a study of 3,176 undergraduate students of this age group from Mexico City. To estimate the number of people with MetS by state, we multiplied its prevalence derived from the BMI range found in the Mexico City sample by the BMI proportions (range and state) obtained from the Mexico 2006 national survey on health and nutrition. Finally, to estimate the total number of young people with MetS in Mexico, its prevalence by state was multiplied by the share of young population in each state according to the National Population and Housing Census 2010. Based on these figures, we estimated the national prevalence of MetS at 15.8%, the average BMI at 24.1 (standard deviation = 4.2), and the prevalence of overweight people (BMI ≥25) of that age group at 39.0%. These results imply that 2,588,414 young Mexicans suffered from MetS in 2010. The Yucatan peninsula in the south and the Sonora state in the north showed the highest rates of MetS prevalence. The calculation of the MetS prevalence by BMI range in a sample of the population, and extrapolating it using the BMI proportions by range of the total population, was found to be a useful approach. We conclude that the BMI is a valuable public health tool to estimate MetS prevalence in the whole country, including its geographical distribution.

Keywords: Metabolic syndrome, public health, geographical distribution, young mexicans, Mexico City, Mexico.

Introduction

The metabolic syndrome (MetS) involves certain clinical findings (dyslipidemia, hyperglycemia, hypertension and obesity) and constitutes a risk factor for diabetes and cardiovascular disease, including cardiac arrest. It is a major public health problem worldwide, mainly due to overfeeding and a sedentary lifestyle (Seidell, 2000; WHO, 2000; Popkin and Gordon-Larsen, 2004; Conrier et al., 2008; James, 2008; Low and Chin, 2009), but the details of the interaction between the factors involved in MetS are still largely unknown (Varga et al., 2009). Although obesity, defined by the World Health Organization (WHO) as abnormal or excessive fat accumulation that may impair health (http://www.who.int/mediacentre/factsheets/fs311/en), is recognized as a major risk for early death (Ezzati et al., 2002), its association with MetS is not constant. The American Heart Association (AHA) considers five associated factors (Table 1) of which obesity is not a mandatory part (Grundy et al., 2005; Alberti et al., 2009). Despite this, there is strong evidence at the clinical as well as the biochemical levels that abdominal adiposity plays a central role in the development of MetS (Donath and Shoelson, 2011).

The clinical entity of MetS has been questioned because of diagnostic imprecision (Reaven, 2005; Simmons et al., 2010; Reaven, 2011). However, in our opinion, MetS is still a useful definition that should be

Table 1. Reference values of anthropometric and clinical parameters of the metabolic syndrome (definition proposed by Alberti et al., 2009).

Parameter	Cut-off level
Waist circumference	≥80 cm in women; ≥90 cm in men
Blood pressure	≥130 mm Hg systolic; ≥85 mm Hg diastolic
Triglycerides	≥150 mg/dl
HDL cholesterol	<50 mg/dl in women; <40 mg/dl in men
Fasting glucose	≥100 mg/dl

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considered in the evaluation framework that includes insulin resistance pathophysiology, diabetes type 2 and cardiovascular disease (Cornier et al., 2008). We also believe that knowing its geographical distribution should facilitate the design of public health strategies to manage resources optimally.

Abdominal adiposity can be indirectly estimated through two measures: body mass index (BMI) and waist circumference. Both measures have weaknesses and strengths (Szarek et al., 2009) but since the former is the more widely applied and more public health data are available based on this parameter, we decided to focus on BMI. Since obesity has a correlation to MetS prevalence (Villalpando et al., 2007; Ntandou et al., 2009), we investigated the differences in BMI range by geographical frequency to estimate how it varies depending on where in the country people live.

Materials and methods

In order to estimate MetS prevalence by state, data from four sources were collected and combined:

(i) the Mexican National Population and Housing Census 2010 (http://www.censo2010.org.mx/) whose data are reported aggregated in predefined age groups;

(ii) a truncated part of the National Census 2010 including about 10% of the total records (http://www.inegi.org.mx/est/contenidos/espanol/soc/sis/microdatos). This part (here called the microdata) was included because each record represents an individual person, which allowed us to calculate proportions in the predefined census age groups;

(iii) the Mexican 2006 National Survey on Health and Nutrition (ENSANUT 2006) (http://www.insp.mx/encuesta-nacional-salud-y-nutricion-2006.html); and

(iv) a study sample of 3,176 young people aged 17-24 years with clinical and anthropometric parameters available.

