Analytical Study of the geographical distribution and seasonality patterns of COVID-19 cases in primary care units: a descriptive analytical study

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ABSTRACT

Aims: To determine Geographic Distribution and Seasonality Patterns of COVID-19 Cases in Primary Care Units, in Puebla State, Mexico.
Study design:A descriptive, analytical, multicentre and cross-sectional study was conducted.
Place and Duration of Study: Hospital and Ambulatory Care Medical Units. The study was conducted from July 1st to December 31st, 2024, with COVID-19 Mexican patients attending an outpatient consultation at several units in Puebla State, Mexico, from September 29th, 2022 to June 3rd, 2023.
Methodology: Data on health and sociodemographic variables were collected through a retrospective design, using the SINOLAVE system.
Results: We included 10,558 patients with COVID-19, mainly females (n=5,991; 56.7%, CI95% 55.8-57.7). COVID-19 activity displayed seasonal patterns, with primary peaks occurring in winter. The geographic distribution of COVID-19 cases across the municipalities in the state of Puebla, Mexico (n= 121 municipalities), reveals significant variation in the number of reported cases. Puebla City represents the primary hotspot of cases in the state. The mainly comorbidities in patients with COVID-19 were hypertension, type 2 diabetes and obesity.
Conclusion: The Geographic Distribution and Seasonality Patterns of COVID-19 Cases in Primary Care Units provides a comprehensive overview of epidemiological trends at the primary care level and highlights priority areas for intervention. The high prevalence of no communicable diseases such as hypertension, diabetes, and obesity require a comprehensive response focused on prevention and risk factor management. Seasonal variations and the variability in the case count across municipalities highlight the need for targeted public health interventions for managing COVID-19. Additionally, the variability in comorbidities across sexes underscores the need for personalized approaches to manage COVID-19.It is recommended that the public health system develop tailored health education programmes to address the specific needs of high-prevalence areas. Implementing initiatives for early screening and management of comorbidities may also mitigate the impact of COVID-19. Furthermore, ongoing surveillance of seasonal patterns and geographical distribution will be crucial for timely and effective public health responses.

Keywords: COVID-19; non-communicable diseases; primary care; seasonal variation.

1. INTRODUCTION

To understand the geographic distribution and seasonality patterns of COVID-19 cases in primary care units is critical for effective healthcare planning and resource allocation (Kyaw et al. 2024). These units serve as the first line of defence in managing the healthy attention and communicable diseases management (National Academies Press (US) 2016)., offering essential insights into local transmission dynamics (Kyaw et al. 2024) and the broader impact of Social Determinants of Health (SDOH) (Viezzer & Biondi 2021, Kodera et al. 2020, Das et al. 2021, Li et al. 2021, Mansour et al. 2021).Geographic distribution analysis reveals the spatial patterns of COVID-19 cases across regions (Lopez-Hernandez et al. 2024, Lopez-Hernandez 2022, Chung et al. 2024, Wiemken et al. 2023, Viezzer & Biondi 2021). Factors such as population density, urbanization, and socioeconomic conditions influence significantly the case numbers in primary care settings (Viezzer & Biondi 2021, Reyes et al. 2012, Alsubaie et al. 2016, Hu et al. 2024). Urban areas often report higher case counts due to greater population density and increased social interactions (Viezzer & Biondi 2021, Lopez-Hernandez et al. 2024, Lopez-Hernandez 2022, Hu et al. 2024). Conversely, rural regions may face challenges in reporting and managing cases due to limited healthcare infrastructure (Chen et al. 2019, Castillo 2024). By leveraging georeferencing tools like Geographic Information System (GIS), policymakers can identify hotspots, allocate resources more efficiently, and implement targeted interventions.

On the other hand, seasonality has also emerged as a key factor in COVID-19 transmission. "COVID-19 cases exhibited distinct seasonal patterns across age groups and sexes" (López-Hernández et al. 2024). Variations in temperature, humidity, and human behaviour contribute to fluctuating case numbers throughout the year, peaks during winter and summer dominated the overall population trends (López-Hernández et al. 2024, Kyaw et al. 2024, Magers et al. D'Amico et al. 2022, Pramanik et al. 2022). Analysing seasonal patterns can help healthcare providers anticipate surges in cases and in consequence, prepare primary care units. Data for such analyses typically come from electronic health records, national reporting systems, and geospatial datasets. Therefore, mapping the spatial and temporal patterns of COVID-19 cases could provide a comprehensive view of how the disease behaves in different environments and seasons. These insights are invaluable for designing vaccination campaigns, optimizing testing strategies, and ensuring equitable access to healthcare.

