

# Spatio-temporal trend in detections of diabetes mellitus and systematic arterial hypertension in IMSS users, 2004-2019

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**Abstract:** Background: Diabetes Mellitus (DM) and heart diseases, which include Systemic Arterial Hypertension (SAH), have been positioned as the two main causes of mortality in Mexico, which represents important challenges for the different health institutions. Objective: To analyze the spatio-temporal trend of DM and SAH based on the detections made in first and second level units of the Instituto Mexicano del Seguro Social, during the period 2004-2019. Material and methods: Ecological study in which detection rates of both diseases were calculated per 1,000 persons according to year, triennium and representation. The spatio-temporal trend was analyzed by spatial statistics using Geographic Information Systems. Results: During 2004-2019 there were 9 399 889 and 11 862 069 detections on average of DM and SAH, respectively. Regarding DM, the detection rate ranged from 203.4 (2004) to 384.4 (2019) per 1000 persons, this trend increased in Tamaulipas. While SAH decreased from 1140.2 (2004) to 352 (2019) per 1000 persons in Veracruz Sur and Tamaulipas, respectively. Conclusions: The observed spatio-temporal trend can contribute to organizing and guiding, according to representation and level of care, institutional programs, integrated care protocols, clinical practice guidelines and other public policy instruments available at the Instituto Mexicano del Seguro Social to improve early detection, care, control and access to medications for DM and SAH.

**Key words:** diabetes mellitus; hypertension; health services research; geographic information systems; epidemiology

## 1 Introduction

The most recent National Health and Nutrition Survey (ENSANUT) [1] reported that, as of 2018, 10.3% of the Mexican population had a prior medical diagnosis of diabetes mellitus (DM), which is higher than the 2012 figure (9.2%). However, the actual figure could range between 30% and 50% due to subclinical and undiagnosed cases [2]. The same trend has been observed with regard to Systemic Arterial Hypertension (SAH), whose prevalence in Latin America and the Caribbean ranges between 20% and 35% [3]; however, in Mexico, the percentage of the individuals aged 20 years and older with a prior medical diagnosis was 18.4%, compared to 16.6% in 2012 [1]. Thus, the epidemiological significance of these two chronic degenerative diseases lies in the fact that, according to the World Health Organization (WHO), they rank

among the top 10 causes of death worldwide [4]. In Mexico, according to figures from the National Institute of Statistics and Geography (INEGI) [5], they represent the two leading causes of mortality, with rates having increased in recent years. In 2019 alone [5], these two conditions accounted for 39% of all deaths, as 23.5% (n = 156,041) of recorded deaths were due to heart disease associated with hypertension [6], and 15.7% (n = 104,354) were due to diabetes.

It was recently reported that the Mexican Social Security Institute (IMSS) provides health services to 51% of the Mexican population [7]. It is worth noting that, of the country's total population, 74% of patients diagnosed with DM [8] and 46.6% diagnosed with SAH [9] receive medical care through the IMSS.

Furthermore, these two diseases account for the top two reasons for seeking care in Family Medicine at the IMSS [10], and they are among the top ten reasons for specialized care [11] and are the leading causes of mortality [12], according to 2019 data.

In addition to the above, it is possible that, as a consequence of the SARS-CoV-2 (COVID-19) pandemic that began in February 2020 in Mexico, there may be a significant backlog in terms of screenings and health promotion initiatives aimed at mitigating the effects of chronic degenerative diseases, the impact of which was reflected in the necessary reduction of health services to care for COVID-19 patients, as well as care focused on chronic conditions (cancers, DM, SAH, among others).

In this context, the generation and analysis of indicators become important to recognize the magnitude of DM and SAH detections as the main diseases requiring preventive and curative care for IMSS beneficiaries, as well as to identify the underlying changes and trends in such actions; not only to appropriately allocate and distribute available resources—both material and human—but also to identify which Decentralized Administrative Operation Bodies (DAOBs), also known as representations, where it is necessary to strengthen institutional programs aimed at the prevention, detection, diagnosis, treatment, and control of both diseases, which are prioritized as complementary strategies to the screenings conducted at the national level. Therefore, the objective of this study was to analyze the spatio-temporal trend of DM and SAH detections performed in IMSS primary and secondary care units during the 2004 – 2019 period.