The National Institute of Statistics, Geography and Informatics (Instituto Nacional de Estadística y Geografía, INEGI), provided the two population datasets and Figure 1 shows schematically how all the datasets were utilized to harvest the information sought.

The sample

The investigation to evaluate the health of young Mexicans was carried out from 2008 to 2010. The study sample included a total of 3,176 undergraduate students, 17 to 24 years-old, randomly chosen from two public universities, one located in the eastern part,

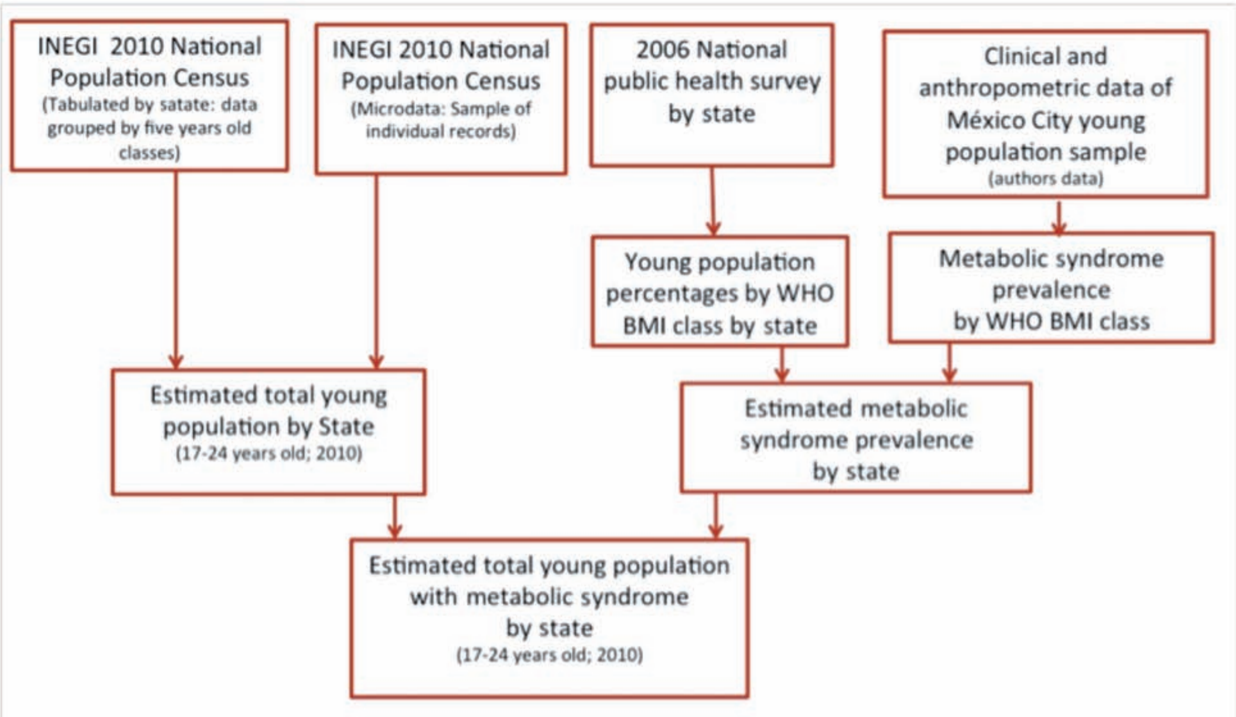

Fig. 1. Methodology to estimate MetS prevalence in young Mexicans by state.

the other in the northern part of the Mexico City metropolitan area. All participants signed an informed consent form.

Blood samples were taken for determination of glucose, high-density lipoproteins (HDL) and triglycerides. Anthropometric data (height, weight and waist circumference + blood pressure) were collected from each student by two physicians of the team (Murguía-Romero et al., 2010). The blood samples were analyzed by CARPERMOR S.A. de C.V., a Mexican, internationally certified and accredited reference laboratory (http://www.carpermor.com.mx).