Examining the geographic distribution and seasonality of COVID-19 cases in primary care units, highlights the interplay between environmental and social factors in disease spread. Policymakers and healthcare providers can use these findings to strengthen pandemic responses and to prepare for future public health challenges. Therefore, this knowledge is essential for healthcare management and response to the public health system. By identifying regional and temporal trends, this research can directly inform practical applications such as optimising vaccination campaigns, refining public health interventions, and ensuring equitable access to healthcare resources. Understanding how COVID-19 behaves across different regions and seasons allows policymakers to allocate resources more effectively, prioritize areas with the highest need, and anticipate potential surges. Furthermore, this study could reduce significant gaps in our understanding of the geographical patterns of COVID-19 at the primary care level, where early interventions are crucial for managing care attention. The research of this nature is vital for improving public health responses and preparing for future outbreaks, ultimately contributing to more resilient healthcare systems.

1.1 The Aim of the Study.

To determine the Geographic Distribution and Seasonality Patterns of COVID-19 Cases in Primary Care Units, in Puebla, Mexico.

2. MATERIAL AND METHODS

2.1 Study design and settings.

A descriptive, cross-sectional, analytical and multicentre (table 1) study was designed and conducted with Mexican patients attending outpatient consultations in Hospitals and Family Medicine Units, in Puebla State, Mexico. The data collection followed a retrospective approach and was sourced from secondary data, from September 29, 2022 to June 03, 2023. The SINOLAVE system (Sistema de NotificaciónenEpidemiología de Influenza by its acronym in Spanish) was used to gather sociodemographic and clinical variables (such as age, sex, outpatient consultations data, occupation, municipality, unit of Assignment, type of Admission, reporting Unit of Care, Date of Notification on the Platform, Date of Care Admission to the Unit, Date of Symptom Onset, sign and symptoms, discharge reason, death, severe case and comorbidities). The study was conducted from July 1st to December 31st, 2024. Records with incomplete information (187 entries) and duplicate entries (193 records) were removed.Duplicates were identified based on identical case identifiers, while incomplete records were those missing key variables such as age, sex, or geographic location. This rigorous data-cleaning process enhances the study's validity and reliability.

Table 1. Medical units and COVID-19 patients attended by unit.

Reporting Medical Units	Covid-19 Patients Attended
UMF 57 La Margarita	2274
UMF 6 Puebla	2197
UMF 55 Puebla	1190
UMF 12 San Pedro Cholula	1154
UMF 1 Puebla	1045
UMF 2 Puebla	648
HE UMAE Puebla	252
UMFH 11 San Martin Texmelucan	252
UMF 8 Mayorazgo	219
UMF 22 Teziutlan	185
UMF 9 Santa Maria Coapan	167
UMF 13 Puebla	159
UMF 30 Tehuacan	131
HGZ 20 La Margarita	128
UMF 7 San Bartolo	117
HTO UMAE Puebla	94
UMF 3 San Felipe Hueyotlipan	50
UMF 58	46
UMFH 24 Izucar De Matamoros	44
HGZ 15 Tehuacan	37
UMF 34 Atlixco	32
HGSZ 10 Nuevo Necaxa	31
HGZ 23 Teziutlan	22
UMF 14 Pueblo Nuevo	21
UMF 21 Puebla	20

HGZ 5 Metepec	18
UMF 47 San Miguel Xoxtla	6
UMFH 16 Tecamachalco	6
UMFH 33 Villa Rafael Lara Grajales	6
UMFH 31 Chietla	2
UMAA 1 Puebla	1
UMF 27 Villa De Ajalpan	1
UMF 41 Huejotzingo	1
UMF 50 Acatlan Osorio	1
UMFH 26 Atencingo	1

Source: Prepared by the authors using data from the SINOLAVE System, September to December 2022 and January to June 2023.

2.2 Study Population, Data Collection and Instruments.

The study population included all subjects (N=10,558, both sexes) aged 18 yearsold and older with COVID-19 registered on the SINOLAVE system platform (after purging the removed records [n=380 people]).It is worthy highlighting those studies involving the entire population, as in this case, do not require specific selection criteria. The collected data was stored in an Excel workbook, which served as the statistical database for subsequent analysis. This procedure ensured the accuracy, quality, and reliability of the extracted data, supporting the integrity of our study's findings.

2.3Statistical analysis.

The study analysed all COVID-19 cases with complete records reported in the SINOVALE system, ensuring a comprehensive dataset. This approach was designed to meet the study's objective of examining the geographic distribution and seasonal patterns of COVID-19 cases in primary care units. The categorical variables are described as absolute frequency and percentage, and quantitative variables as mean, standard deviation (SD), and interquartile range (IQR). Confidence Interval 95% (CI95%) was included.Categorical variables were compared using Yates' corrected chi-square (X^2) test and likelihood ratio, as appropriate. Quantitative variables were compared using the Mann-Whitney U test or Student's T test as appropriate. A P value < 0.05 (two-tailed test) was considered significant.

2.4Ethical Considerations.