## **2 Materials and methods**

An exploratory ecological study was conducted using the Federal Government's Open Data platform as a secondary source. Data on the detection of diabetes mellitus [13] and systemic arterial hypertension [14] for the period 2004–2019 were retrieved from this platform, based on IMSS data. From this source, the number of detections of DM (E11) and SAH (I10) in the general population was obtained, taking into account the years of the study, in accordance with criteria established in the International Classification of Diseases, 10th Revision (ICD-10) [15].

To analyze the temporal trend of each disease, crude rates were initially calculated, with the numerator being the number of cases reported by each IMSS regional office during 2004–2019; while the denominator used the average population enrolled with a family physician—beneficiaries—for the same unit of analysis and period, sourced from the Health Information Division within the Unit of Education, Research, and Health Policies of Medical Benefits Directorate of the IMSS [16].

Likewise, the rates were adjusted by year, considering the following three-year periods: 2004–2006, 2007–2009, 2010–2012, 2013–2015, and 2016–2018; with the aim of minimizing potential random effects resulting from differences in the size of the eligible population enrolled in each health center during the study period, which could alter the underlying temporal trend in the number of cases detected at each health center. In a subsequent stage, linear regression was used to statistically evaluate the changes and trends in the adjusted detection rate per thousand beneficiaries for both DM and SAH.

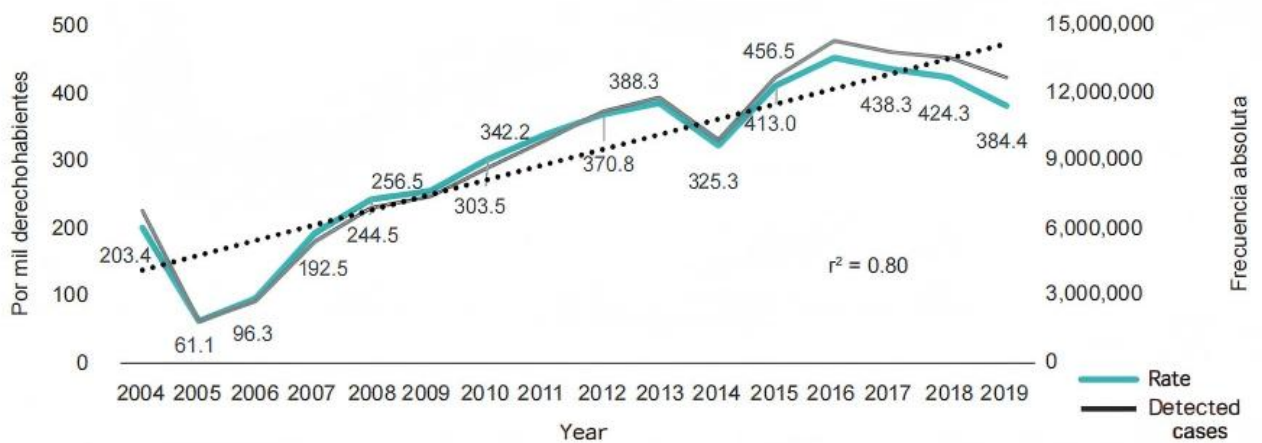
In addition, the indicators for each disease were georeferenced to visualize their spatial distribution and variation over

the study period; the values were organized into quintiles with the following categories of detection probability (per 1,000 beneficiaries): very high, high, medium, low, and very low. A final analysis consisted of geographically evaluating the observed pattern of the adjusted detection rate for DM and SHA (2004–2019) by representation, which was performed using the spatial clustering technique [17]; as a result, it was determined whether the concentration and observed changes in high and low rate values were random occurrences ( $p < 0.05$ ), independent of the population assigned to the family physician (denominator) or the detection activities conducted at each representation, as this technique only evaluates the location and distribution of values for a given variable. Spatio-temporal trend results were presented using graphs and analytical maps developed in the Geographic Information Systems QGIS and GeoDa.