BMI calculation

The BMI was calculated for the Mexico City sample of 3,176 students and for the subjects in the records of the Mexico ENSANUT 2006, using the well-known formula:

$$BMI = weight/height^2$$

where weight is measured in kilograms (kg) and the height in meters (m). Following the WHO recommendations, the BMI classes were divided into five groups underweight (<18.5); normal range; (divided in two subclasses: 18.5 to < 23.0, and 23.0 to < 25.0); pre-obese (25.0 to <30.0), and obese (≥30.0) (http://apps.who.int/bmi/; WHO, 1986, 1995, 2004). For both samples, only the records of persons within the target age range (17-24 years) were accepted for the study.

Estimating MetS prevalence

We estimated the MetS prevalence in the Mexico City study sample using an international definition according to Alberti et al. (2009) to create three classes (here referred to as "metabolic condition"). Students showing normal reference values (Table 1) were classified as "healthy", those with one or two results outside the normal as "undefined", and those with three or more results outside the normal limits as "MetS". We further disaggregated the data, presenting them in a 3 x 5 matrix of the percentages of people with the various metabolic conditions by BMI class. In order to estimate the numbers of 17-24 years old subjects in each of the three classes, including those with MetS by each state in Mexico, we extrapolated the matrix percentages to the BMI class percentages obtained from the ENSANUT 2006. The resulting proportions were multiplied by the total number of 17-24 years old in the country. To estimate the total Mexican population of the target age-range by state, we used the data from the 2010 National Population Census (http://www.censo2010.org.mx/) that presents the population in 5-year groups, choosing the age-ranges of 15-19 years and 20-24 years, and the micro-data sample that reports the age for each individual (http://www.inegi.org.mx/est/contenidos/espanol/soc/sis/microdatos). The first source revealed the total number of young people by state in two age ranges, 15-19 years and 20-24 years), and the second the proportion belonging to the age group of 17-19 years by state, making it possible to exclude the 15-16 years age group and thus arrive at the 17-24 years reference group we were targeting.

Results

MetS prevalence by BMI range

The MetS prevalence in the sample of 3,176 young people in Mexico City (Table 2, Fig. 2) is ascendant with respect to BMI, i.e. there were more obese subjects (48.6%) than underweight ones (0.6%). All BMI classes included MetS prevalence greater than zero and, as expected, the higher the BMI class, the greater the MetS prevalence.

Table 2. Probabilities for young Mexicans to present the various metabolic condition disaggregated by BMI class.

			Group of 17-24 years old			Projected probability		
BMI class	BMI range	Total	Healthy	Undefined*	MetS	Healthy	Undefined*	MetS
Underweight	<18.5	162	95	66	1	58.6%	40.7%	0.6%
Normal range 1	18.5 - <23.0	1,344	566	741	37	42.1%	55.1%	2.8%
Normal range 2	23.0 - <25.0	651	153	442	56	23.5%	67.9%	8.6%
Pre-obese	25.0 - <30.0	725	57	510	158	7.9%	70.4%	21.8%
Obese	≥30.0	294	4	147	143	1.4%	50.0%	48.6%

* Those with alteration in one or two of the five components of MetS.