The study was conducted in accordance with the Good Clinical Practice Guidelines of our laws and the Declaration of Helsinki for human experiments. The protocol was approved by The Local Committee of Health Research 2108 at the Zone General Hospital number 20, IMSS (Instituto Mexicano del Seguro Social by its acronyms in Spanish). COFEPRIS record 19 CI 21 114 054. CONBIOETICA record 21 CEI 001 20201117. The Data was treated confidentially. Since this study utilized a secondary database, authorization was obtained from the relevant committee to ensure proper handling of the information in compliance with ethical guidelines. To guarantee confidentiality, only the principal investigators had access to the complete dataset, including identifiable patient information (e.g., names). The patient names were replaced with unique identification numbers. The assigned number allows the data to be linked to a specific individual without revealing the individual's identity. This approach ensured that all patient data were handled under ethical standards and maintained the highest level of confidentiality throughout the study. This anonymization was conducted before sharing the dataset for statistical analysis with some researchers. After the statistical analysis, only the processed statistical data was available to the rest of the research team.

3. RESULTS AND DISCUSSION.

3.1 Characteristicsofthe study population.

We included 10,558patients with COVID-19, ofwhich 5,991are females (56.7%, CI95%55.8-57.7) and 4,567are males (43.3%, CI95% 42.3-44.2). The average age was 40.34 years old (SD=14.63, range=81, minimum age=18, maximum age=99 years old, median age=38 [IQR=28-50]) years old.The median age was higher in female patients (39.00 years old, IQR=29-50, range=81 years old, minimum age=18 years old, maximum age=99 years old) compared to male patients (36.00 years old, IQR=28-48, range=79 years old, minimum age=18-year-old, maximum age=97 years old; p<0.001, Median Test between independent groups).

3.2 Seasonally trend for cases of COVID-19.

In our study population, COVID-19 activity displayed seasonal patterns. Thecase numbers begin to increase in October, followed by a steeper rise in November, leading into the winter months. The total number of cases reached its highest point in January. This gradual increase aligns with the onset of colder temperatures in many regions and heightened social interactions. This suggests a significant surge during the winter months, likely influenced by factors such as increased indoor gatherings during the holiday season and colder weather. However, a steady decline in cases is observed after January, with a noticeable drop by March and continuing through May (figure 1).

The distribution of cases between males and females appears similar across months, with males showing slightly higher numbers in certain months (e.g., January and February), suggesting that gender-based differences are relatively minor and consistent over the months (figure 1).

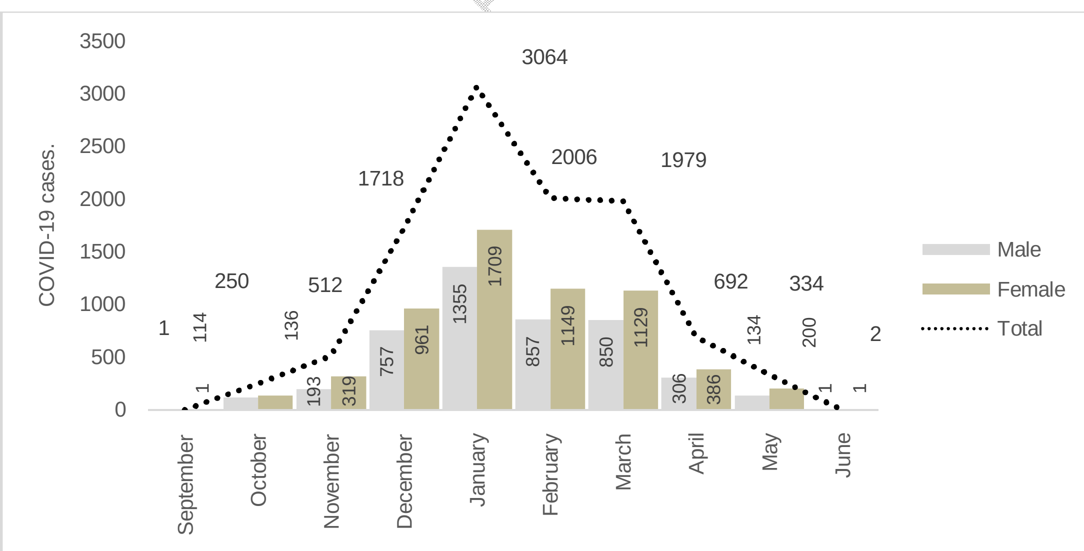

Fig. 1. Seasonal pattern of COVID-19 activity in the total population study.

Source: Prepared by the authors using data from the SINOLAVE System,September to December 2022 and January to June 2023.

3.3Geographic distribution of COVID-19 cases.

The geographic distribution of COVID-19 cases across the municipalities in the state of Puebla, Mexico (n= 121 municipalities), reveals significant variation in the number of reported cases.Puebla City represents the primary hotspot of cases in the state. Other municipalities with notably high case counts are San Pedro Cholula, Cuautlancingo, San Martín Texmelucan, San Andrés Cholula, TeziutlánAmozoc, Juan C. Bonilla and Atlixco. Municipalities such as Huejotzingo, Rafael Lara Grajales and San Salvador El Verde exhibit moderate case counts. Some municipalities, like Juan Galindo and Chignautla, show small clusters of cases, possibly linked to local outbreaks. Municipalities near the state borders, such as Tehuacán and Izúcar de Matamoros, have relatively high counts, potentially reflecting cross-regional travel or economic activity. Small municipalities with exceptionally high counts, like Cuautlancingo, stand out, possibly due to concentrated outbreaks or underreporting in surrounding areas. Finally, many municipalities reported single-digit cases, such as Acateno, Altepexi, and Atempan, each with 1–2 cases (table 2).