### 3 Results

#### Magnitude and Spatio-Temporal Trend of Diabetes Mellitus (DM) Detection.

During the study period, there were, on average, 9,399,889 cases of DM detected, with 2016 being the year with the highest number (Figure 1). In absolute terms, the regions of Nuevo León, Jalisco, Eastern Mexico, Southern Mexico City, and Northern Mexico City, in that order, accounted for 40% of the detections made nationwide during 2004–2019.



\*Per 1,000 beneficiaries

Source: Own elaboration based on data published by the Ministry of Health on the detection of diabetes mellitus and systemic arterial hypertension by delegation of the Mexican Institute of Social Security (IMSS), 2000–2019.

Figure 1. Temporal trend in the detection\* of diabetes mellitus (DM) in the IMSS, 2004–2019

The overall rate was 309 cases of DM per 1,000 beneficiaries. When analyzing this indicator adjusted by year, an upward trend ( $p < 0.01$ ) was observed in the number of cases per 1,000 beneficiaries (Figure 1), with the rate ranging from 203.4 (2004) to 384.4 (2019), representing a 47% increase. If the trend observed during the study period continues, DM detections in the IMSS are expected to increase to 512.2 per 1,000 beneficiaries this year.

In terms of regional representation, however, geographical variations were observed during the study period. In the first three-year period (2004–2006), for example, Oaxaca was the only region to record an atypically high rate of 152.2 cases per 1,000 beneficiaries; in the following period (2007–2009), there were nine regions, located mainly in the center of the country, which had the highest DM detection rates, ranging from 238.7 to 262 per 1,000 beneficiaries; whereas in the other three-year periods, this spatial pattern shifted toward the center (Northern and Southern Mexico City, Morelos, Western and Eastern State of Mexico, Tlaxcala, Puebla), the north (Coahuila, Nuevo León, Tamaulipas), and the northwest (Baja California Sur). This means that the highest number of DM detections per thousand beneficiaries occurred in those areas. Additionally, it was found that the interquartile range increased fivefold between the first three-year period and the

last, that is, it changed from 12.7 to 64.8 detections per thousand beneficiaries, which corroborates the trend observed in Figure 1.

However, considering the analysis period (2004–2019), seven regions were identified in the highest quintile of the DM detection rate, located in the north and center of the country (Figure 2), with values ranging from 304.6 (Nuevo León) to 344.6 (North Federal District) DM cases per thousand beneficiaries. In contrast, the lowest quintile included Querétaro and Guanajuato (central-west), as well as Chiapas, Tabasco, Campeche, Quintana Roo, and Yucatán (southeast and the peninsula), whose values were below the recorded average (276.8 per 1,000 beneficiaries).

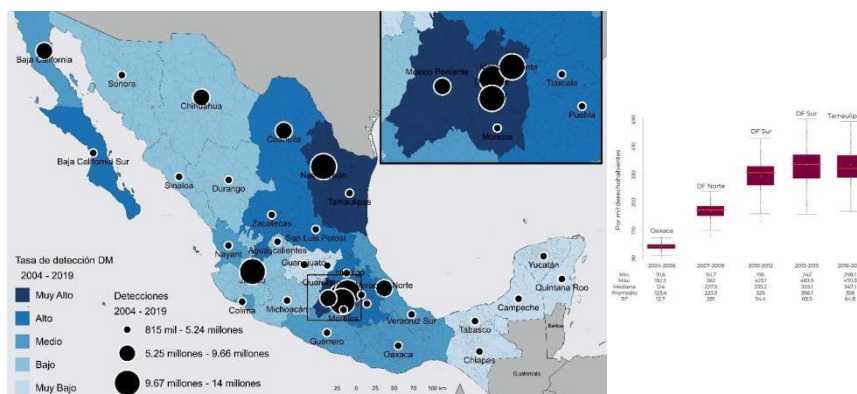
The analysis of spatial patterns, on the other hand, identified two areas where the trend in DM detections per thousand beneficiaries has increased and decreased significantly ( $p < 0.05$ ) (Figure 3). The first zone comprised the Federal District (North and South), the State of Mexico (East and West), and Morelos; whereas in Yucatán, Quintana Roo, Campeche, and Tabasco, the trend was downward.