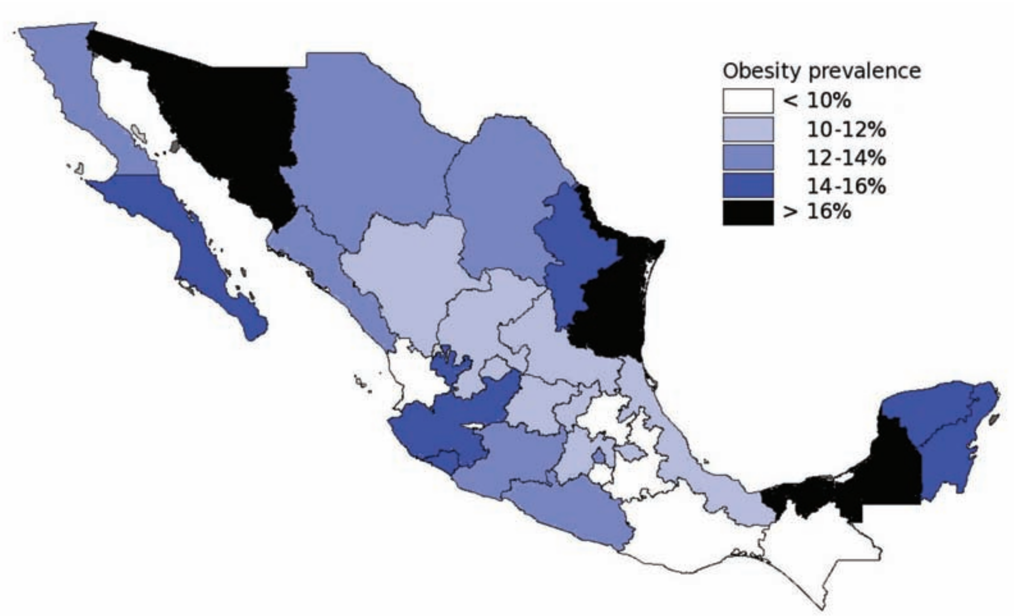

Fig. 2. Estimated obesity prevalence in young Mexicans by state. State percentage of obese people by BMI range (BMI ≥30).

Population percentages by BMI range

The data from the Mexican ENSANUT 2006 allowed us to estimate the percentages of young population by BMI class in each state (Table 3). At the national level, the estimated prevalence of underweight people was 5.7%, while those within the normal range were 55.3% and those classified as overweight (pre-obese + obese) were 39.0%. If the subdivisions are taken into account, the figures are 37.9% for normal range 1 with 17.4% for normal range 2, while the pre-obese and the obese were 26.5% and 12.5%, respectively.

The percentages at the national level can be seen as the aggregation of the geographic components at the state level (Fig. 3). As can be seen, there is a wide variation from low to high values, i.e. the underweight class runs from 1.6% (Yucatan) to 9.5% (Chihuahua), normal range 1 from 31.4% (Yucatan) to 44.8% (Hidalgo), normal range 2 from 11.4% (San Luis Potosi) to 23.5% (Puebla), pre-obese from 19.1% (Guerrero) to 35.0% (the State of Mexico), and obese runs from 8.1% (Hidalgo) to 17.1% (Tabasco).

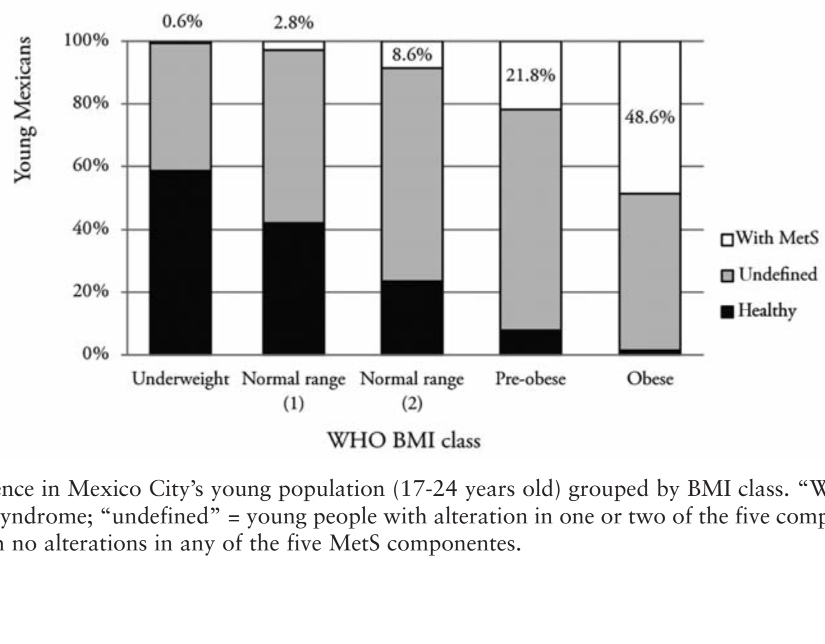

Fig. 3. MetS prevalence in Mexico City's young population (17-24 years old) grouped by BMI class. "With MetS" = young people with the metabolic syndrome; "undefined" = young people with alteration in one or two of the five components of MetS; "healthy" = young people with no alterations in any of the five MetS componentes.