Table 2. Geographic distribution of COVID-19 cases, in Puebla State, Mexico.

Municipalities.	Total population	Males	Females
Acajete	16, 0.15 (0.09-0.24)	10, 0.22 (0.09-0.37)	6, 0.1 (0.03-0.18)
Acateno	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Acatlan	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Acatzingo	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Ahuazotepec	1, 0.01 (0-0.04)	1, 0.02 (0-0.07)	
Altepexi	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Alvaro Obregon	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Amozoc	93, 0.88 (0.71-1.07)	43, 0.94 (0.68-1.23)	50, 0.83 (0.6-1.07)
Apetatitlan de Antonio Carvajal	1, 0.01 (0-0.03)	1, 0.02 (0-0.09)	
Apizaco	5, 0.05 (0.01-0.09)	2, 0.04 (0-0.11)	3, 0.05 (0-0.12)
Atempan	2, 0.02 (0-0.05)	1, 0.02 (0-0.07)	1, 0.02 (0-0.05)
Atlixco	51, 0.48 (0.36-0.62)	22, 0.48 (0.28-0.7)	29, 0.48 (0.32-0.67)
Atoyatempan	2, 0.02 (0-0.05)		2, 0.03 (0-0.08)
Ayotoxco de Guerrero	1, 0.01 (0-0.03)		1, 0.02 (0-0.07)
Azcapotzalco	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Calpan	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Calpulalpan	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Chapulco	4, 0.04 (0.01-0.08)	2, 0.04 (0-0.11)	2, 0.03 (0-0.08)
Chiautempan	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Chiautla	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Chiautzingo	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Chietla	7, 0.07 (0.02-0.11)	3, 0.07 (0-0.15)	4, 0.07 (0.02-0.15)
Chignahuapan	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Chignautla	11, 0.1 (0.05-0.16)	4, 0.09 (0.02-0.18)	7, 0.12 (0.03-0.22)
Coronango	39, 0.37 (0.26-0.49)	18, 0.39 (0.22-0.57)	21, 0.35 (0.22-0.5)
Coxcatlan	5, 0.05 (0.01-0.09)	3, 0.07 (0-0.15)	2, 0.03 (0-0.08)
Cuautitlan	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Cuautlancingo	279, 2.64 (2.32-	118, 2.58 (2.15-	161, 2.69 (2.29-

	2.96)	3.06)	3.1)
El Carmen Tequexquitla	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Epatlan	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Guadalajara	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Heroica Ciudad de Juchitan de Zaragoza	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Huamantla	3, 0.03 (0-0.07)		3, 0.05 (0-0.12)
Huauchinango	9, 0.09 (0.03-0.14)	2, 0.04 (0-0.11)	7, 0.12 (0.03-0.22)
Huejotzingo	28, 0.27 (0.17-0.37)	14, 0.31 (0.15-0.48)	14, 0.23 (0.12-0.35)
Hueyapan	2, 0.02 (0-0.05)	1, 0.02 (0-0.07)	1, 0.02 (0-0.05)
Hueytamalco	4, 0.04 (0.01-0.08)	2, 0.04 (0-0.11)	2, 0.03 (0-0.08)
Ixtacamaxtitlan	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Iztapalapa	3, 0.03 (0-0.07)	1, 0.02 (0-0.07)	2, 0.03 (0-0.08)
Izucar de Matamoros	42, 0.4 (0.28-0.53)	18, 0.39 (0.22-0.59)	24, 0.4 (0.25-0.57)
Jalacingo	2, 0.02 (0-0.05)	1, 0.02 (0-0.07)	1, 0.02 (0-0.05)
Juan C. Bonilla	59, 0.56 (0.42-0.7)	23, 0.5 (0.31-0.72)	36, 0.6 (0.42-0.8)
Juan Galindo	14, 0.13 (0.07-0.21)	4, 0.09 (0.02-0.18)	10, 0.17 (0.07-0.27)
La Magdalena Tlaltelulco	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Libres	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Martinez de la Torre	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Mazapiltepec de Juarez	2, 0.02 (0-0.05)	1, 0.02 (0-0.07)	1, 0.02 (0-0.05)
Metepec	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Miguel Hidalgo	2, 0.02 (0-0.05)		2, 0.03 (0-0.08)
Morelia	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Nativitas	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Naucalpan de Juarez	2, 0.02 (0-0.05)	2, 0.04 (0-0.11)	
Nezahualcoyotl	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Nopalucan	12, 0.11 (0.06-0.19)	7, 0.15 (0.04-0.28)	5, 0.08 (0.02-0.17)
Oaxaca de Juarez	4, 0.04 (0.01-0.08)		4, 0.07 (0.02-0.13)
Ocoyucan	19, 0.18 (0.1-0.27)	8, 0.18 (0.07-0.31)	11, 0.18 (0.08-0.28)
Orizaba	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Palmar de Bravo	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Papalotla de Xicohtencatl	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Piaxtla	1, 0.01 (0-0.04)		1, 0.02 (0-0.05)
Puebla	8243, 78.07 (77.26-78.82)	3594, 78.69 (77.51-79.9)	4649, 77.6 (76.51-78.68)
Quecholac	2, 0.02 (0-0.05)	2, 0.04 (0-0.11)	
Rafael Lara Grajales	26, 0.25 (0.16-0.35)	11, 0.24 (0.11-0.39)	15, 0.25 (0.13-0.38)
Salina Cruz	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
San Andres Cholula	187, 1.77 (1.51-2.02)	75, 1.64 (1.29-2.04)	112, 1.87 (1.52-2.24)
San Felipe Teotlalcingo	4, 0.04 (0.01-0.08)	1, 0.02 (0-0.07)	3, 0.05 (0-0.12)
San Gabriel Chilac	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
San Gregorio Atzompa	13, 0.12 (0.06-0.2)	5, 0.11 (0.02-0.22)	8, 0.13 (0.05-0.23)