#### 4 Magnitude and spatio-temporal trend of systemic arterial hypertension (SAH) detection

Regarding SAH, an average of 11,862,069 detections were made (2004–2019), with the highest number recorded in 2004 (Figure 4). In contrast, at the administrative division level, Nuevo León, Jalisco, Eastern Mexico, and Southern Mexico City The North and South regions accounted for the highest percentage of hypertension diagnoses during the study period, namely 35.4%.

The overall SAH detection rate was 390 per 1,000 beneficiaries, and unlike the trend observed for DM detections, the behavior for SAH detections was irregular. This means that while an increase was observed in some years, there was a decrease in others (Figure 4), which was corroborated by analyzing the detection rate by three-year period. In this regard, the interquartile range increased from 42.3 (2004–2006) to 57.4 (2010–2012) detections per thousand beneficiaries, and in the last three-year period (2016–2018), the indicator decreased to 47.9. However, when comparing the detection rate recorded in 2005 and 2019—taking into account that in 2004 a value three times higher than the annual average (355.3 per thousand beneficiaries) was recorded—a 33% increase in the number of detections per thousand beneficiaries was identified (Figure 4).

Furthermore, when analyzing the magnitude of this indicator by three-year period, it was found that at the beginning of the study period (2004–2006), the highest values were concentrated in districts such as Veracruz Sur (488), Oaxaca (487.4), and Veracruz Norte (483); in contrast, in the following three-year periods, this pattern shifted toward the center (2010–2012) and in the northern part of the country (2016–2018), with rates ranging from 411.3 (Northern Mexico City) to 420.5 (Tamaulipas) cases per 1,000 residents, respectively.

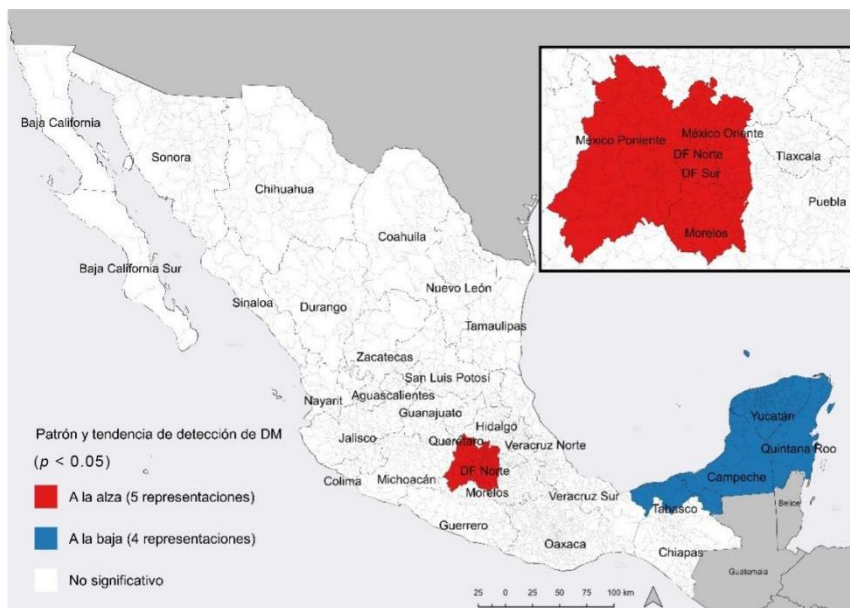


\*IQR = Interquartile range

\*\*Per thousand beneficiaries

Source: Own elaboration based on data published by the Ministry of Health on the detection of diabetes mellitus and systemic arterial hypertension by delegation of the Mexican Institute of Social Security (IMSS), 2000–2019.