Table 3. Percentage of BMI classes of young Mexicans by state. (Based on ENSANUT 2006 - http://www.insp.mx/encuesta-nacional-salud-y-nutricion-2006.html).

State	Population*	Underweight	Normal range 1	Normal range 2	Pre-obese	Obese
01 Aguascalientes	174,171	12,396 (7.1%)	68,181 (39.1%)	35,330 (20.3%)	40,289 (23.1%)	17,975 (10.3%)
02 Baja California	462,535	36,442 (7.9%)	168,194 (36.4%)	100,917 (21.8%)	92,507 (20.0%)	64,475 (13.9%)
03 Baja California Sur	91,230	6,128 (6.7%)	30,977 (34.0%)	15,999 (17.5%)	24,169 (26.5%)	13,957 (15.3%)
04 Campeche	126,187	3,464 (2.7%)	44,537 (35.3%)	21,773 (17.3%)	35,629 (28.2%)	20,784 (16.5%)
05 Coahuila	381,042	33,621 (8.8%)	140,089 (36.8%)	57,904 (15.2%)	97,128 (25.5%)	52,300 (13.7%)
06 Colima	96,472	6,460 (6.7%)	35,316 (36.6%)	15,504 (16.1%)	25,410 (26.3%)	13,782 (14.3%)
07 Chiapas	749,743	34,221 (4.6%)	320,430 (42.7%)	155,548 (20.7%)	177,325 (23.7%)	62,219 (8.3%)
08 Chihuahua	478,187	45,542 (9.5%)	153,703 (32.1%)	89,186 (18.7%)	125,239 (26.2%)	64,517 (13.5%)
09 Distrito Federal	1,205,041	57,884 (4.8%)	410,451 (34.1%)	226,274 (18.8%)	347,304 (28.8%)	163,128 (13.5%)
10 Durango	242,810	9,182 (3.8%)	99,981 (41.2%)	44,889 (18.5%)	60,192 (24.8%)	28,566 (11.8%)
11 Guanajuato	829,572	34,710 (4.2%)	305,449 (36.8%)	149,254 (18.0%)	246,442 (29.7%)	93,717 (11.3%)
12 Guerrero	506,191	23,184 (4.6%)	214,455 (42.4%)	102,398 (20.2%)	96,601 (19.1%)	69,553 (13.7%)
13 Hidalgo	385,747	10,425 (2.7%)	172,767 (44.8%)	75,958 (19.7%)	95,320 (24.7%)	31,277 (8.1%)
14 Jalisco	1,101,193	99,714 (9.1%)	446,547 (40.6%)	156,075 (14.2%)	225,441 (20.5%)	173,416 (15.7%)
15 México	2,255,862	131,592 (5.8%)	817,750 (36.3%)	263,184 (11.7%)	789,552 (35.0%)	253,784 (11.2%)
16 Michoacán	662,080	44,139 (6.7%)	239,278 (36.1%)	123,124 (18.6%)	169,585 (25.6%)	85,954 (13.0%)
17 Morelos	258,649	15,327 (5.9%)	105,376 (40.7%)	41,192 (15.9%)	75,679 (29.3%)	21,075 (8.1%)
18 Nayarit	155,452	10,463 (6.7%)	61,284 (39.4%)	28,400 (18.3%)	42,600 (27.4%)	12,705 (8.2%)
19 Nuevo León	640,103	53,536 (8.4%)	221,126 (34.5%)	102,416 (16.0%)	167,591 (26.2%)	95,434 (14.9%)
20 Oaxaca	542,519	27,250 (5.0%)	227,908 (42.0%)	106,522 (19.6%)	128,817 (23.7%)	52,022 (9.6%)
21 Puebla	866,186	19,989 (2.3%)	346,474 (40.0%)	203,221 (23.5%)	213,215 (24.6%)	83,287 (9.6%)
22 Querétaro	272,498	12,433 (4.6%)	103,611 (38.0%)	52,842 (19.4%)	71,492 (26.2%)	32,120 (11.8%)
23 Quintana Roo	211,673	3,884 (1.8%)	71,852 (33.9%)	35,927 (17.0%)	66,997 (31.7%)	33,013 (15.6%)
24 San Luis Potosí	373,385	26,544 (7.1%)	162,803 (43.6%)	42,470 (11.4%)	102,637 (27.5%)	38,931 (10.4%)
25 Sinaloa	403,394	35,279 (8.7%)	164,118 (40.7%)	64,420 (16.0%)	90,495 (22.4%)	49,082 (12.2%)
26 Sonora	367,099	26,221 (7.1%)	129,468 (35.3%)	54,082 (14.7%)	86,858 (23.7%)	70,470 (19.2%)
27 Tabasco	344,532	11,993 (3.5%)	122,112 (35.4%)	66,508 (19.3%)	77,411 (22.5%)	66,508 (19.3%)
28 Tamaulipas	455,516	26,352 (5.8%)	165,642 (36.4%)	67,763 (14.9%)	114,820 (25.2%)	80,939 (17.8%)
29 Tlaxcala	176,981	4,597 (2.6%)	74,125 (41.9%)	34,477 (19.5%)	44,245 (25.0%)	19,537 (11.0%)
30 Veracruz	1,082,518	49,206 (4.5%)	416,009 (38.4%)	214,714 (19.8%)	277,339 (25.6%)	125,250 (11.6%)
31 Yucatán	294,945	4,815 (1.6%)	92,697 (31.4%)	62,601 (21.2%)	89,085 (30.2%)	45,747 (15.5%)
32 Zacatecas	224,686	20,030 (8.9%)	85,346 (38.0%)	38,318 (17.1%)	57,478 (25.6%)	23,514 (10.5%)
MÉXICO Country	16,418,199	937,023 (5.7%)	6,218,056 (37.9%)	2,849,190 (17.4%)	4,354,892 (26.5%)	2,059,038 (12.5%)