San Jeronimo Tecuanipan	6, 0.06 (0.02-0.1)	4, 0.09 (0.02-0.18)	2, 0.03 (0-0.08)
San Jose Chiapa	10, 0.09 (0.04-0.15)	6, 0.13 (0.04-0.24)	4, 0.07 (0.02-0.13)
San Jose del Progreso	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
San Martin Texmelucan	216, 2.05 (1.79-2.33)	110, 2.41 (1.97-2.89)	106, 1.77 (1.44-2.14)
San Matias Tlalancaleca	7, 0.07 (0.03-0.11)	4, 0.09 (0.02-0.18)	3, 0.05 (0-0.12)
San Miguel Xoxtla	5, 0.05 (0.01-0.09)	2, 0.04 (0-0.11)	3, 0.05 (0-0.12)
San Nicolas de los Ranchos	2, 0.02 (0-0.05)		2, 0.03 (0-0.08)
San Pablo Del Monte	4, 0.04 (0.01-0.08)	1, 0.02 (0-0.07)	3, 0.05 (0-0.12)
San Pedro Cholula	468, 4.43 (4.04-4.85)	179, 3.92 (3.35-4.53)	289, 4.82 (4.27-5.36)
San Pedro Yeloixtlahuaca	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
San Salvador El Seco	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
San Salvador El Verde	20, 0.19 (0.1-0.27)	10, 0.22 (0.09-0.37)	10, 0.17 (0.07-0.28)
Santa Ana Nopalucan	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Santa Catarina Tlaltempan	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Santa Isabel Cholula	1, 0.01 (0-0.04)	1, 0.02 (0-0.07)	
Santiago Miahuatlan	4, 0.04 (0.01-0.08)	1, 0.02 (0-0.07)	3, 0.05 (0-0.12)
Soltepec	2, 0.02 (0-0.05)	2, 0.04 (0-0.11)	
Taxco de Alarcon	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Tecali de Herrera	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Tecamachalco	7, 0.07 (0.02-0.12)	3, 0.07 (0-0.15)	4, 0.07 (0.02-0.13)
Tecomatlan	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Tehuacan	319, 3.02 (2.68-3.32)	134, 2.93 (2.43-3.42)	185, 3.09 (2.69-3.52)
Teolocholco	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Tepanco de Lopez	2, 0.02 (0-0.05)	1, 0.02 (0-0.07)	1, 0.02 (0-0.05)
Tepatlaxco de Hidalgo	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Tepeaca	4, 0.04 (0.01-0.08)		4, 0.07 (0.02-0.13)
Tepeojuma	2, 0.02 (0-0.05)		2, 0.03 (0-0.08)
Teteles de Avila Castillo	4, 0.04 (0.01-0.09)	1, 0.02 (0-0.09)	3, 0.05 (0-0.12)
Tetla de la Solidaridad	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Teziutlan	162, 1.53 (1.32-1.79)	51, 1.12 (0.81-1.45)	111, 1.85 (1.54-2.22)
Tlacotepec de Benito Juarez	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Tlahuapan	5, 0.05 (0.01-0.09)	2, 0.04 (0-0.11)	3, 0.05 (0-0.12)
Tlalmanalco	1, 0.01 (0-0.04)	1, 0.02 (0-0.07)	
Tlaltenango	3, 0.03 (0-0.07)	2, 0.04 (0-0.11)	1, 0.02 (0-0.05)
Tlatlauquitepec	11, 0.1 (0.05-0.17)	5, 0.11 (0.02-0.22)	6, 0.1 (0.03-0.18)
Tlaxcala	12, 0.11 (0.06-0.19)	7, 0.15 (0.04-0.28)	5, 0.08 (0.02-0.17)
Tlaxco	2, 0.02 (0-0.05)		2, 0.03 (0-0.08)
Tonala	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Totolac	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Tula de Allende	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Valle de Bravo	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Veracruz	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	