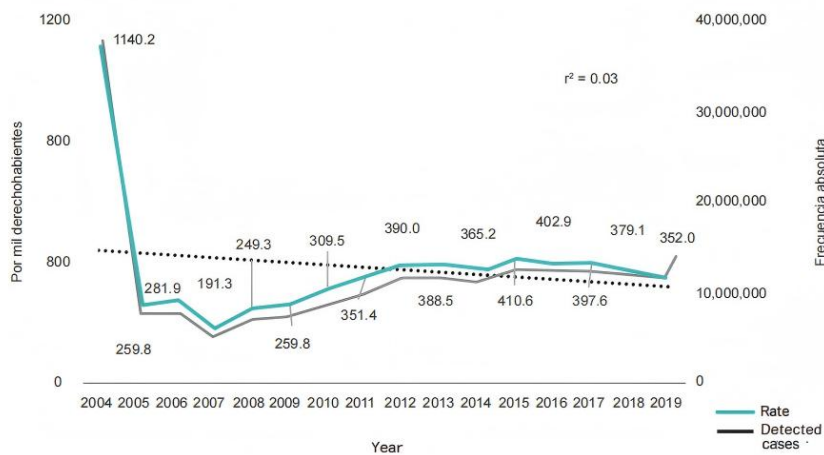
Figure 2. Frequency of detections and geographic distribution of diabetes mellitus (DM) detection\*\* rate by representation and triennium



\*Per 1,000 beneficiaries

Source: Own elaboration based on data published by the Ministry of Health on the detection of diabetes mellitus and systemic arterial hypertension by delegation of the Mexican Institute of Social Security (IMSS), 2000–2019.

Figure 3. Spatial pattern and trend of diabetes mellitus (DM) detection\* rate by representation, 2004–2019



\*Per thousand beneficiaries

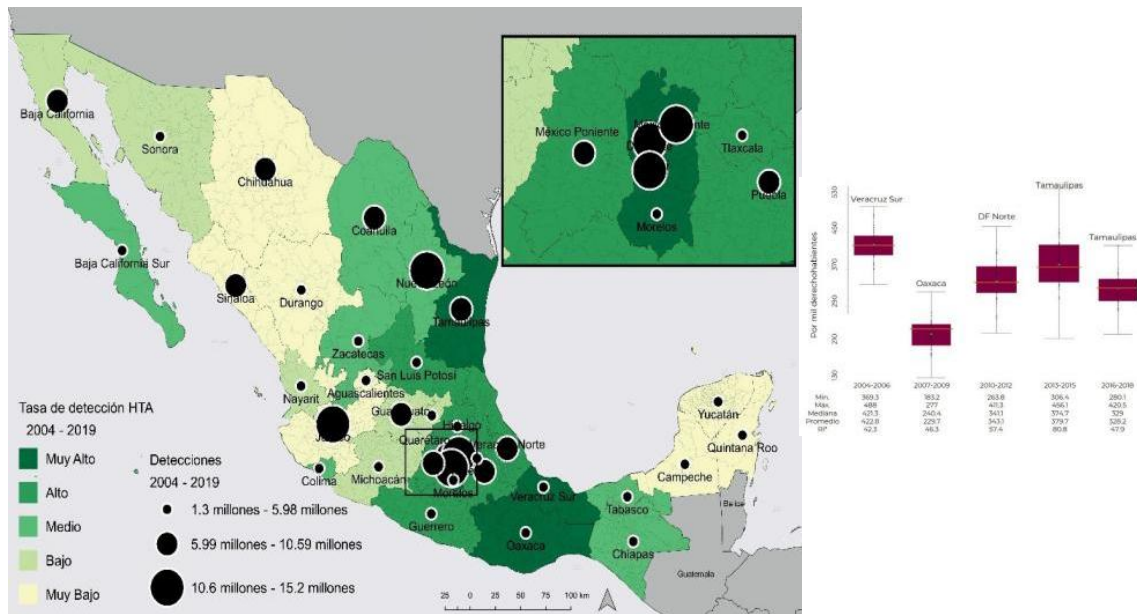
Source: Own elaboration based on data published by the Ministry of Health on the detection of diabetes mellitus and systemic arterial hypertension by delegation of the Mexican Institute of Social Security (IMSS), 2000–2019.