*Estimated number of people of the 17-24 year age group based on the National Population Census 2010 (http://www.censo2010.org.mx/) and the microdata sample of individual records of the national census (http://www.inegi.org.mx/est/contenidos/espanol/soc/sis/microdatos/).

Estimation of MetS prevalence by state

The MetS prevalence estimation based on BMI ranges was 15.8% for the whole country, varying from 13.3% in Chiapas to 18.4% in Quintana Roo (Fig. 4, Table 4). The states of Sonora and Tabasco plus those of the Yucatan peninsula (Campeche, Quintana Roo and Yucatan) showed the highest prevalence of MetS (>18%). Hidalgo, Nayarit and the southern States of Chiapas and Oaxaca showed the lowest MetS prevalence rates (<14%); while Sinaloa state showed the highest percentage of those regarded as healthy (28.8%). None of the states had a proportion higher than 30% belonging to the healthy category. The three big city states (Mexico State, Distrito Federal and Nuevo Leon) showed MetS prevalence rates above the national average (15.8%). Our estimate is that 2,588,414 of the Mexican population aged 17-24 years belong to the MetS category (Table 4).

Table 4. Estimated population and MetS prevalence in young Mexicans by state (based on the MetS distribution by BMI range of the study sample (Table 2), applied to the structure of BMI ranges by state (Table 3)).