Xalapa	1, 0.01 (0-0.03)	1, 0.02 (0-0.09)	
Xicotepec	5, 0.05 (0.01-0.09)	2, 0.04 (0-0.11)	3, 0.05 (0-0.12)
Xiutetelco	7, 0.07 (0.02-0.12)		7, 0.12 (0.03-0.22)
Yaonahuac	1, 0.01 (0-0.03)	1, 0.02 (0-0.09)	
Yauhquemecan	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Zacapoaxtla	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Zacatelco	7, 0.07 (0.02-0.12)	5, 0.11 (0.02-0.2)	2, 0.03 (0-0.08)
Zacatlan	4, 0.04 (0.01-0.08)	3, 0.07 (0-0.13)	1, 0.02 (0-0.05)
Zaragoza	3, 0.03 (0-0.06)	1, 0.02 (0-0.07)	2, 0.03 (0-0.08)
Zautla	1, 0.01 (0-0.03)	1, 0.02 (0-0.07)	
Zinacatepec	1, 0.01 (0-0.03)		1, 0.02 (0-0.05)
Total	10558, 100 (100-100)	4567, 100 (100-100)	5991, 100 (100-100)

Source: Prepared by the authors using data from the SINOLAVE System, September to December 2022 and January to June 2023.

In Puebla, which has the highest number of cases (8,243 in total), males (3,594 cases, 78.69%) have a slightly higher proportion than females (4,649 cases, 77.6%), although both figures are comparable. In municipalities such as San Pedro Cholula (females=4.82% versus males=3.92%) and Cuautlancingo (females=2.69% versus males=2.58%), women account for a higher proportion of cases. In contrast, in municipalities such as Nopalucan and San Jose Chiapa, males exhibit higher cases count. However, some municipalities report cases exclusively in one gender, such as Acateno and Acatlán, where cases are recorded solely among females. Meanwhile, municipalities like Atempan and Atlixco show an even distribution between sexes(table 2).

3.4Comorbidities in patients with COVID-19.

The analysis of comorbidities among patients with COVID-19 reveals that hypertension is the most common comorbidity and obesity, is the second. Smoking, pregnancy, asthma, cardiovascular disease, and chronic kidney disease also show considerable frequency. However, immunosuppression, HIV, cancer, chronic obstructive pulmonary disease and chronic liver disease are less frequent but critical comorbidities. Conditions such as neurological disorders, lactation, and puerperium are rare among the reported cases, yet they may require specialized clinical attention (table 3).Hypertension, diabetes, and obesity are the most common comorbidities among COVID-19 patients, with notable differences across both sexes. Females exhibit higher prevalence of hypertension, diabetes, obesity, asthma, chronic liver disease and cancer, while smoking, cardiovascular disease, immunosuppression, Chronic Obstructive Pulmonary Disease and HIV/AIDS are more prevalent among males. Conditions like pregnancy, lactation, and puerperium are naturally limited to women. Finally, the prevalence of chronic kidney disease and neurological diseases were similar (table 3).

Table 3. Prevalence of the non-communicable diseases in the total COVID-19 population.

Comorbidities	Total population	Males	Females
Hypertension	1113, 10.54 (9.98-11.15)	415, 9.09 (8.26-9.92)	698, 11.65 (10.87-12.49)
Diabetes	771, 7.3 (6.8-7.8)	288, 6.31 (5.61-7.01)	483, 8.06 (7.36-8.76)
Obesity	753, 7.13 (6.67-7.62)	316, 6.92 (6.22-7.64)	437, 7.29 (6.63-7.95)

Smoking	339, 3.21 (2.86-3.57)	243, 5.32 (4.66-6)	96, 1.6 (1.3-1.9)
Pregnancy	133, 1.26 (1.05-1.47)	No applicate	133, 2.22 (1.84-2.59)
Asthma	91, 0.86 (0.69-1.04)	24, 0.53 (0.33-0.74)	67, 1.12 (0.85-1.39)
CD	88, 0.83 (0.66-1)	47, 1.03 (0.74-1.34)	41, 0.68 (0.5-0.9)
CKD	82, 0.78 (0.62-0.94)	35, 0.77 (0.53-1.03)	47, 0.78 (0.57-1.02)
Immunosuppression	52, 0.49 (0.36-0.63)	28, 0.61 (0.39-0.85)	24, 0.4 (0.25-0.55)
HIV/AIDS	46, 0.44 (0.31-0.57)	39, 0.85 (0.61-1.14)	7, 0.12 (0.03-0.22)
Cancer	40, 0.38 (0.27-0.5)	11, 0.24 (0.11-0.39)	29, 0.48 (0.3-0.67)
COPD	32, 0.3 (0.2-0.42)	15, 0.33 (0.18-0.5)	17, 0.28 (0.17-0.43)
CLD	15, 0.14 (0.08-0.23)	5, 0.11 (0.02-0.22)	10, 0.17 (0.08-0.28)
Neurological disease	10, 0.09 (0.04-0.16)	4, 0.09 (0.02-0.18)	6, 0.1 (0.02-0.18)
Lactation	4, 0.04 (0.01-0.08)	No applicate	4, 0.07 (0.02-0.13)
Puerperium	2, 0.02 (0-0.05)	No applicate	2, 0.03 (0-0.08)