Figure 4 Temporal trend of systemic arterial hypertension (SAH) detection\* among IMSS beneficiaries, 2004–2019

Figure 5 shows the variations in the indicator calculated for SAH by representation (2004–2019). As a result, seven delegations located in the southeast (Oaxaca, Southern Veracruz), central (Mexico City—North and South—, Eastern

Mexico, Morelos), and northern (Tamaulipas) parts of the country; while another eight recorded lower values, between 327 and 331 detections per 1,000 beneficiaries, located in the southeast and the peninsula (Campeche, Quintana Roo, Yucatán), the west (Jalisco, Aguascalientes), and the northwest (Sinaloa, Durango, Chihuahua).

The spatial pattern analysis, on the other hand, identified the areas where the trend in the number of detections has increased and decreased ( $p < 0.05$ ) during the 2004–2019 period (Figure 6); the former included a total of eleven representations, mainly from the central and southern parts of the country, while the latter consisted of nine, located in the northwest, west, and the Yucatán Peninsula.



\*IQR = Interquartile range

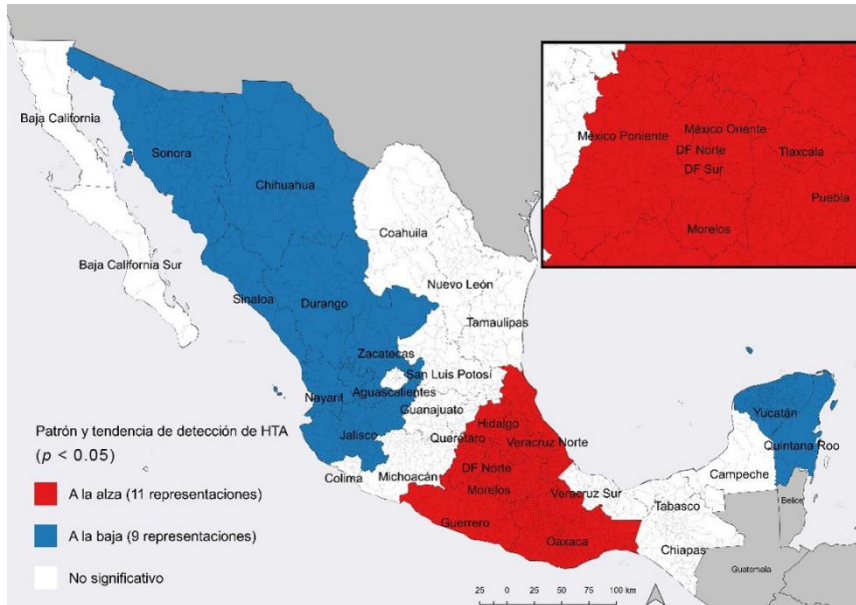
\*\*Per 1,000 beneficiaries

Source: Own elaboration based on data published by the Ministry of Health on the detection of diabetes mellitus and systemic arterial hypertension by delegation of the Mexican Institute of Social Security (IMSS), 2000–2019.

Figure 5 Frequency of detections and geographic distribution of systemic arterial hypertension (SAH) detection rate by representation and triennium

## 5 Discussion

The spatio-temporal trend in the detection of diabetes mellitus (DM) and systemic arterial hypertension (SAH) among IMSS beneficiaries showed geographically distinct patterns across regions and throughout the study period. While DM detections per thousand beneficiaries increased repeatedly (47%) and shifted from Oaxaca (2004–2006) to Southern Mexico City and Tamaulipas (2017–2019), the indicator related to SAH increased (33%) and decreased (31%) during the same period; at the regional level, the highest detection rate was observed in Tamaulipas, Southern Veracruz, and Oaxaca during the last three-year period analyzed. In this regard, the variations and differences observed between 2004 and 2019 may be useful for identifying which IMSS regional offices should further strengthen and improve early detection efforts for DM and SAH, primarily at the primary care level; or those focused on the management, control, and reduction of the number of complications in treated patients who were likely detected through such strategies, for example, in second- and third-level hospitals.