State	Population	Healthy	Undefined*	With MetS
01 Aguascalientes	174,171	49,314 (28.3%)	100,287 (57.6%)	2 4,570 (14.1%)
02 Baja California	462,535	128,184 (27.7%)	263,822 (57.0%)	70,529 (15.2%)
03 Baja California Sur	91,230	23,208 (25.4%)	52,434 (57.5%)	15,588 (17.1%)
04 Campeche	126,187	30,036 (23.8%)	73,324 (58.1%)	22,827 (18.1%)
05 Coahuila	381,042	103,706 (27.2%)	216,706 (56.9%)	60,630 (15.9%)
06 Colima	96,472	25,279 (26.2%)	55,308 (57.3%)	15,885 (16.5%)
07 Chiapas	749,743	213,990 (28.5%)	435,892 (58.1%)	99,861 (13.3%)
08 Chihuahua	478,187	126,733 (26.5%)	274,124 (57.3%)	77,330 (16.2%)
09 Distrito Federal	1,205,041	299,380 (24.8%)	702,397 (58.3%)	203,264 (16.9%)
10 Durango	242,810	65,485 (27.0%)	140,631 (57.9%)	36,694 (15.1%)
11 Guanajuato	829,572	211,902 (25.5%)	485,432 (58.5%)	132,238 (15.9%)
12 Guerrero	506,191	141,572 (28.0%)	289,199 (57.1%)	75,419 (14.9%)
13 Hidalgo	385,747	108,702 (28.2%)	225,259 (58.4%)	51,786 (13.4%)
14 Jalisco	1,101,193	312,666 (28.4%)	615,628 (55.9%)	172,899 (15.7%)
15 México	2,255,862	565,975 (25.1%)	1,314,328 (58.3%)	375,559 (16.6%)
16 Michoacán	662,080	175,696 (26.5%)	381,496 (57.6%)	104,888 (15.8%)
17 Morelos	258,649	71,621 (27.7%)	150,425 (58.2%)	36,603 (14.2%)
18 Nayarit	155,452	43,553 (28.0%)	90,303 (58.1%)	21,596 (13.9%)
19 Nuevo León	640,103	167,979 (26.2%)	365,234 (57.1%)	106,890 (16.7%)
20 Oaxaca	542,519	153,172 (28.2%)	314,033 (57.9%)	75,314 (13.9%)
21 Puebla	866,186	232,097 (26.8%)	509,454 (58.8%)	124,636 (14.4%)
22 Querétaro	272,498	71,872 (26.4%)	158,413 (58.1%)	42,213 (15.5%)
23 Quintana Roo	211,673	48,404 (22.9%)	124,270 (58.7%)	38,999 (18.4%)
24 San Luis Potosí	373,385	106,009 (28.4%)	213,096 (57.1%)	54,280 (14.5%)
25 Sinaloa	403,394	116,293 (28.8%)	228,486 (56.6%)	58,615 (14.5%)
26 Sonora	367,099	93,212 (25.4%)	207,268 (56.5%)	66,619 (18.1%)
27 Tabasco	344,532	84,028 (24.4%)	197,455 (57.3%)	63,048 (18.3%)
28 Tamaulipas	455,516	114,901 (25.2%)	259,379 (56.9%)	81,237 (17.8%)
29 Tlaxcala	176,981	47,516 (26.8%)	103,106 (58.3%)	26,360 (14.9%)
30 Veracruz	1,082,518	287,988 (26.6%)	629,132 (58.1%)	165,398 (15.3%)
31 Yucatán	294,945	66,621 (22.6%)	174,213 (59.1%)	54,111 (18.3%)
32 Zacatecas	224,686	63,441 (28.2%)	128,717 (57.3%)	32,528 (14.5%)
MÉXICO country	16,418,19	4,350,536 (26.5%)	9,479,250 (57.7%)	2,588,414 (15.8%)

*Young people with alteration in one or two of the five components of MetS

Discussion

The association of MetS prevalence rates with BMI ranges was obtained from a sample representing only two geographic units (Mexico State and Distrito Federal) and this association was used to extrapolate estimates for all the other states of the country, based on the assumption that the geographical factors involved in the geographical variation of obesity are the same as those for MetS.

The ENSANUT 2006 is a valuable database for making geographical estimations for Mexico, both at the state and the country levels; nevertheless, we suspect that MetS prevalence calculated here could be overestimated, the reason being that ENSANUT is most probably biased due to the participation of non-healthy people in the survey. Mexico's MetS map (Fig. 2) shows a qualitative comparison between the states, but more studies are needed to confirm or modify these results with more reliable data.