CD= cardiovascular disease. CKD= chronic kidney disease. HIV= human immunodeficiency virus. AIDS= acquired immunodeficiency syndrome. COPD= chronic obstructive pulmonary disease. CLD= chronic liver disease.Source: Prepared by the authors using data from the SINOLAVE System, September to December 2022 and January to June 2023.

3.5Discussion.

The magnitude of the COVID-19 pandemic has permeated every area of academia, politics, industry, and healthcare (Reeves et al. 2021). For academia, the COVID-19 pandemic also disrupted traditional education systems, leading to a massive shift toward online learning platforms and highlighting disparities in digital access and infrastructure (Dhawan 2020). Research efforts also experienced a transformation, with significant redirection of funding and attention toward understanding the virus and developing therapeutic solutions (Cook & Lauer 2021). The pandemic's influence on politics was equally profound, shaping new public health policies. Countries faced challenges in balancing public health priorities with economic stability, leading to debates on lockdown measures, mask mandates, and vaccine distribution (Hale et al., 2021).Industry sectors, particularly tourism, entertainment, and manufacturing, experienced substantial disruptions, forcing businesses to adopt innovative practices and digital transformation strategies to survive (McKinsey & Company, 2020). Conversely, the pandemic catalyzed growth in e-commerce, telehealth, and remote work technologies, permanently altering consumer behaviour and workplace norms (Brynjolfsson et al., 2020).In healthcare, the pandemic placed unprecedented strain on medical systems worldwide (Ranney et al. 2020), exposing disparities and the need for robust crisis management infrastructure (World Health Organization [WHO], 2020). Moreover, it led to the rapid development and deployment of vaccines, showcasing the potential of global collaboration in biomedical innovation (Polack et al., 2020). Also, underscored the interconnectedness of global systems and the importance of resilience and adaptability in the face of global health crises.In this context, the data of our study highlights the critical role of reporting medical units in tracking and managing the care of COVID-19 patients. By systematically documenting patient numbers and outcomes, these units provide valuable insights into the distribution and impact of the pandemic across different regions. This information is essential for evaluating healthcare system performance, identifying resource needs, and informing public health strategies to improve patient outcomes and control disease spread.

3.5.1 Study Population Characteristics

Our study identified a lower median age (38 years old) compared to findings from other studies, including those focused on Mexican population (Lopez-Hernandez et al. 2024, Anguiano-Velazquez et al. 2024, Lopez-Hernandez 2022, Liu et al. 2021, Merow & Urban 2020, Choi et al. 2021, Suarez et al. 2020, Ukwishaka et al. 2023). Notably, the age difference between the sexes was statistically significant, with females being slightly older. These disparities may reflect variations in health-seeking behaviours, underlying health conditions, or differing exposure risks (Lopez-Hernandez et al. 2024). Furthermore, the study emphasizes that the absolute number of COVID-19 cases was higher among females, consistent with findings from other research (Lopez-Hernandez et al., 2024) but differing from reports in several other countries (O'Brien et al. 2020, Chen et al. 2020, Guan et al. 2020,Kalyanaraman et al. 2020, Klein et al. 2020, Mazumder et al. 2020, Nikpouraghdamet al. 2020, Wang et al. 2020).Variations in exposure risks also play a crucial role. Women are more likely to work in frontline occupations, such as healthcare and caregiving roles, increasing their likelihood of exposure to the virus (Henneberger & Cox-Ganser 2024, Vargese et al. 2022). On the other hand, sociocultural factors and occupational patterns in some regions may place men at greater risk, particularly in outdoor or industrial settings with limited infection control measures (O'Brien et al., 2020a). These findings underscore the complex interplay of biological, behavioural, and sociocultural factors contributing to sex-specific differences in COVID-19 infection rates and outcomes. Understanding these dynamics is essential for designing targeted public health interventions and equitable healthcare policies.