\*Per thousand beneficiaries

Source: Own elaboration based on data published by the Ministry of Health on the detection of diabetes mellitus and systemic arterial hypertension by delegation of the Mexican Institute of Social Security (IMSS), 2000–2019.

Figure 6. Spatial pattern and trend of systemic arterial hypertension (SAH) detection\* rate by representation, 2004–2019

Indeed, the importance of timely screening and diagnosis of both diabetes mellitus (DM) and systemic arterial hypertension (SAH) lies in improving disease management and anticipating and reducing potential complications in patients [9,18], so it is also important to identify the levels of care at which each of these strategies should be targeted to increase their impact, for example, based on service productivity or screening coverage, in relation to the eligible population of each medical unit or facility. From a clinical perspective, blood pressure control proves to be a highly cost-effective measure for reducing mortality at young ages [3], since complications of SAH are related, among other factors, to the duration of the disease [9]. Thus, identifying the regional representations where the number of screenings per thousand beneficiaries decreased significantly during 2004–2019 could be useful for strengthening actions aimed at increasing this indicator, preferably at an early stage and in family medicine units. Whereas in those areas where the opposite occurred (the central and southern regions of the country)—which possibly suggests lower productivity in terms of screenings and services, lower coverage of the population eligible for screening, lower availability of resources, and so on—it would be advisable to ensure access to clinical care and promote adherence to pharmacological treatment (second-level care) as a complementary and indispensable step to screening efforts. This is justified because in previous years it was reported that between 40% and 50% of Mexicans were unaware they had the condition until they were diagnosed with SAH [9,19], and among those hypertensive patients, only half have blood pressure levels under control [19]. A similar situation has been observed in countries such as Argentina, Chile, Colombia, and Brazil, where only 57.1% of the adult population is aware of their diagnosis, while 18.8% have their blood pressure under control [3].

Although early diagnosis of DM is also a key strategy, it is recommended that this strategy ensure and, in turn, complement the availability of health services with sufficient capacity to handle the volume of cases detected [18]; furthermore, a higher risk of hypertension has been reported in this same group [6], specifically, between 1.5 and 2 times higher [20]. Thus, the evidence could explain the fact that the Federal District (North and South), Eastern Mexico, Morelos, and Tamaulipas regions recorded the highest detection rate per thousand beneficiaries for both DM and SAH during the

study period; whereas in other representations,, where this relationship was reversed, this could reflect lower performance in terms of the number of cases detected per thousand beneficiaries. Although the regions of Jalisco, Nuevo León, Western Mexico, and Mexico City (North and South) detected a higher number of cases of DM and SAH (Figures 2 and 5), this was not the case with regard to the population enrolled in Family Medicine (detection rates) in Jalisco, as it fell into the very low quintile in terms of the detection rate for DM and SAH. The opposite was true in Nuevo León, Western Mexico, and Mexico City (North and South), where the frequency of detections and the rates (both) were higher compared to the other regions. Therefore, it is possible that a higher detection rate of DM and/or SAH (per thousand beneficiaries) does not necessarily depend on greater availability of medical facilities [21] — as shown by Jalisco (n = 126), Nuevo León (n = 60), Western Mexico (n = 49), Northern Mexico City (n = 28), and Southern Mexico City (n = 38) — but rather on meeting established targets (indicators) or making the most of available resources, for example, through the PrevenIMSS or DiabetIMSS modules.