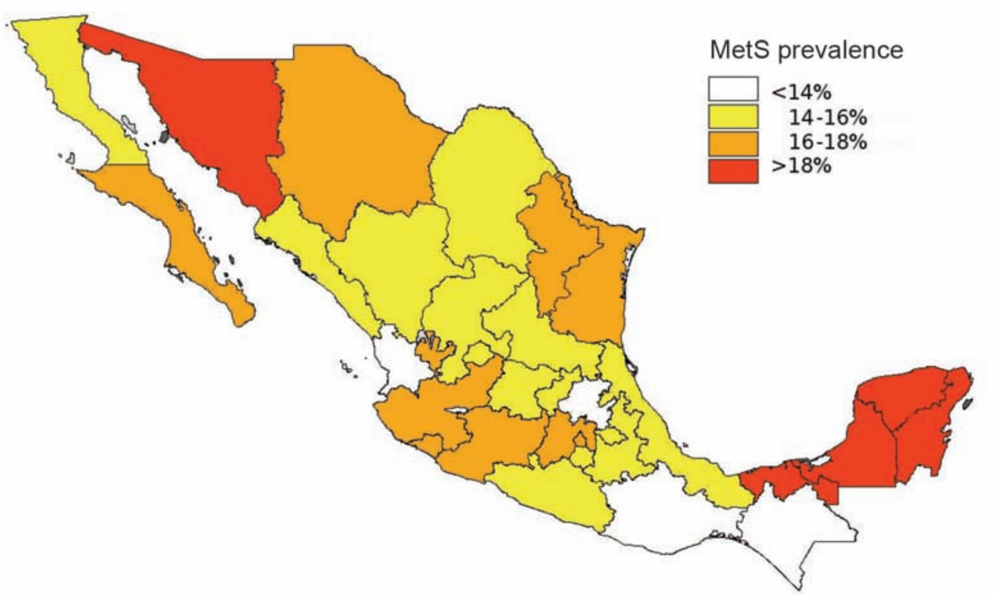

Fig. 4. Estimated MetS prevalence in young Mexicans by state (MetS definition according to Alberti et al., 2009).

The finding that all BMI classes include MetS prevalence greater than zero implies that obesity is not a mandatory factor of MetS. The fact that BMI classes "underweight" and "normal range" include MetS prevalence rates greater than zero, suggests that the naming of the BMI ranges is inadequate in the context of MetS. Thus, a more clear and contextualized meaning of the term "normal range" is required.

The methodology applied in this study recognizes clearly that there is a geographical variation of obesity (and all the other BMI classes as well). MetS and obesity have a non-homogeneous geographical distribution across the Mexican territory. Some regions present MetS prevalence higher than others resulting in a geographical pattern that can best be appreciated when judged from a map (Figs. 3 and 4). Many factors are responsible for this pattern, and there is evidence that Mexicans are genetically predisposed to MetS-related disorders as suggested by Goodarzi et al. (2004) and Weissglas-Volkov et al. (2010). Particularly, the high prevalence estimated in south-eastern Mexico could be the consequence of a genetic factor predisposing this population to MetS (Sanchez-Corona et al., 2004). Such genetic pre-disposal should be seen in the context of lifestyle, e.g. the evolutionary forces that acted on ancient Americans act differently now as the current population is overfed, a completely different situation compared with that of 1,000 years earlier and before. Another fact to be considered with regard to the geographical distribution of the MetS is that of the Mexican culinary diversity and abundance, which shows vast geographical differences.

The finding of a non-homogeneous geographical MetS distribution in Mexico is very valuable since it emphasizes the need to adapt prevention strategies, as well as interventions, to the regional situation.

Conclusions

The estimated MetS prevalence for Mexico according to the method proposed is 15.8%. This prevalence can be geographically disaggregated, showing its variation at the state level from 13.3% to 18.4%. While the states of the peninsula of Yucatan (Campeche, Quintana Roo and Yucatan), plus Sonora and Tabasco, show the highest MetS prevalence in young Mexicans, the southern states (Chiapas and Oaxaca), plus Hidalgo and Nayarit, present the lowest. More than 2,5 million young people in Mexico are estimated to have MetS, which is a current challenge and a potentially future greater risk scenario from a public health point of view.

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