3.5.2 Seasonal Trends and Geographic distributionof COVID-19 Cases

Geographic Disparities in COVID-19 Cases are essential for understanding the urban hotspots and rural challenges faced by the healthcare system. This analysis suggests that healthcare systems should prepare for increased cases loads during the winter months by improving resource allocation, testing, and vaccination campaigns. Seasonal patterns can offer valuable insights into predicting future surges and guiding public health interventions accordingly.In Puebla State, as in Mexico City, we observed a similar seasonal pattern, with higher case numbers during the colder months (December to February) and lower numbers during the warmer months (April to June) (Lopez-Hernandez 2024). However, our findings differ to reported data by Wiemken et al., whorevealed a clear annual seasonality in COVID-19 cases, hospitalizations, and mortality rates, predominantly occurring between November and April (Wiemken et al. 2023). Moreover, COVID-19 waves differ among countries. In the United States and Europe, the seasonal impact of COVID-19 was most notable from January to March (Wiemken et al. 2023). In Saudi Arabia, COVID-19 waves occurred from May to August, while in Mexico, waves were observed from December to February. Brazil experienced waves from June to September in 2020 and from November to December in 2022. Similarly, the Philippines had waves from July to December in both 2020 and 2022, while Singapore reported waves from October to December in 2021 and 2022. South Africa exhibited waves from December to February during the periods of 2020-2021 and 2021-2022. Conversely, no clear seasonal pattern was identified in countries such as Argentina, Thailand, Bahrain, Malaysia, Morocco, and Qatar (Kyaw et al. 2024).In Russia, temperature seasonality observed in the humid continental region and the diurnal temperature range in the sub-Arctic region were found to have the greatest impact on COVID-19 transmission (Kyaw et al. 2024, D'Amicoet al. 2022). This finding also supports the hypothesis that environmental factors, such as temperature, and human behaviours, such as spending more time indoors, influence COVID-19 transmission (Lopez-Hernandez et al. 2024). On the other hand, municipalities with the highest case counts are likely influenced by their high population density and urbanization. In contrast, municipalities with moderate case counts are likely semi-urban areas, benefiting from their proximity to larger urban centres. Many municipalities reported only a small number of cases, likely due to lower transmission rates associated with reduced population density and mobility.

3.5.3 Sex Differences in Comorbidities

In Mexico City, previous studies show that in mature adults and elderly, the top three comorbidities in patients with COVID-19 are hypertension, diabetes and obesity (Lopez-Hernandez et al. 2024), similarlyto our findings in Puebla's population in Mexico. According to several authors, metabolic conditions in COVID-19 patients are prominent (Silaghi-Dumitrescu et al. 2023), and the most common comorbidities are hypertension, diabetes, cancer, neurodegenerative diseases, cardiovascular diseases, obesity, and kidney diseases(Lopez-Hernandez et al. 2024, Lopez-Hernandez 2022). Moreover, in the United States, the most prevalent comorbidities are the same but in a different order (hypertension 56%, obesity 42%, and diabetes 34%) ((Kammar-García et al. 2020). Other studies in Mexican population reported that diabetes, hypertension, and obesity were the only comorbidities that were risk factors associated with COVID-19 across all models of association (Kammar-García et al. 2020, Lopez-Hernandez 2022). Sex-specific analysis revealed notable differences in disease prevalence (Lopez-Hernandez et al. 2024). Hypertension and T2D were common in both sexes, but obesity was significantly more prevalent in males. These data were different compared to Mexican population living in Mexico City, potentially reflecting lifestyle factors (Lopez-Hernandez et al. 2024).

3.6Limitations and applications.

Preventive strategies and treatment protocols should account for demographic-specific vulnerabilities, particularly in managing chronic diseases and addressing seasonal peaks. Seasonal variations and the variability in the case count across municipalities highlight the need for targeted public health interventions for managing COVID-19. Additionally, the variability in comorbidities across sexes underscores the need for personalized approaches to manage COVID-19. Therefore, it is necessary a continuous and adaptive epidemiological surveillance to effectively respond to changes in disease trends.

4. CONCLUSION.

In conclusion, a study of the Geographic Distribution and Seasonality Patterns of COVID-19 Cases in Primary Care Units provides a comprehensive overview of epidemiological trends at the primary care level and highlights priority areas for intervention. The high prevalence of no communicable diseases such as hypertension, diabetes, and obesity require a comprehensive response focused on prevention and risk factor management. To optimize the response at the primary care level, it is recommended to implement strategies focused on prevention programs with differentiated approaches and strengthen epidemiological surveillance to identify seasonal patterns. This approach will allow a more efficient allocation of resources and an improvement in population health outcomes. Sex-specific differences are more pronounced in areas with smaller populations or lower total case numbers. Cultural, demographic, and exposure factors could explain these differences, warranting a more detailed analysis to better understand the local dynamics of the virus transmission.

CONSENT.

The study was conducted using a secondary data source, and no informed consent was obtained since the research relied on a pre-existing database. The handling of the information was approved by the ethics committee, ensuring compliance with the appropriate ethical standards.

ETHICAL APPROVAL.

The protocol was approved by The Local Committee of Health Research 2108 in Zone General Hospital number 20, IMSS (Instituto Mexicano del Seguro Social by its acronyms in

Spanish). COFEPRIS record 19 CI 21 114 054. CONBIOETICA record 21 CEI 001 20201117.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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