In this context, the increase in the detection rate of DM and SAH per thousand beneficiaries may present a twofold challenge for the IMSS in terms of meeting the potential demand for health services—primarily managing those cases that may receive a confirmed diagnosis following screening—as well as promoting healthy habits and lifestyles and improving quality of life through health services at every level of care. This can be achieved, for example, by strengthening institutional programs such as PrevenIMSS or DiabetIMSS; the latter is based on techniques, methodologies, and experiences to improve metabolic control, identify complications early, and provide timely management to patients [22]; Otherwise, as is the case with hypertensive patients, more serious consequences may arise, such as coronary artery disease, heart failure, and stroke [3,6], among others, which could well justify the design and consolidation of a program focused solely on this type of patient.

In addition to the above, the demographic transition characterizing our country [7], which is underpinned by increased life expectancy (75.2 years in 2020) [23], the adult and older adult population (49.7% aged 30 or older in 2020) [22], suggests that the demand for and care of DM or SAH within the IMSS could increase, since the risk of diagnosis for both conditions rises with age [2,3,8,22,24,25], a trend that would also align with the one observed at the national level [1]. Additionally, the most recent ENSANUT (2018) reported that Mexico City, Nuevo León, and Tamaulipas accounted for the highest percentage of the population aged 20 years and older with a medical diagnosis of DM, while for SAH it was Veracruz [1]. Thus, these are the IMSS representations where the number of cases detected per thousand beneficiaries for both diseases increased between 2004 and 2019. This result, therefore, could highlight the importance of continuously carrying out this type of initiative, with the aim not only of increasing the frequency of detections but also of ensuring that they occur at appropriate stages, which could certainly improve the diagnosis and management of both conditions. There is also the possibility that the increase in detections of both diseases may be related, among other factors, to population aging, urbanization rates, and the concentration of the population in cities rather than rural areas; this aligns with the aforementioned data, where a higher number of detections (per thousand beneficiaries) was identified during the study period. The rise in urbanization rates implies, for example, changes in lifestyles and dietary habits, such as increased consumption of processed foods high in carbohydrates, salt, and fats, among other factors.

However, the limitations of this study, which relied on secondary data, lie in the estimation and adjustment of rates that did not take into account factors such as sex or age. While this data was not available, it could have provided greater certainty in distinguishing the probability of detecting DM and SAH by demographic group, as well as the potential implications and complications for the insured population.

On the other hand, although both diseases were analyzed geographically separately (due to data availability), the

results can serve as the basis for developing new epidemiological studies that examine, with greater territorial precision—for example, at the hospital unit level—the availability of infrastructure, material resources, and human resources to meet not only current demand, where necessary, but also potential demand, based on the detections made, which could be subsequently confirmed through diagnostic tests; as well as identifying the reasons behind the geographically differentiated patterns of DM and SAH detection rates. Nevertheless, the evidence presented involved the 35 IMSS regional offices and an analysis of a 16-year study on the magnitude and trends in the detection of both chronic degenerative diseases—which are priorities—in IMSS-affiliated facilities, and which to some extent reflects the potential coverage and actions carried out by each OOAD during the analysis period.

## **6 Conclusions**

The spatio-temporal trend in the detection of DM increased over the study period, particularly in Federal District (North and South), Mexico (East and West), Morelos, Tamaulipas, and Nuevo León; while the SAH indicator decreased in certain regions (Oaxaca, Chiapas, Tabasco, and southern Veracruz) and increased significantly in others (Tamaulipas). Therefore, we consider that the observed trends may suggest, on the one hand, the efforts and actions undertaken by each OOAD to detect both conditions in the beneficiary population and, furthermore, that through such actions, DM is detected more frequently than SAH. On the other hand, the evidence may be useful for organizing, prioritizing, and reorienting institutional programs, care protocols, and clinical practice guidelines, among other public policy instruments, in accordance with the situation and context of each representation as well as the three levels of care, with the aim of improving care, management, and access to medications for DM and SAH among IMSS beneficiaries who require them.

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## **Conflicts of Interest**

The author declares no conflicts of interest regarding the publication of this paper.

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